ASME-B31.5

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ASME B31.5-2001

(Revision of ASME B31.5-1992)

REFRIGERATION PIPING AND HEAT TRANSFER COMPONENTS

ASME CODE FOR PRESSURE PIPING, B31

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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REFRIGERATION PIPING AND HEAT TRANSFER COMPONENTS

ASME CODE FOR PRESSURE PIPING, B31

ASME B31.5-2001
(Revision of ASME B31.5-1992)

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The 2001 edition of this Code is being issued with an automatic update service that includes Addenda, Interpretations, and Cases. The next edition is scheduled for publication in 2006.

The use of Addenda allows revisions made in response to public review comments or committee actions to be published on a regular basis; revisions published in Addenda will become effective 6 months after the Date of Issuance of the Addenda.

ASME issues written replies to inquiries concerning interpretations of technical aspects of the Code. The Interpretations are published in a separate supplement.

Periodically certain actions of the ASME B31 Committee will be published as Cases. While these Cases do not constitute formal revisions of the Code, they may be used in specifications, or otherwise, as representing considered opinions of the Committee. The Cases are published in a separate supplement.

In this edition of the Code, U.S. customary units are given first, with SI metric units in parentheses. Values in U.S. Customary units are to be regarded as the standard, unless otherwise agreed between the contracting parties. Instructions are given in those tables that have not been converted for converting tabular data in U.S. units to appropriate SI units.

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FOREWORD

The need for a national code for pressure piping became increasingly evident from 1915 to 1925. To meet this need, the American Engineering Standards Committee (later changed to American Standards Association, then changed to United States of America Standards Institute, and now known as the American National Standards Institute) initiated project B31 in March 1926, at the request of the American Society of Mechanical Engineers and with that Society the sole administrative sponsor. Because of the wide field involved, Sectional Committee B31, later changed to Standards Committee, was composed of representatives of some 40 different engineering societies, industries, government bureaus, institutes, and trade associations. After several years work, the first edition was published in 1935 as an American Tentative Standard Code for Pressure Piping.

In order to keep the Code abreast of current developments in piping design, welding, stress computations, new dimensional and material standards and specifications, and increases in the severity of service conditions, revisions, supplements, and new editions of the Code were published as follows:

B31.1-1942	American Standard Code for Pressure Piping
B31.1a-1944	Supplement 1
B31.1b-1947	Supplement 2
B31.1-1951	American Standard Code for Pressure Piping
B31.1a-1953	Supplement 1 to B31.1-1951
B31.1-1955	American Standard Code for Pressure Piping

In 1952, a new section of the Code was published to cover Gas Transmission and Distribution Piping Systems. In 1955, after a review by B31 Executive and Sectional Committees, a decision was made to develop and publish other industry sections as separate code documents of the American Standard Code for Pressure Piping.

The first edition of Refrigeration Piping was published as ASA B31.5-1962 superseding Section 5 of B31.1-1955. This Section was revised in 1966. Following approval by the Sectional Committee and the sponsor, this revision was approved by the United States of America Standards Institute on September 8, 1966, and designated USAS B31.5-1966. Revision of this Section was approved on April 18, 1974, by the American National Standards Institute and designated ANSI B31.5-1974.

In December 1978, the American National Standards Committee B31 was reorganized as the ASME Code for Pressure Piping, B31. Committee under procedures developed by the American Society of Mechanical Engineers and accredited by the American National Standards Institute. The Code designation was also changed to ANSI/ASME B31.

Previous editions of this Code include those of 1983, 1987, 1989, and 1992. The 2001 Edition of the Code is a compilation of the 1992 Edition and the B31.5a-1994 Addenda.

In this, the 2001 Edition, the Scope of the Code has been expanded to include heat transfer components. Refrigerant design pressures and refrigerant classifications in this Edition refer to ANSI/ASHRAE 15 and 34.

This Code was approved as an American National Standard on August 15, 2001.

ASME CODE FOR PRESSURE PIPING, B31

(The following is the roster of the Committee at the time of approval of this Code.)

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INTRODUCTION

(01)

The ASME B31 Code for Pressure Piping consists of a number of Sections, each an American National Standard, which collectively constitute the Code. Hereinafter in this Introduction and in the text of this Code Section B31.5, when the word "Code" is used without identifying a specific Code Section, it means this Code Section.

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

The Code contains basic reference data and formulas necessary for design. It is intended to state these requirements in terms of basic design principles to the fullest possible extent, supplemented with specific requirements, where necessary, to obtain uniform interpretation of principle. It contains prohibitions in areas where practices or designs are known to be unsafe. In other areas the Code contains warnings or "flags" where caution is known to be necessary, but where it is considered that a direct prohibition would be unwarranted.

The Code includes:

(a) references to material specifications and component standards which are acceptable for Code usage;

(b) references to acceptable dimensional standards for the elements comprising piping systems;

(c) requirements for the pressure design of component parts and assembled units;

(d) requirements for the evaluation and limitation of stresses, reactions, and movements associated with pressure, temperature, and external forces, and for the design of pipe supports;

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

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

It is the intent of the Code that this Edition and subsequent Addenda not be retroactive and that, unless agreement is specifically made between contracting parties to use other issues, or the regulatory body having jurisdiction imposes the use of other issues, the latest Code and Addenda, issued 6 months prior to the original contract date for the first phase of activity covering a piping system(s), be the governing document for all design, materials, fabrication, erection, examination, and testing activities for the piping system(s) until the completion of the work and initial operation.

Manufacturers and users of piping are cautioned against making use of revisions less restrictive than former requirements without having assurance that they have been accepted by the proper authorities in the jurisdiction where the piping is to be installed.

Users of this Code are advised that in some locations legislation may establish jurisdiction over the subject matter of this Code.

It is the Owner's responsibility to determine which Code Section is applicable to the piping installation. A piping installation can be a pipeline or piping system, the piping within an operating unit of a plant, or the piping within a plant or building. The Owner at his discretion may select any Section determined to be generally applicable. Some of the factors that shall be considered by the Owner are: jurisdictional requirements, limitations of the Code Section, and the applicability of other Codes and Standards. All of the applicable requirements of the selected Code Section must be followed.

Attention of Code users is directed to the fact that the numbering of the Divisions and the text therein may not be consecutive. This is not the result of editorial or printing errors. An attempt has been made to follow a uniform outline of the various Sections. Therefore, the same subject, in general, appears under the same number and subnumber in all Sections.

The Code is under the direction of the ASME Code for Pressure Piping Committee, B31, organized under procedures of the American Society of Mechanical Engineers that have been accredited by the American National Standards Institute.

The Committee is a continuing one and is organized to keep the Code current with new developments in materials, construction, and usage. Addenda are issued periodically. New Editions are published at 3 to 5 year intervals.

Rules for each Code Section have been developed considering the needs for a certain set of piping system applications. Some piping system applications considered for each Code Section are:

B31.1, Power Piping: piping systems, primarily steam and water used for heating or power production typically found in electric generation stations, industrial and institutional plants, and central and district heating plants; district heating systems;

B31.3, Process Piping: piping systems, primarily process and utility piping typically found in chemical, textile, semiconductor and cryogenic plants, paper mills, petroleum refineries, loading terminals, natural gas processing plants, bulk plants, compounding plants, and tank farms;

B31.4, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids: piping transporting liquids between facilities such as tank farms and processing plants; piping at pipeline terminals, tank farms, pump stations, pressure reducing stations, and metering stations;

B31.5, Refrigeration Piping and Heat Transfer Components: refrigerant piping, heat transfer, and piping components;

B31.8, Gas Transmission and Distribution Piping Systems: gas transmission and distribution systems including compressor stations, metering and regulation stations; gas gathering pipelines;

B31.9, Building Services Piping: piping systems within specified pressure, temperature, and size limits for building services for industrial, commercial, public, institutional, and multi-unit residential buildings; and

B31.11, Slurry Transportation Piping: piping transporting aqueous slurries between facilities such as a processing plant and a receiving plant, and piping at pipeline terminals, storage facilities, pump stations, and pressure reducing stations.

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 covering preparation of technical inquiries).

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 that the Case was effective on the original contract date or was adopted before completion of the work and that the contracting parties agree to its use.

Requests for interpretations or suggestions for revisions should be addressed to the Secretary, ASME B31 Committee, Three Park Avenue, New York, NY 10016-5990.

SUMMARY OF CHANGES

Revisions, additions, deletions, and errata to the ASME B31.5-1992 Edition and its addenda are included in this edition. A margin designator, **(01)**, is used to identify the affected material and corresponds to the items listed in the Summary of Changes pages. The margin designators will remain on the pages until the 2006 Edition of B31.5 is published.

Page	*Location*	*Change*
Cover	Title	Revised
i	Title Page	Revised
iii–vii	Contents	Revised
viii	Foreword	Revised
xiii, xiv	Introduction	Revised
1–5	500	First sentence revised
	500.1.1	Revised
	500.1.3(c)	Revised
	500.1.3(d)	Added
	500.1.5	Deleted
	500.2	(1) Definitions of *condenser; condenser coil; evaporator; evaporator coil; header;* and *heat transfer component* added (2) Definitions of *brazed joints; piping; refrigerant and refrigerant mixtures: Class 1; refrigerant and refrigerant mixtures: Class 2; secondary coolant;* and *soldered joint* revised (3) Definition of *pressure vessel, refrigerant* deleted
6	501.2.4	Revised
7	502.2.2	Redesignated from 502.2.3
	502.2.3	Redesignated from 502.2.4
	502.2.4	Redesignated from 502.2.5
8	502.2.5	Redesignated from 502.2.6
	502.2.6	Redesignated from 502.2.7
	502.3.1(b)	Revised
	502.3.1(c)	Revised
9	502.3.1(e)	Revised
10–22	Table 502.3.1	Revised
	Part 2	Title revised
	503	Title revised

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10–22	504	Title revised
	504.1.1(b)	Revised in its entirety
	Fig. 504.1.1-A	Deleted
	Fig. 504.1.1-B	Deleted
	504.1.3	Revised in its entirety
	504.1.4	Deleted
23	504.2.1(e)	Added
	504.3.1(b)(2)	Revised
	504.3.1(c)(1)	Revised
	504.3.1(c)(2)	Revised
	504.3.1(d)(1)	Revised
	504.3.1(d)(2)	Revised
24	504.3.1(e)(2)	Revised
	504.3.1(f)(1)	Revised
	504.3.1(f)(2)(a)	Revised
26	504.3.1(g)(3)	Revised
	504.3.1(g)(3)(a)	Revised
	504.3.1(g)(3)(b)	Revised
29, 30	Fig. 504.3.1-C	Revised
	504.3.2(a)	Revised
	504.3.2(b)	Second paragraph revised
	504.3.2(d)	Nomenclature revised
	504.4.1(a)	Equation (7) renumbered as (10)
	504.4.1(b)	Revised
31, 32	504.4.2	(1) First paragraph editorially revised (2) Nomenclature revised
	504.5.1(a)	Nomenclature revised
	504.5.2(a)	Revised
	504.5.2(b)	Revised
	504.5.3	Revised
	504.6	Added
	504.7	Title revised
	504.7(c)	Added

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33, 34	505.1	Revised
	505.1.1	Revised in its entirety
	505.1.3	Added
	505.2.2	Revised
	506.3	Revised in its entirety
	508.3	Second paragraph revised
	508.4	Revised
	508.5.2(b)	Revised
35, 36	514(d)	Revised
	514(e)	Revised
	514(f)	Revised
	515.1	Title added
	515.2	Title added
	515.3	Title added
	517	Revised
37	519.3.1	Revised
38, 39	Table 519.3.1	Added
	519.4.2(c)	Revised
	Table 519.3.2	Added
40–42	Table 519.3.6	Revised
43	519.4.5(a)	Revised
	519.4.5(b)	Revised
	519.4.5(c)	Revised
	Fig. 519.4.5-A	Title revised
44	Fig. 519.4.5-B	Title revised
	519.4.6	Revised
46	521.3.1(a)	Revised
47	Table 521.3.1	Redesignated from Table 521.3.5 and revised
48	523.2.1	Revised
	523.2.2	First paragraph revised
	523.2.2(e)	Revised
	523.2.2(f)(2)–(5)	Subparagraphs (2) through (5) revised

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	523.2.4	Revised
	523.2.6	Revised
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	Table 523.2.2	Added
	Fig. 523.2.2	Revised
55	Table 526.1	Revised
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	527.1.2	Redesignated from 527.2.2
	527.2	Redesignated from 527.3
	527.2.1	Redesignated from 527.3.1
	527.2.1(c)	Redesignated from 527.3.1(a); second paragraph revised
57	Fig. 527.1.2	Redesignated from Fig. 527.2.2; general notes revised
	Fig. 527.2.1-A	Redesignated from Fig. 527.3.1-A and revised
	Fig. 527.2.1-B	Redesignated from Fig. 527.3.1-B
58	527.2.2	Redesignated from 527.3.2
	527.3	Redesignated from 527.4
	527.3.1	Redesignated from 527.4.1 and revised
	527.3.2	Redesignated from 527.4.2
	527.3.2(d)(1)	Redesignated from 527.4.2(d)(1) and revised
	527.3.2(d)(2)	Redesignated from 527.4.2(d)(2) and revised
	527.3.2(d)(4)	Redesignated from 527.4.2(d)(4) and revised
	527.3.3	Redesignated from 527.4.4
	527.3.4	Redesignated from 527.4.5
	527.3.5	Redesignated from 527.4.6
	527.3.5(b)	Redesignated from 527.4.6(b) and nomenclature revised
59	Fig. 527.3.3-A	Redesignated from Fig. 527.4.4-A
	Fig. 527.3.3-B	Redesignated from Fig. 527.4.4-B and revised

Page	*Location*	*Change*
60	Fig. 527.3.3-C	Redesignated from Fig. 527.4.4-C and revised
	Fig. 527.3.5-A	Redesignated from Fig. 527.4.6-A
	Fig. 527.3.5-B	Redesignated from Fig. 527.4.6-B
	Fig. 527.3.5-C	Redesignated from Fig. 527.4.6-C
61	527.3.6	Redesignated from 527.4.7
	527.3.7	Redesignated from 527.4.8
	527.4	Redesignated from 527.5
	527.4.1	Redesignated from 527.5.1
	Fig. 527.3.5-D	Redesignated from Fig. 527.4.6-D
62	Fig. 527.3.6-A	Redesignated from Fig. 527.4.7-A
	Fig. 527.3.6-B	Redesignated from Fig. 527.4.7-B
	527.5	Redesignated from 527.6
63	527.6	Redesignated from 527.7
	528.1.1	Revised
	528.2	Title revised
	528.2.1	Revised in its entirety
	528.2.2	Revised
	528.2.4	Revised in its entirety
	528.2.5	Added
	528.3.1	Revised
	528.4.2	Revised
64	528.4.4	Revised
65, 66	Table 531.2.1	Revised
67	531.3.9(b)(2)	Revised
	531.3.9(c)	Revised
	535.2.1	Revised
	535.3	Redesignated from 535.4
68	535.4	Redesignated from 535.5
	535.5	Redesignated from 535.6
	535.6	Redesignated from 535.7
	535.7	Redesignated from 535.8
	535.8	Redesignated from 535.9
	535.9	Redesignated from 535.10

Page	*Location*	*Change*
69–72	Chapter VI	Revised in its entirety
73–75	Appendix A	Revised

SPECIAL NOTE:

In this Edition of the Code, SI (metric) units have been added. U.S. customary units are given first, with SI (metric) units in parentheses.

The interpretations to ASME B31.5 are included as a separate section for the user's convenience.

CHAPTER I
SCOPE AND DEFINITIONS

(01) 500 GENERAL STATEMENTS

This Refrigeration Piping and Heat Transfer Components Code is a Section of the American Society of Mechanical Engineers Code for Pressure Piping, B31. This Section is published as a separate document for simplicity and convenience of Code users. The users of this Code are advised that in some areas legislation may establish governmental jurisdiction over the subject matter covered by the Code. The owner of a complete piping installation shall have the overall responsibility for compliance with this Code.

It is required that the engineering design specify any special requirements pertinent to the particular service involved. For example, the engineering design shall not for any service specify a weld quality lower than that stipulated in para. 527.4.2(d) for the Code-required visual examination quality and for the types of welds involved; but where service requirements necessitate added quality and more extensive nondestructive examination, these are to be specified in the engineering design and any revision thereto, and when so specified, the Code requires that they be accomplished.

500.1 Scope

(01) **500.1.1** This Code prescribes requirements for the materials, design, fabrication, assembly, erection, test, and inspection of refrigerant, heat transfer components, and secondary coolant piping for temperatures as low as −320°F (−196°C), whether erected on the premises or factory assembled, except as specifically excluded in the following paragraphs.

500.1.2 Users are advised that other piping Code Sections may provide requirements for refrigeration piping in their respective jurisdictions.

500.1.3 This Code shall not apply to:

(a) any self-contained or unit systems subject to the requirements of Underwriters Laboratories or other nationally recognized testing laboratory;

(b) water piping;

(01) *(c)* piping designed for external or internal gage pressure not exceeding 15 psi (105 kPa) regardless of size; or

(d) pressure vessels, compressors, or pumps, but does include all connecting refrigerant and secondary coolant piping starting at the first joint adjacent to such apparatus. (01)

500.1.5 DELETED (01)

500.2 Definitions (01)

For convenience in reference, some of the more common terms relating to piping are defined in this subdivision.

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

automatic welding: welding with equipment that 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 generally used in the welding of piping.

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

brazed joints: a joint obtained by the joining of metal parts with alloys that melt at temperatures higher than 800°F (427°C), but less than the melting temperatures of the jointed parts.

brine: a secondary coolant that is a solution of a salt and water.

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

compressor: a specific machine, with or without accessories, for compressing a given refrigerant vapor.

condenser: that part of a refrigerating system designed to liquify refrigerant vapor by the removal of heat.

condenser coil: a condenser constructed of pipe or tube, not enclosed in a pressure vessel.

design pressure: see para. 501.

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, and pumps, designed for attachment to pipe or piping components.

evaporator: that part of a refrigerating system designed to vaporize liquid refrigerant to produce refrigeration.

evaporator coil: an evaporator constructed of pipe or tube, not enclosed in a pressure vessel.

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 making a welded, brazed, or soldered joint.

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 joint.

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

fusion: see *weld.*

gas metal-arc welding (GMAW): an arc welding process wherein coalescence is produced by heating with an arc between a continuous filler metal (consumable) electrode and the work. Shielding is obtained entirely from an externally supplied gas or gas mixture. (Some methods of this process are called MIG or CO_2 welding.)

gas tungsten-arc welding (GTAW): an arc welding process wherein coalescence is produced by heating with an arc between a single tungsten (nonconsumable) electrode and the work. Shielding is obtained from a gas or gas mixture. Pressure may or may not be added. (This process is sometimes called TIG welding.)

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.

header: a pipe or tube (extruded cast or fabricated) to which a number of other pipes or tubes are connected.

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

heat transfer component: the pressure containing portion of equipment used for heat transfer including pipes, tubes, coils, or other components and their headers not constructed as pressure vessels (see *evaporator coil* and *condenser coil).*

heat treatment

annealing, full: heating a metal to a temperature above a critical temperature and holding above that range for a proper period of time, followed by cooling to below that range.

normalize: 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.

stress-relief heat treatment: uniform heating of a structure or portion thereof to a sufficient temperature below the critical range to relieve the major portion of the residual stresses, followed by uniform cooling.

high side: the parts of a refrigerating system subjected to condenser pressure.

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

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

limited charge system: a system in which, with the compressor idle, the internal volume and total refrigerant charge are such that the design pressure will not be exceeded by complete evaporation of the refrigerant charge.

low side: the parts of a refrigerating system subjected to evaporator pressure.

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

mechanical joint: a joint obtained by joining of metal parts through a positive holding mechanical construction.

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

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

pipe: a tubular component, usually cylindrical, used for conveying fluid and normally designated "pipe" in the applicable specification. It also includes similar components designated "tube." Types of welded pipe, according to the method of manufacture, are defined as follows:

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.

electric-fusion welded pipe: pipe having a longitudinal or spiral butt joint wherein coalescence is produced in the preformed tube by manual or automatic electric-arc welding. The weld may be single or double 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 lap joint or a lock-seam joint.

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 or spiral 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.

double submerged-arc welded pipe: pipe having a longitudinal butt joint produced by at least two passes, one of which is on the inside of the pipe. Coalescence is produced by heating with an electric arc or arcs between the 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 for the inside and outside welds is obtained from the electrode or electrodes.

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 force welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round pass welding rolls.

pipe supporting elements: elements that consist of fixtures and structural attachments. They do not include support structures and equipment, such as stanchions, towers, building frames, pressure vessels, mechanical equipment, and foundations.

fixtures: elements that 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: elements that are welded, bolted, or clamped to the pipe, such as clips, lugs, rings, clamps, clevises, straps, and skirts.

piping: the pipe and tube for interconnecting the various parts in a refrigeration system, which includes pipe, tube, flanges, bolting, gaskets, valves, and fittings; other pressure-containing parts, such as heat transfer components, expansion joints, strainers, and filters; devices that serve such purposes as mixing, separating, snubbing, distributing, metering, or controlling flow; and pipe supporting elements.

postheating: the application of heat to an assembly after a welding, brazing, soldering, or cutting operation.

preheating: the application of heat to the base metal immediately before a welding, brazing, soldering, or cutting operation.

premises: the buildings and that part of the grounds of one property, where an installation would affect the safety of those buildings or adjacent property.

pressure vessel: see Section VIII, Division 1, ASME Boiler and Pressure Vessel Code (hereinafter referred to as the ASME BPV Code).

refrigerant and refrigerant mixtures: the fluid used for heat transfer in a refrigerating system that absorbs heat during evaporation at low temperature and pressure, and releases heat during condensation at a higher temperature and pressure. The safety classification group consists of two characters, e.g., A1 or B2. The capital letter indicates the toxicity and the Arabic numeral indicates the flammability, based on the following criteria (see Table 500.2):

Class A: refrigerants for which toxicity has not been identified at concentrations less than or equal to 400 ppm (parts per million), based on data used to determine Threshold Limit Values-Time Weighted Average (TLV-TWA) or consistent indices.

Class B: refrigerants for which there is evidence of toxicity at concentrations below 400 ppm, based on data used to determine TLV-TWA or consistent indices.

TABLE 500.2 REFRIGERANT CLASSIFICATION

Group [Note (1)]	Refrigerant	Name	Chemical Formula
A1	R-11	Trichlorofluoromethane	CCl_3F
A1	R-12	Dichlorodifluoromethane	CCl_2F_2
A1	R-13	Chlorotrifluoromethane	$CClF_3$
A1	R-13B1	Bromotrifluoromethane	$CBrF_3$
A1	R-14	Tetrafluoromethane	CF_4
B1	R-21	Dichlorofluoromethane	$CHCl_2F$
A1	R-22	Chlorodifluoromethane	$CHClF_2$
B2	R-30	Methylene chloride	CH_2Cl_2
B2	R-40	Methl chloride	CH_3Cl
A1	R-113	Trichlorotrifluoroethane	CCl_2FCClF_2
A1	R-114	Dichlorotetrafluoroethane	$CClF_2CClF_2$
A1	R-115	Chloropentafluoroethane	$CClF_2CF_3$
B1	R-123	Dichlorotrifluoroethane	$CHCl_2CF_3$
A1	R-134a	Tetrafluoroethane	CH_2FCF_3
A2	R-142b	1-Chloro-1, 1-Difluoroethane	CH_3CClF_2
A2	R-152a	1,1-Difluoroethane	CH_3CHF_2
A3	R-170	Ethane	C_2H_6
A3	R-290	Propane	C_3H_8
A1	R-C318	Octafluorocyclobutane	C_4F_8
A1	R-400	. . .	$CCl_2F_2/C_2Cl_2F_4$
A1	R-500	Dichlorodifluoromethane, 73.8%, and ethylidene fluoride, 26.2%	CCl_2F_2/CH_3CHF_2
A1	R-502	Chlorodifluoromethane, 48.8%, and chloropentafluoroethane, 51.2%	$CHClF_2/CClF_2CF_3$
Note (2)	R-503	R-23 (40.1%) & R-13 (59.9%)	$CHF_3/CClF_3$
A3	R-600	N-butane	C_4H_{10}
A3	R-600a	Isobutane (2 methyl propane)	$CH(CH_3)_3$
B2	R-611	Methyl formate	$HCOOCH_3$
B2	R-717	Ammonia	NH_3
A1	R-744	Carbon dioxide	CO_2
B1	R-764	Sulfur dioxide	SO_2
A3	R-1150	Ethylene	C_2H_4
A3	R-1270	Propylene	C_3H_6

NOTES:
(1) Information in this table is established by ANSI/ASHRAE 34 and is shown here for convenience.
(2) No classification assigned as of this date.

Class 1: refrigerants that do not show flame propagation when tested in air at 14.7 psia (100 kPa) and 65°F (18°C).

Class 2: refrigerants having a lower flammability limit (LFL) of more than 0.00625 lb/ft^3 (0.10 kg/m^3) at 70°F (21°C) and 14.7 psia (100 kPa) and a heat of combustion of less than 8,174 Btu/lb (19 000 kJ/kg).

Class 3: refrigerants that are highly flammable as defined by having an LFL of less than or equal to 0.00625 lb/ft^3 (0.10 kg/m^3) at 70°F (21°C) and 14.7 psia (100 kPa) or a heat of combustion greater than or equal to 8,174 Btu/lb (19 000 kJ/kg).

refrigerating system: a combination of interconnecting refrigerant containing parts constituting a closed refrigerant circuit in which a refrigerant is circulated for the purpose of extracting heat.

reinforcement of weld: weld metal in excess of the specified weld size.

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 of a joint measured on the center line of the root cross section.

seal weld: any weld used primarily to provide a specific degree of tightness against leakage.

secondary coolant: any liquid used for the transmission of heat without a change in its state and having no flash point, or a flash point above 150°F (66°C) as determined by ASTM D 93.

self-contained system: a complete factory-made and factory-tested system in a suitable frame or enclosure that is fabricated and shipped in one or more sections and in which no refrigerant containing parts are connected in the field other than by companion flanges or block valves.

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

shall: where "shall" or "shall not" is used for a provision specified, that provision is intended to be a Code requirement.

shielded metal-arc welding (SMAW): 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 provisions that are not mandatory but recommended good practice.

size of weld

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, or corner joint.

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

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

soldered joint: a gas-tight joint obtained by the joining of metal parts with metallic mixtures or alloys that melt at temperatures not exceeding 840°F (449°C) and above 400°F (204°C).

submerged arc welding (SAW): an arc welding process wherein coalescence is produced by heating an arc(s) between a bare metal electrode or electrodes and the work. The arc 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.

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

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

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.

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

tube: see *pipe.*

undercut: a groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal.

weld: a localized coalescence of metal wherein coalescence is produced by heating to suitable temperature, with or without the application of pressure, and with or without the use of filler metal. The filler metal has a melting point approximately the same as the base metals.

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

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

welding procedures: the detailed methods and practices including all joint welding procedures involved in the production of a weldment.

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

CHAPTER II
DESIGN

PART 1
CONDITIONS AND CRITERIA

501 DESIGN CONDITIONS

501.1 General

Paragraph 501 defines the temperatures, pressures, and various forces applicable to the design of piping systems. It also states considerations that shall be given to ambient and mechanical influences and various loadings.

501.2 Pressure

501.2.2 Internal Design Pressure. The piping component shall be designed for an internal pressure representing the most severe condition of coincident pressure and temperature expected in normal operation or standby (including fluid head). The most severe condition of coincident pressure and temperature shall be that condition that results in the greater required piping component thickness and the highest component rating.

Any piping connected to components other than piping shall have a design pressure no less than the lowest design pressure of any component to which it is connected.

501.2.3 External Design Pressure. The piping component shall be designed for an external pressure representing the most severe condition of coincident pressure and temperature expected during shutdown or in normal operation (including fluid head) considering possible loss of internal pressure. Refrigerant piping systems shall be designed to resist collapse when the internal pressure is zero absolute and the external pressure is atmospheric. This is to permit drying the pipe by evacuation. The most severe condition of coincident pressure and temperature shall be that condition that results in the greatest required pipe thickness and the highest component rating.

501.2.4 Minimum Design Pressure. Minimum design gage pressure shall be not less than 15 psi (105 kPa) and, except as noted in para. 501.2.5, shall be not less than the saturation pressure of the refrigerant at the following temperatures: (01)

(a) low sides of all systems: 80°F (27°C);

(b) high side of water or evaporatively cooled systems: 104°F (40°C); and

(c) high sides of air cooled systems: 122°F (50°C).

501.2.5 Minimum Design Pressure for Specific Service

(a) Design pressure for either high or low side need not exceed the critical pressure of the refrigerant unless the system is intended to operate at these conditions.

(b) When components of a system are protected by a pressure relief device, the design pressure of the piping need not exceed the setting of the pressure relief device.

(c) In a compound system the piping between stages shall be considered the low side of the next higher stage compressor.

501.3 Temperature

In this Code, metal temperature of piping in service is considered to be the temperature of the fluid conveyed.

501.3.1 Brittle Fracture. Consideration must be given to a reduction in impact strength occurring in some materials when subjected to low temperatures. Notch effects should be avoided. See para. 523.2.

501.4 Ambient Influences

501.4.1 In the design of refrigeration piping systems, consideration must be given to the influence of ambient temperature.

501.4.2 Fluid Expansion Effects (Increased Pressure). Consideration must be given to expansion of liquid refrigerant trapped in or between closed valves and a means provided to prevent overpressure.

501.5 Dynamic Effects

501.5.1 Impact. Impact forces, including hydraulic shock and liquid slugging, caused by either external or internal conditions shall be considered in the design of piping components.

501.5.2 Wind. The effect of wind loading should be taken into account in the design of exposed piping as described in ANSI A58.1.

501.5.3 Earthquake (Seismic Forces). Piping systems located in regions where earthquakes are a factor shall be designed for a horizontal force in conformity with good engineering practice using governmental data as a guide in determining the earthquake (seismic force). However, this force is not to be considered as acting concurrently with lateral wind force.

501.5.4 Vibration. Piping shall be arranged and supported with consideration to vibration (see para. 521.3.5).

501.5.5 Discharge Reactions. Piping systems shall be designed, arranged, and supported so as to withstand reaction forces due to let down or discharge of fluids.

501.6 Weight Effects

The following weight effects combined with loads and forces from other causes shall be taken into account in the design of piping.

501.6.1 Live Loads. The live load consists of the weight of the fluid transported, and snow and ice loads, if the latter will be encountered.

501.6.2 Dead Loads. Dead loads consist of the weight of the piping components and insulation, and other superimposed permanent loads.

501.6.3 Test Loads. The test load consists of the weight of the test fluid.

501.7 Thermal Expansion and Contraction Loads

When a piping system is prevented from free thermal expansion and contraction as a result of anchors and restraints, thrusts and moments are set up that must be taken into account as required by paras. 502 and 519. Consideration must be given to stresses developed inside pipe walls by large rapid temperature changes of the contents.

502 DESIGN CRITERIA

502.1 General

Paragraph 502 pertains to ratings, stress values, stress criteria, design allowances, and minimum design values, and formulates the permissible variations to these factors used in the design of piping.

502.2 Pressure-Temperature Design Criteria for Piping Components

502.2.1 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 526.1.

502.2.2 Ratings: Normal Operating Conditions. For normal operation the design pressure and design temperature shall be within the pressure-temperature ratings for all components used. (01)

502.2.3 Ratings: Allowance for Variations From Normal Operation. It is recognized that variations in pressure and temperature inevitably occur, and therefore the piping system shall be considered safe for occasional operation for short periods at higher than the design pressure or temperature. (01)

Either pressure, or temperature, or both, may exceed the design values if the stress in the pipe wall calculated by the formulas using the maximum expected pressure during the variation does not exceed the S value allowable for the maximum expected temperature during the variation by more than the following allowances for the periods of duration indicated:

(a) up to 15% increase above the S value during 10% of the operating period; and

(b) up to 20% increase above the S value during 1% of the operating period.

502.2.4 Considerations for Local Conditions and Transitions. When two lines that operate at different pressure-temperature conditions are connected, the valve segregating the two lines shall be rated for the more severe condition. When a line is connected to a piece of equipment that operates at a higher pressure-temperature condition than that of the line, the valve segregating the line from the equipment shall be rated for at least the operating condition of the equipment. If, however, (01) the valve is a sufficient distance from the pipe or piece of equipment operating under the more severe service condition, with the result that the temperature of this valve would be lower than the more severe service condition, this valve may be rated for the most severe coexistent pressure-temperature condition to which it will be actually subjected in normal operation. However, the piping between the more severe conditions and the valve shall be designed to withstand the operating conditions of the equipment or piping to which it is connected.

(01) **502.2.5 Standards and Specifications.** Where there are manufacturers' standards of long standing, as is the case for flanges, valves, and fittings for certain refrigerants, these shall be permitted for the particular refrigerant service listed by the manufacturer.

(01) **502.2.6 Use of Criteria.** The design conditions mentioned in para. 501 determine the thickness of metal or other material required in the piping system. This thickness can be determined by one of three methods:

(a) by a combination of allowable stresses for the materials at the various temperature and mathematical formulas that link together the design condition and the thickness of metal or other material required;

(b) by a pressure-temperature rating for the individual components; or

(c) by an outright requirement that certain standardized components be used or not be used.

502.3 Allowable Stresses and Other Stress Limits

502.3.1 Allowable Stress Values

(a) The allowable stress values to be used for design calculations shall conform to Table 502.3.1 unless otherwise modified by requirements of this Code.

For pipe and tube that do not contain longitudinal or spiral joints, the Table shows the basic allowable stress *S*. It is the allowable hoop stress.

For pipe and tube that do contain longitudinal or spiral joints, the Table shows the product *SE* of the basic allowable stress *S* and the longitudinal or spiral joint factor *E*. *SE* is the allowable hoop stress.

For materials for which Table 502.3.1 shows longitudinal or spiral joint factors *E*, divide the *SE* value shown in the Table above by the joint factor *E* to get the allowable stress *S* for Code computations in Part 5, Chapter II, where the joint factor *E* need not be considered.

The stress values in the tables are grouped according to temperature, and in every case the temperature is the metal temperature. Allowable stresses for materials not listed shall not exceed those determined using the basis in (b) below for ferrous materials and in (c) below for nonferrous materials.

(b) The basis of establishing basic allowable stress values for ferrous materials in this Code is as follows. The mechanical properties for materials as developed by the ASME BPV Code were used for establishing stress values. (01)

At 100°F (38°C) and below, an allowable stress value was established at the lower value of stress obtained from using 25% of the specified minimum tensile strength at room temperature, or 62.5% of the specified minimum yield strength for 0.2% offset at room temperature.

At temperatures above 100°F (38°C) but below 400°F (205°C), allowable stress values were established that did not exceed 62.5% of the average expected yield strength for 0.2% offset at temperature, or did not exceed 25% of the average expected tensile strength at temperature.

For structural grade material a quality factor of 0.92 shall be applied.

(c) The basis for establishing basic allowable stress values for nonferrous materials in this Code is as follows. (01)

The basic allowable stress values for temperatures over 100°F (38°C) determined as the lowest of the following when the tensile and yield strengths are obtained from standard short-time tests made at the temperature under consideration:

(1) one-fourth of the tensile strength as adjusted to minimum;

(2) two-thirds of the yield strength as adjusted to minimum;

(3) the stress producing a creep rate of 0.01% in 1,000 hr; and

(4) the stress producing rupture in 100,000 hr.

At 100°F (38°C) and below, an allowable stress value was established at the lowest value of stress obtained by using one-fourth of the specified minimum tensile strength at room temperature, or two-thirds of specified minimum yield strength at room temperature.

The tensile strength and yield strength are adjusted to minimum by multiplying the test results by the ratio of the minimum specified or expected tensile or yield strength to the actual room temperature tensile or yield strength for the lot of material under test.

The creep and stress-rupture strengths are determined by plotting the results of the creep and stress-rupture tests in the manner described in "Interpretation of Creep and Stress-Rupture Data" by Francis B. Foley, Metal Progress, June 1947, pp. 951–958.

(*d*) Allowable stress values in shear shall be 0.80 of the values obtained from para. 502.3.1 and Table 502.3.1, and allowable stress values in bearing shall be 1.60 of the values obtained from para. 502.3.1 and Table 502.3.1.

(01) (*e*) When steel materials of unknown specifications are used at a temperature not to exceed 400°F (204°C) for structural supports and restraints, the allowable stress value shall not exceed 12.0 ksi (86 MPa).

(*f*) For components not having established pressure-temperature ratings, allowable stress values may be adjusted in accordance with para. 502.2.4 for other than normal operation.

502.3.2 Limits of Calculated Stresses Due to Sustained Loads and Thermal Expansion or Contraction

(*a*) *Internal Pressure Stresses.* The calculated stress due to internal pressure shall not exceed the allowable stress values given in Table 502.3.1 except as permitted by paras. 502.3.2(b), (c), and (d).

(*b*) *External Pressure Stresses.* Stress due to external pressures shall be considered safe when the wall thickness of the piping component and means of stiffening meet the requirements of paras. 503 and 504.

(*c*) *Allowable Stress Range for Expansion Stresses in Systems Stressed Primarily in Bending and Torsion.* The expansion stress range *SE* (see para. 519.4.5) shall not exceed the allowable stress range S_A given by Eq. (1):

$$S_A = f(1.25\, S_c + 0.25\, S_h) \tag{1}$$

where

S_c = basic material allowable stress at minimum (cold) normal temperature (use *S*, not *SE* from para. 502.3.1 and Table 502.3.1)

S_h = basic material allowable stress at maximum (hot) normal temperature (use *S*, not *SE* from para. 502.3.1 and Table 502.3.1)

NOTE: Does not include abnormal conditions, such as exposure to fires.

f = stress-range reduction factor for cyclic conditions [see Note (1)] for total number *N* of full temperature cycles over total number of years during which system is expected to be in active operation (read or interpolate from Fig. 502.3.2). By full temperature cycles is meant the number of cycles of temperature change from minimum to maximum temperature expected to be encountered [see Note (2)].

NOTES:

(1) Applies to essentially noncorrosive services. Corrosion can sharply decrease cyclic life. Corrosion resistant materials should be used where a large number of major stress cycles is anticipated.

(2) If the range of temperature changes varies, equivalent full temperature cycles may be computed from the equation:

$$N = N_E + r_1^5 N_1 + r_2^5 N_2 + \ldots + r_n^5 N_n$$

where

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

$N_1, N_2, \ldots, N_n$ = number of cycles of less temperature change $\Delta T_1, \Delta T_2, \ldots, \Delta T_n$

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

(*d*) The sum of the longitudinal stresses (in the corroded condition) due to pressure, weight, and other sustained external loading shall not exceed S_h. Where the sum of these stresses is less than S_h, the difference between S_h and this sum may be added to the term in parentheses in Eq. (1).

In calculating the longitudinal pressure stress, consider the internal pressure as acting only on the area established by the internal diameter.

502.3.3 Limits of Calculated Stresses Due to Occasional Loads

(*a*) *Operation.* The sum of the longitudinal stresses produced by pressure, live and dead loads, and those produced by occasional loads, such as wind or earthquake, may not exceed 1.33 times the allowable stress values given in Table 502.3.1. It is not necessary to consider wind and earthquake as occurring concurrently.

(*b*) *Test.* Stresses due to test conditions are not subject to the limitations of para. 502.3 of this Code. It is not necessary to consider other occasional loads, such as wind and earthquake, as occurring concurrently with the live, dead, and test loads existing at the time of test.

502.4 Allowances

502.4.1 Corrosion and Erosion. When corrosion or erosion is expected, an increase in wall thickness of the components over that dictated by other design requirements shall be provided, consistent with the expected life of the particular piping involved.

(01)

TABLE 502.3.1 MAXIMUM ALLOWABLE STRESS VALUES, ksi

Multiply by 1,000 to Obtain psi

Material	Spec. No.	Grade, Type, or Class	Min. Temp., °F [(1) & (2)]	Min. Tensile Strength, ksi (3)	Min. Yield Strength, ksi (3)	Longitudinal or Spiral Joint Factor
Seamless Carbon Steel Pipe and Tube						
Steel pipe	ASTM A 53	A	B	48.0	30.0	...
Steel pipe	ASTM A 53	B	B	60.0	35.0	...
Steel pipe	ASTM A 106	A	B	48.0	30.0	...
Steel pipe	ASTM A 106	B	B	60.0	35.0	...
Steel pipe	ASTM A 106	C	B	70.0	40.0	...
Steel tube	ASTM A 179	...	−20	47.0	26.0	...
Steel tube	ASTM A 192	...	−20	47.0	26.0	...
Steel tube	ASTM A 210	A-1	−20	60.0	37.0	...
Steel pipe	ASTM A 333	1	−50	55.0	30.0	...
Steel pipe	ASTM A 333	6	−50	60.0	35.0	...
Steel tube	ASTM A 334	1	−50	55.0	30.0	...
Steel tube	ASTM A 334	6	−50	60.0	35.0	...
Steel pipe	API 5L	A	B	48.0	30.0	...
Steel pipe	API 5L	B	B	60.0	35.0	...
Carbon Steel Pipe and Tube						
Steel pipe	ASTM A 53	F	−20	45.0	25.0	0.60
Steel pipe	API 5L	A 25	−20	45.0	25.0	0.60
Carbon Steel Pipe and Tube Electric Resistance Welded Pipe and Tube						
Steel pipe	ASTM A 53	A	B	48.0	30.0	0.85
Steel pipe	ASTM A 53	B	B	60.0	35.0	0.85
Steel pipe	ASTM A 135	A	B	48.0	30.0	0.85
Steel pipe	ASTM A 135	B	B	60.0	35.0	0.85
Steel tube	ASTM A 178	A	−20	47.0	26.0	0.85
Steel tube	ASTM A 178	C	−20	60.0	37.0	0.85
Steel tube	ASTM A 214	...	−20	47.0	26.0	0.85
Steel tube	ASTM A 226	...	−20	47.0	26.0	0.85
Steel pipe	ASTM A 333	1	−50	55.0	30.0	0.85
Steel pipe	ASTM A 333	6	−50	60.0	35.0	0.85
Steel tube	ASTM A 334	1	−50	55.0	30.0	0.85
Steel tube	ASTM A 334	6	−50	60.0	35.0	0.85
Steel pipe	ASTM A 587	...	−20	48.0	30.0	0.85
Steel pipe	API 5L	A	B	48.0	30.0	0.85
Steel pipe	API 5L	B	B	60.0	35.0	0.85
Carbon Steel Pipe and Tube Electric Fusion Welded Pipe						
Steel Pipe [Note (4)]	ASTM A 134	A 283 Gr. A	B	45.0	24.0	0.80
Steel Pipe [Note (4)]	ASTM A 134	A 283 Gr. B	B	50.0	27.0	0.80
Steel Pipe [Note (4)]	ASTM A 134	A 283 Gr. C	A	55.0	30.0	0.80

(01)

TABLE 502.3.1 MAXIMUM ALLOWABLE STRESS VALUES, ksi

Multiply by 1,000 to Obtain psi

For Metal Temperatures, °F, Not Exceeding							
−20 to 100	150	200	250	300	350	400	Spec. No.
							Seamless Carbon Steel Pipe and Tube
12.0	12.0	12.0	12.0	12.0	12.0	12.0	ASTM A 53
15.0	15.0	15.0	15.0	15.0	15.0	15.0	ASTM A 53
12.0	12.0	12.0	12.0	12.0	12.0	12.0	ASTM A 106
15.0	15.0	15.0	15.0	15.0	15.0	15.0	ASTM A 106
17.5	17.5	17.5	17.5	17.5	17.5	17.5	ASTM A 106
11.8	11.8	11.8	11.8	11.8	11.8	11.8	ASTM A 179
11.8	11.8	11.8	11.8	11.8	11.8	11.8	ASTM A 192
15.0	15.0	15.0	15.0	15.0	15.0	15.0	ASTM A 210
13.8	13.8	13.8	13.8	13.8	13.8	13.8	ASTM A 333
15.0	15.0	15.0	15.0	15.0	15.0	15.0	ASTM A 333
13.8	13.8	13.8	13.8	13.8	13.8	13.8	ASTM A 334
15.0	15.0	15.0	15.0	15.0	15.0	15.0	ASTM A 334
12.0	12.0	12.0	12.0	12.0	12.0	12.0	API 5L
15.0	15.0	15.0	15.0	15.0	15.0	15.0	API 5L
							Carbon Steel Pipe and Tube
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
							Carbon Steel Pipe and Tube Electric Resistance Welded Pipe and Tube
10.2	10.2	10.2	10.2	10.2	10.2	10.2	ASTM A 53
12.8	12.8	12.8	12.8	12.8	12.8	12.8	ASTM A 53
10.2	10.2	10.2	10.2	10.2	10.2	10.2	ASTM A 135
12.8	12.8	12.8	12.8	12.8	12.8	12.8	ASTM A 135
10.0	10.0	10.0	10.0	10.0	10.0	10.0	ASTM A 178
12.8	12.8	12.8	12.8	12.8	12.8	12.8	ASTM A 178
10.0	10.0	10.0	10.0	10.0	10.0	10.0	ASTM A 214
10.0	10.0	10.0	10.0	10.0	10.0	10.0	ASTM A 226
11.7	11.7	11.7	11.7	11.7	11.7	11.7	ASTM A 333
12.8	12.8	12.8	12.8	12.8	12.8	12.8	ASTM A 333
11.7	11.7	11.7	11.7	11.7	11.7	11.7	ASTM A 334
12.8	12.8	12.8	12.8	12.8	12.7	12.7	ASTM A 334
10.2	10.2	10.2	10.2	10.2	10.2	10.2	ASTM A 587
10.2	10.2	10.2	10.2	10.2	10.2	10.2	API 5L
12.8	12.8	12.8	12.8	12.8	12.8	12.8	API 5L
							Carbon Steel Pipe and Tube Electric Fusion Welded Pipe
8.3	...	8.3	...	8.3	...	...	ASTM A 134
9.2	...	9.2	...	9.2	...	...	ASTM A 134
10.1	...	10.1	...	10.1	...	...	ASTM A 134

(01)

TABLE 502.3.1 MAXIMUM ALLOWABLE STRESS VALUES, ksi (CONT'D)

Multiply by 1,000 to Obtain psi

Material	Spec. No.	Grade, Type, or Class	Min. Temp., °F [(1) & (2)]	Min. Tensile Strength, ksi (3)	Min. Yield Strength, ksi (3)	Longitudinal or Spiral Joint Factor
Carbon Steel Pipe and Tube Electric Fusion Welded Pipe (Cont'd)						
Steel Pipe [Note (4)]	ASTM A 134	A 283 Gr. D	A	60.0	33.0	0.80
Carbon Steel Pipe and Tube Copper Brazed Tubing						
Steel tube	ASTM A 254	...	...	42.0	25.0	...
Low and Intermediate Alloy Steel Pipe and Tube Seamless Alloy Steel Pipe and Tube						
3½Ni pipe	ASTM A 333	3	−150	65.0	35.0	...
Cr-Cu-Ni-Al pipe	ASTM A 333	4	−150	60.0	35.0	...
2½Ni pipe	ASTM A 333	7	−100	65.0	35.0	...
2Ni pipe	ASTM A 333	9	−100	63.0	46.0	...
3½Ni tube	ASTM A 334	3	−150	65.0	35.0	...
2½Ni tube	ASTM A 334	7	−100	65.0	35.0	...
2Ni tube	ASTM A 334	9	−100	63.0	46.0	...
Low and Intermediate Alloy Steel Pipe and Tube Electric Resistance Welded Pipe and Tube						
3½Ni pipe	ASTM A 333	3	−150	65.0	35.0	0.85
2½Ni pipe	ASTM A 333	7	−100	65.0	35.0	0.85
2Ni pipe	ASTM A 333	9	−100	63.0	46.0	0.85
3½Ni tube	ASTM A 334	3	−150	65.0	35.0	0.85
2½Ni tube	ASTM A 334	7	−100	65.0	35.0	0.85
Austenitic Stainless Steel Pipe and Tube Seamless Pipe and Tube						
18-8 tube	ASTM A 213	TP304	−425	75.0	30.0	...
18-8 tube	ASTM A 213	TP304L	−425	70.0	25.0	...
18-8 pipe	ASTM A 312	TP304	−425	75.0	30.0	...
18-8 pipe	ASTM A 312	TP304L	−425	70.0	25.0	...
18-8 pipe	ASTM A 376	TP304	−425	75.0	30.0	...
18-8 pipe	ASTM A 376	TP304	−425	70.0	30.0	...
Austenitic Stainless Steel Pipe and Tube Welded Pipe and Tube						
18-8 tube	ASTM A 249	TP304	−425	75.0	30.0	0.85
18-8 tube	ASTM A 249	TP304L	−425	70.0	25.0	0.85
18-8 pipe	ASTM A 312	TP304	−425	75.0	30.0	0.85
18-8 pipe	ASTM A 312	TP304L	−425	70.0	25.0	0.85

TABLE 502.3.1 MAXIMUM ALLOWABLE STRESS VALUES, ksi (CONT'D) (01)

Multiply by 1,000 to Obtain psi

For Metal Temperatures, °F, Not Exceeding							
−20 to 100	150	200	250	300	350	400	Spec. No.
							Carbon Steel Pipe and Tube Electric Fusion Welded Pipe (Cont'd)
11.0	...	11.0	...	11.0	...	...	ASTM A 134
							Carbon Steel Pipe and Tube Copper Brazed Tubing
6.0	5.8	5.5	5.1	4.7	4.0	3.0	ASTM A 254
							Low and Intermediate Alloy Steel Pipe and Tube Seamless Alloy Steel Pipe and Tube
16.3	16.3	16.3	16.3	16.3	16.3	16.3	ASTM A 333
15.0	15.0	15.0	15.0	15.0	15.0	15.0	ASTM A 333
16.3	16.3	16.3	...	16.3	16.3	16.3	ASTM A 333
15.7	...	...	...	...	...	...	ASTM A 333
16.3	16.3	16.3	...	16.3	16.3	16.3	ASTM A 334
16.3	16.3	16.3	16.3	16.3	16.3	16.3	ASTM A 334
15.7	...	...	...	...	...	...	ASTM A 334
							Low and Intermediate Alloy Steel Pipe and Tube Electric Resistance Welded Pipe and Tube
13.8	...	13.8	...	13.8	13.8	13.8	ASTM A 333
13.8	...	13.8	...	13.8	...	13.8	ASTM A 333
13.4	...	...	...	...	...	...	ASTM A 333
13.8	...	13.8	...	13.8	13.8	13.8	ASTM A 334
13.8	13.8	13.8	13.8	13.8	13.8	13.8	ASTM A 334
							Austenitic Stainless Steel Pipe and Tube Seamless Pipe and Tube
18.8	...	17.8	...	16.6	...	16.2	ASTM A 213
16.7	...	16.5	...	15.3	...	14.7	ASTM A 213
18.8	...	17.8	...	16.6	...	16.2	ASTM A 312
16.7	...	16.5	...	15.3	...	14.7	ASTM A 312
18.8	...	17.8	...	16.6	...	16.2	ASTM A 376
17.5	...	16.6	...	15.5	...	15.1	ASTM A 376
							Austenitic Stainless Steel Pipe and Tube Welded Pipe and Tube
16.0	...	15.1	...	14.1	...	13.8	ASTM A 249
14.2	...	14.0	...	13.0	...	12.5	ASTM A 249
16.0	...	15.1	...	14.1	...	13.8	ASTM A 312
14.2	...	14.0	...	13.0	...	12.5	ASTM A 312

(01)

TABLE 502.3.1 MAXIMUM ALLOWABLE STRESS VALUES, ksi (CONT'D)

Multiply by 1,000 to Obtain psi

Material	Spec. No.	NPS	Copper or Copper Alloy No.	Temper	Min. Tensile Strength, ksi (3)	Min. Yield Strength, ksi (3)
Seamless Copper and Copper Alloy Pipe and Tube						
Copper pipe	ASTM B 42	All	C10200 C12000 C12200	Annealed (O61)	30.0	9.0
Copper pipe [Note (5)]	ASTM B 42	$\frac{1}{8}$–2 incl.	C10200 C12000 C12200	Hard drawn (H80)	45.0	40.0
Copper pipe [Note (5)]	ASTM B 42	2–12 incl.	C10200 C12000 C12200	Light drawn (H55)	36.0	30.0
Red brass pipe	ASTM B 43	All	C23000	Annealed (O61)	40.0	12.0
Copper tube	ASTM B 68	All	C10200 C12000 C12200	Light anneal, soft anneal (O50, O60)	30.0	9.0
Copper tube	ASTM B 75	All	C10200 C12000 C12200 C14200	Light anneal, soft anneal (O50, O60)	30.0	9.0
Copper tube [Note (5)]	ASTM B 75	All	C10200 C12000 C12200 C14200	Light drawn (H55)	36.0	30.0
Copper tube [Note (5)]	ASTM B 75	Up to 4	C10200 C12000 C12200 C14200	Hard drawn (H80)	45.0	40.0
Copper tube [Note (5)]	ASTM B 88	All	C10200 C12000 C12200	Drawn general purpose (H58)	36.0	30.0
Copper tube	ASTM B 88	All	C10200 C12000 C12200	Light anneal (O50)	30.0	9.0
Copper tube [Note (5)]	ASTM B 111	Up to $3\frac{1}{8}$	C10200 C12000 C12200 C14200	Light drawn (H55)	36.0	30.0
Copper tube [Note (5)]	ASTM B 111	Up to $3\frac{1}{8}$	C10200 C12000 C12200 C14200	Hard drawn (H80)	45.0	40.0
Copper alloy	ASTM B 111	Up to $3\frac{1}{8}$	C19200	Annealed (O61)	38.0	12.0
Red brass condenser tube	ASTM B 111	Up to $3\frac{1}{8}$	C23000	Annealed (O61)	40.0	12.0

TABLE 502.3.1 MAXIMUM ALLOWABLE STRESS VALUES, ksi (CONT'D) (01)

Multiply by 1,000 to Obtain psi

For Metal Temperatures, °F, Not Exceeding							
100	150	200	250	300	350	400	Spec. No.
							Seamless Copper and Copper Alloy Pipe and Tube
6.0	5.1	4.8	4.8	4.7	4.0	3.0	ASTM B 42
11.3	11.3	11.3	11.3	11.0	10.3	4.3	ASTM B 42
9.0	9.0	9.0	9.0	8.7	8.5	8.2	ASTM B 42
8.0	8.0	8.0	8.0	8.0	7.0	5.0	ASTM B 43
6.0	5.1	4.8	4.8	4.7	4.0	3.0	ASTM B 68
6.0	5.1	4.8	4.8	4.7	4.0	3.0	ASTM B 75
9.0	9.0	9.0	9.0	8.7	8.5	8.2	ASTM B 75
11.3	11.3	11.3	11.3	11.0	10.3	4.3	ASTM B 75
9.0	9.0	9.0	9.0	8.7	8.5	8.2	ASTM B 88
6.0	5.1	4.8	4.8	4.7	4.0	3.0	ASTM B 88
9.0	9.0	9.0	9.0	8.7	8.5	8.2	ASTM B 111
11.3	11.3	11.3	11.3	11.0	10.3	4.3	ASTM B 111
7.5	7.0	6.7	6.5	6.1	...	...	ASTM B 111
8.0	8.0	8.0	8.0	8.0	7.0	5.0	ASTM B 111

(01) TABLE 502.3.1 MAXIMUM ALLOWABLE STRESS VALUES, ksi (CONT'D)

Multiply by 1,000 to Obtain psi

Material	Spec. No.	NPS	Copper or Copper Alloy No.	Temper	Min. Tensile Strength, ksi (3)	Min. Yield Strength, ksi (3)
Seamless Copper and Copper Alloy Pipe and Tube (Cont'd)						
Muntz metal condenser tube	ASTM B 111	Up to 3⅛	C28000	Annealed (O61)	50.0	20.0
Admiralty metal condenser tube	ASTM B 111	Up to 3⅛	C44300 C44400 C44500	Annealed (O61)	45.0	15.0
Aluminum bronze condenser tube	ASTM B 111	Up to 3⅛	C60800	Annealed (O61)	50.0	19.0
Aluminum brass condenser tube	ASTM B 111	Up to 3⅛	C68700	Annealed (O61)	50.0	18.0
95Cu-5Ni condenser tube	ASTM B 111	Up to 3⅛	C70400	Annealed (O61)	38.0	12.0
95Cu-5Ni condenser tube	ASTM B 111	Up to 3⅛	C70400	Light drawn (H55)	40.0	30.0
90Cu-10Ni condenser tube	ASTM B 111	Up to 3⅛	C70600	Annealed (O61)	40.0	15.0
80Cu-20Ni condenser tube	ASTM B 111	Up to 3⅛	C71000	Annealed (O61)	45.0	16.0
70Cu-30Ni condenser tube	ASTM B 111	Up to 3⅛	C71500	Annealed (O61)	52.0	18.0
Copper tube	ASTM B 280	Up to 1⅝	C10200 C12000 C12200	Soft anneal (O60)	30.0	9.0
Copper silicon A pipe	ASTM B 315	Up to 12	C65500	Annealed (O61)	50.0	15.0
90Cu-10Ni pipe	ASTM B 466	Up to 6	C70600	Soft anneal (O60)	38.0	13.0
70Cu-30Ni pipe	ASTM B 466	Up to 6	C71500	Soft anneal (O60)	52.0	18.0
Welded Copper and Copper Alloy Pipe and Tube						
90Cu-10Ni pipe and tube [(6)]	ASTM B 467	Up to 4½ incl.	C70600	Welded and annealed (WO61)	40.0	15.0
90Cu-10Ni pipe and tube [(6)]	ASTM B 467	Over 4½	C70600	Welded and annealed (WO61)	38.0	13.0
70Cu-30Ni pipe and tube [(6)]	ASTM B 467	Up to 4½ incl.	C71500	Welded and annealed (WO61)	50.0	20.0
70Cu-30Ni pipe and tube [(6)]	ASTM B 467	Over 4½	C71500	Welded and annealed (WO61)	45.0	15.0
70Cu-30Ni pipe and tube [(6)]	ASTM B 467	Up to 2	C71500	Welded, drawn, and tempered	72.0	50.0
Copper tube [Note (6)]	ASTM B 543	Up to 3½	C12200	Light cold worked (WC55)	32.0	15.0
Copper alloy tube [Note (6)]	ASTM B 543	Up to 3⅛	C19400	Annealed (WO61)	45.0	15.0
Copper alloy tube [Note (6)]	ASTM B 543	Up to 3⅛	C19400	Light cold worked (WC55)	45.0	22.0
Red brass tube [Note (6)]	ASTM B 543	Up to 3⅛	C23000	Annealed (WO61)	40.0	12.0
Red brass tube [Note (6)]	ASTM B 543	Up to 3⅛	C23000	Light cold worked (WC55)	42.0	20.0
Admiralty metal tube [Note (6)]	ASTM B 543	Up to 3⅛	C44300 C44400 C44500	Annealed (WO61)	45.0	15.0
Aluminum brass tube [(6)]	ASTM B 543	Up to 3⅛	C68700	Annealed (WO61)	50.0	18.0
95Cu-5Ni tube [Note (6)]	ASTM B 543	Up to 3⅛	C70400	Annealed (WO61)	38.0	12.0
90Cu-10Ni [Note (6)]	ASTM B 543	Up to 3⅛	C70600	Annealed (WO61)	40.0	15.0
90Cu-10Ni [Note (6)]	ASTM B 543	Up to 3⅛	C70600	Light cold worked (WC55)	45.0	35.0
70Cu-30Ni [Note (6)]	ASTM B 543	Up to 3⅛	C71500	Annealed (WO61)	52.0	18.0

TABLE 502.3.1 MAXIMUM ALLOWABLE STRESS VALUES, ksi (CONT'D) (01)

Multiply by 1,000 to Obtain psi

For Metal Temperatures, °F, Not Exceeding							
100	150	200	250	300	350	400	Spec. No.
					Seamless Copper and Copper Alloy Pipe and Tube (Cont'd)		
12.5	12.5	12.5	12.5	12.5	10.8	5.3	ASTM B 111
10.0	10.0	10.0	10.0	10.0	9.8	3.5	ASTM B 111
12.5	12.4	12.2	11.9	11.6	10.0	6.0	ASTM B 111
12.0	11.9	11.8	11.7	11.7	6.5	3.3	ASTM B 111
8.0	8.0	...	...	...	...	...	ASTM B 111
10.0	10.0	...	...	...	...	...	ASTM B 111
10.0	9.7	9.5	9.3	9.0	8.7	8.5	ASTM B 111
10.7	10.6	10.5	10.4	10.3	10.1	9.9	ASTM B 111
12.0	11.6	11.3	11.0	10.8	10.6	10.3	ASTM B 111
6.0	5.1	4.8	4.8	4.7	4.0	3.0	ASTM B 280
10.0	10.0	10.0	10.0	10.0	5.0	5.0	ASTM B 315
8.7	8.4	8.3	8.0	7.8	7.7	7.6	ASTM B 466
12.0	11.6	11.3	11.0	10.8	10.6	10.3	ASTM B 466
					Welded Copper and Copper Alloy Pipe and Tube		
8.5	8.2	8.1	7.9	7.6	7.4	7.2	ASTM B 467
7.4	7.1	7.1	6.8	6.6	6.5	6.5	ASTM B 467
10.6	9.6	8.9	8.8	8.8	8.8	8.8	ASTM B 467
8.5	8.2	8.0	7.8	7.7	7.5	7.3	ASTM B 467
15.3	15.3	15.3	15.3	15.3	14.9	14.7	ASTM B 467
5.1	4.3	4.1	4.0	4.0	3.4	2.5	ASTM B 543
8.5	8.5	8.3	8.1	7.8	7.3	6.0	ASTM B 543
8.5	8.5	8.3	8.1	7.8	7.3	6.0	ASTM B 543
6.8	6.8	6.8	6.8	6.8	5.9	4.2	ASTM B 543
6.8	6.8	6.8	6.8	6.8	5.9	4.2	ASTM B 543
8.5	8.5	8.5	8.5	8.5	8.3	3.0	ASTM B 543
10.2	10.1	10.0	9.9	9.9	5.5	2.7	ASTM B 543
6.8	6.8	...	...	...	...	...	ASTM B 543
8.5	8.2	8.1	7.9	7.6	7.4	7.2	ASTM B 543
8.5	8.2	8.1	7.9	7.6	7.4	7.2	ASTM B 543
10.2	9.9	9.6	9.3	9.2	9.0	8.8	ASTM B 543

(01)

TABLE 502.3.1 MAXIMUM ALLOWABLE STRESS VALUES, ksi (CONT'D)

Multiply by 1,000 to Obtain psi

Material	Spec. No.	NPS	Copper or Copper Alloy No.	Temper	Min. Tensile Strength, ksi (3)	Min. Yield Strength, ksi (3)
Welded Copper and Copper Alloy Pipe and Tube (Cont'd)						
Copper tube	ASTM B 743	...	C10200 C10300 C10800 C12000 C12200	Drawn general purpose (H58)	36.0	30.0
Copper tube	ASTM B 743	...	C10200 C10300 C10800 C12000 C12200	Light anneal, soft anneal (050, 060)	30.0	9.0
Seamless Nickel Base Alloy Pipe and Tube						
Nickel and copper pipe	ASTM B 165	5 O.D. and under	N04400	Annealed	70.0	28.0
Nickel and copper pipe	ASTM B 165	Over 5 O.D.	N04400	Annealed	70.0	25.0
Seamless Aluminum Base Alloy Pipe and Tube						
3003 tube	ASTM B 210	...	...	0	14.0	5.0
3003 tube [Note (7)]	ASTM B 210	...	...	H14	20.0	17.0
6063 tube [Note (8)]	ASTM B 210	...	...	T6	33.0	28.0
6063 tube	ASTM B 210	...	...	T6 welded	17.0	...
6061 tube [Note (8)]	ASTM B 210	...	...	T4	30.0	16.0
6061 tube [Note (8)]	ASTM B 210	...	...	T6	42.0	35.0
6061 tube	ASTM B 210	...	...	T6 welded	24.0	...
6061 tube [Note (8)]	ASTM B 234	...	...	T4	30.0	16.0
6061 tube [Note (8)]	ASTM B 234	...	...	T6	42.0	35.0
6061 tube	ASTM B 234	...	...	T6 welded	24.0	...
3003 tube or pipe	ASTM B 241	...	...	0	14.0	5.0
3003 pipe [Note (7)]	ASTM B 241	Under 1	...	H18	27.0	24.0
3003 pipe [Note (7)]	ASTM B 241	1 and over	...	H112	14.0	5.0
5083 tube	ASTM B 241	...	...	0	39.0	16.0
6063 tube [Note (8)]	ASTM B 241	≤0.500	...	T5	22.0	16.0
6063 tube [Note (8)]	ASTM B 241	...	...	T6	30.0	25.0
6061 tube [Note (8)]	ASTM B 241	...	...	T4	26.0	16.0
6061 pipe [Note (8)]	ASTM B 241	1 and over	...	T6	38.0	35.0
6061 pipe	ASTM B 241	...	...	T6 welded	24.0	...

TABLE 502.3.1 MAXIMUM ALLOWABLE STRESS VALUES, ksi (CONT'D) (01)

Multiply by 1,000 to Obtain psi

For Metal Temperatures, °F, Not Exceeding							
100	150	200	250	300	350	400	Spec. No.
							Welded Copper and Copper Alloy Pipe and Tube (Cont'd)
9.0	9.0	9.0	9.0	8.7	8.5	8.2	ASTM B 743
6.0	5.1	5.1	4.8	4.7	4.0	3.0	ASTM B 743
							Seamless Nickel Base Alloy Pipe and Tube
17.5	...	16.4	...	15.4	...	14.8	ASTM B 165
16.6	...	14.6	...	13.6	...	13.2	ASTM B 165
							Seamless Aluminum Base Alloy Pipe and Tube
3.4	3.4	3.4	3.0	2.4	1.8	1.4	ASTM B 210
5.0	5.0	5.0	4.9	4.3	3.0	2.4	ASTM B 210
8.3	8.3	7.9	7.4	5.5	3.4	2.0	ASTM B 210
4.3	4.3	4.3	4.2	3.9	3.0	2.0	ASTM B 210
7.5	7.5	7.5	7.4	6.9	6.3	4.5	ASTM B 210
10.5	10.5	10.5	9.9	8.4	6.3	4.5	ASTM B 210
6.0	6.0	6.0	5.9	5.5	4.6	3.5	ASTM B 210
7.5	7.5	7.5	7.4	6.9	6.3	4.5	ASTM B 234
10.5	10.5	10.5	9.9	8.4	6.3	4.5	ASTM B 234
6.0	6.0	6.0	5.9	5.5	4.6	3.5	ASTM B 234
3.4	3.4	3.4	3.0	2.4	1.8	1.4	ASTM B 241
6.8	6.8	6.7	6.3	5.4	3.5	2.5	ASTM B 241
3.4	3.4	3.4	3.0	2.4	1.8	1.4	ASTM B 241
9.8	9.8	...	...	...	...	...	ASTM B 241
5.5	5.5	5.4	5.1	4.6	3.4	2.0	ASTM B 241
7.5	7.5	7.4	6.8	5.0	3.4	2.0	ASTM B 241
6.5	6.5	6.5	6.4	6.0	5.8	4.5	ASTM B 241
9.5	9.5	9.5	9.1	7.9	6.3	4.5	ASTM B 241
6.0	6.0	6.0	5.9	5.5	4.6	3.5	ASTM B 241

(01) TABLE 502.3.1 MAXIMUM ALLOWABLE STRESS VALUES, ksi (CONT'D)
Multiply by 1,000 to Obtain psi

Material	ASTM Spec. No.	Grade	Min. Temp., °F [Note (2)]	Specified Min. Strength, ksi		Basic Allowable Stress S, ksi at Metal Temperature, °F [Notes (2), (3), & (4)]			
				Tensile	Yield	Min. Temp. to 100	200	300	400
Iron Castings [Note (5)]									
Gray	A 48	20	−20	20	...	2.0	2.0	2.0	2.0
Gray [Notes (9) & (10)]	A 278	20	−20	20	...	2.0	2.0	2.0	2.0
Gray [Notes (9) & (10)]	A 126	A	−20	21	...	2.0	2.0	2.0	2.0
Gray	A 48	25	−20	25	...	2.5	2.5	2.5	2.5
Gray [Notes (9) & (10)]	A 278	25	−20	25	...	2.5	2.5	2.5	2.5
Gray	A 48	30	−20	30	...	3.0	3.0	3.0	3.0
Gray [Notes (9) & (10)]	A 278	30	−20	30	...	3.0	3.0	3.0	3.0
Gray [Notes (9) & (10)]	A 126	B	−20	31	...	3.0	3.0	3.0	3.0
Gray	A 48	35	−20	35	...	3.5	3.5	3.5	3.5
Gray [Notes (9) & (10)]	A 278	35	−20	35	...	3.5	3.5	3.5	3.5
Gray [Notes (9) & (10)]	A 48	40	−20	40	...	4.0	4.0	4.0	4.0
Gray [Notes (9) & (10)]	A 126	C	−20	41	...	4.0	4.0	4.0	4.0
Gray [Notes (9) & (10)]	A 278	40	−20	40	...	4.0	4.0	4.0	4.0
Gray [Notes (9) & (10)]	A 48	45	−20	45	...	4.5	4.5	4.5	4.5
Gray [Notes (9) & (10)]	A 48	50	−20	50	...	5.0	5.0	5.0	5.0
Gray [Notes (9) & (10)]	A 278	50	−20	50	...	5.0	5.0	5.0	5.0
Gray [Notes (9) & (10)]	A 48	55	−20	55	...	5.5	5.5	5.5	5.5
Gray [Notes (9) & (10)]	A 48	60	−20	60	...	6.0	6.0	6.0	6.0
Gray [Notes (9) & (10)]	A 278	60	−20	60	...	6.0	6.0	6.0	6.0
Ferritic ductile [Notes (9) & (10)]	A 395	...	−20	60	48	9.6	9.6	9.6	9.6
Ferritic ductile [Notes (9), (10), & (11)]	A 536	65-45-12	−20	65	45	10.4	10.4	10.4	10.4
Ferritic ductile [Notes (9), (10), & (11)]	A 536	60-40-18	−20	60	40	9.6	9.6	9.6	9.6
Austenitic ductile [Notes (9) & (10)]	A 571	D, 2M, Cl. 1	−20	65	30	10.4	...	...	...

502.4.2 Threading and Grooving. See definition for *c* in para. 504.1.1(b).

502.4.4 Mechanical Strength. When necessary to prevent damage, collapse, or buckling due to superimposed loads from supports, backfill, or other causes, the pipe wall thickness shall be increased or, if this is impractical or would cause excessive local stresses, the factors that would contribute to damage of the piping shall be compensated for by other design methods.

PART 2 DESIGN OF PIPING COMPONENTS (01)

503 CRITERIA FOR DESIGN OF PIPING COMPONENTS (01)

The design of piping components, considering the effects of pressure, and providing for mechanical, corrosion, and erosion allowances, shall be in accordance with para. 504. In addition, the designs must be checked

TABLE 502.3.1 MAXIMUM ALLOWABLE STRESS VALUES, ksi (CONT'D) (01)

Multiply by 1,000 to Obtain psi

Product Form	ASME Spec. No.	Type/Grade	Min. Tensile Strength, ksi (3)	Min. Yield Strength, ksi (3)	Maximum Allowable Stress, ksi (Multiply by 1,000 to Obtain psi), for Metal Temperature, °F, Not Exceeding [Notes (2) & (3)]					
					−20 to 100	150	200	250	300	400
Carbon Steel										
Plate, sheet	SA-285	A	45	24	11.3	...	11.3	...	11.3	11.3
Steel sheet	SA-414	G	75	45	18.8	18.8	18.8	...	18.8	18.8
Plate, sheet	SA-516	55	55	30	13.8	13.8	13.8	...	13.8	13.8
Plate, sheet	SA-516	60	60	32	15.0	15.0	15.0	...	15.0	15.0
Plate, sheet	SA-516	65	65	35	16.3	16.3	16.3	...	16.3	16.3
Plate, sheet	SA-516	70	70	38	17.5	17.5	17.5	...	17.5	17.5

GENERAL NOTE: Except where specific omissions of stress values occur in this Table, the values in Section II, Part D for Section VIII, Division 1, of the ASME BPV Code may be used to supplement this Table for allowable stresses.

NOTES:

(1) The minimum temperature is that design minimum temperature for which the material is suitable without impact testing other than that required by the specification. See Table 523.2.2 for temperatures A and B.
(2) To convert °F to °C, subtract 32 and then multiply by $\frac{5}{9}$.
(3) To convert ksi to MPa, multiply by 6.895.
(4) A quality factor of 92% is included for structural grade.
(5) Where brazed construction is employed, stress values for annealed material shall be used.
(6) 85% joint efficiency has been used in determining the allowable stress value for welded tube.
(7) For brazed or welded construction or where thermal cutting is employed, stress value for "0" temper material shall be used.
(8) The stress values given for this material are not applicable when either brazing, welding, or thermal cutting is used.
(9) For limits on cast iron, see para. 523.2.3.
(10) For limits on ductile iron, see para. 523.2.4.
(11) Requires a full ferritizing anneal.

for adequacy of mechanical strength under other applicable loadings as given in para. 501.

(01) 504 PRESSURE DESIGN OF PIPING COMPONENTS

504.1 Straight Pipe

504.1.1 General

(a) The required thickness of straight sections of pipe shall be determined in accordance with Eq. (2). (Also, see para. 503.)

$$t_m = t + c \qquad (2)$$

(01) *(b)* The notations described below are used in the equations for the pressure design of straight pipe.

P = internal design pressure (see para. 501.2.2), psig (kPa), or external design pressure (see para. 501.2.3), psi (kPa)

S = applicable allowable hoop stress in accordance with para. 502.3.1 and Table 502.3.1, psi (kPa)

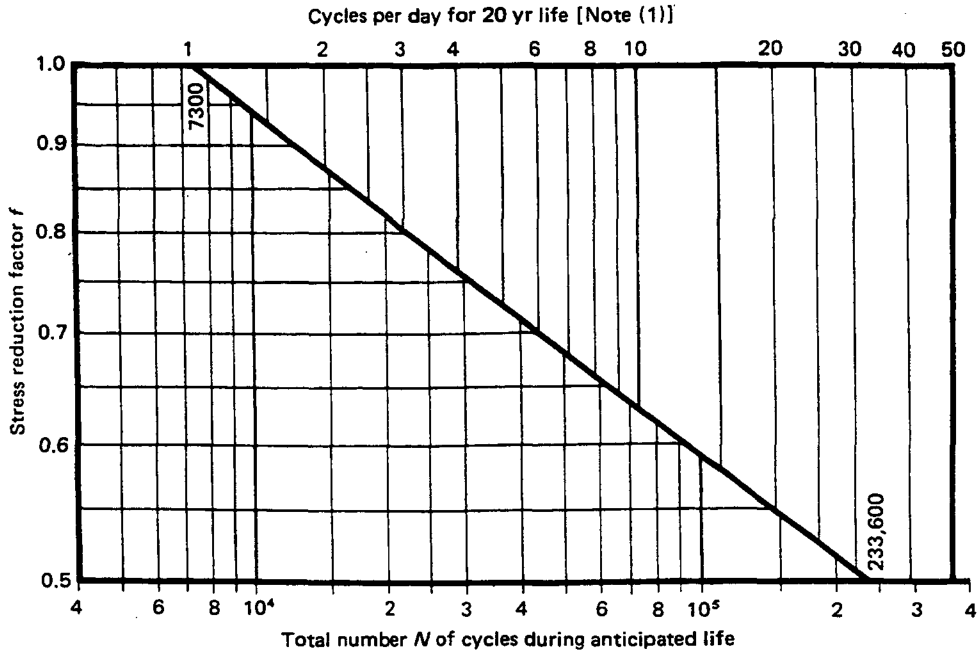
c = for internal pressure, the sum, in. (mm), of the mechanical allowances (thread, groove depth, and manufacturers' minus tolerance) plus corrosion and erosion allowances (see para. 502.4.1). For threaded components, the nominal thread depth (dimension h of ASME B1.20.1, or equivalent) shall apply. For machined surfaces or grooves, where the tolerance is not specified, the tolerance shall be assumed to be $\frac{1}{64}$ in. (0.5 mm) in addition to the specified depth of the cut.

= for external pressure, the sum, in. (mm), of corrosion and erosion allowances plus manufacturer's minus tolerance (see para. 502.4.1)

d = inside diameter of pipe, in. (mm), excluding metal required for corrosion or erosion allowance, manufacturer's minus tolerance, and any allowance required for the depth of internal threads or grooves

t = pressure design thickness, in. (mm), as calculated from Eq. (3) for internal pressure, or in accordance with the procedures given in para. 504.1.3 for external pressure

y = coefficient for materials indicated: for ductile nonferrous materials, use $y = 0.4$ (see Note);



NOTE:
(1) Assuming 365 day per year operation.

FIG. 502.3.2 STRESS RANGE REDUCTION FACTORS

for ferritic steels, use $y = 0.4$ (see Note);
for austenitic steels, use $y = 0.4$ (see Note).
For cast iron, use $y = 0.0$.

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

t_m = minimum required thickness, in. (mm), satisfying requirements for design pressure and mechanical, corrosion, and erosion allowances

NOTE: If D_o/t in range of 4–6, use $y = d/(d + D_o)$ for ductile materials.

(01) FIGS. 504.1.1-A and 504.1.1-B DELETED

504.1.2 Straight Pipe Under Internal Pressure. For metallic pipe with diameter-thickness ratios $D_o/t > 4$, the internal pressure design thickness t shall be calculated using Eq. (3).

$$t = \frac{PD_o}{2(S + Py)} \quad \text{or} \quad t = \frac{Pd}{2(S + Py - P)} \qquad (3)$$

$$P = \frac{2St}{D_o - 2yt}$$

NOTE: The following simpler alternative equation, which gives somewhat greater pipewall thickness, may be employed:

$$t = \frac{PD_o}{2S} \quad \text{or} \quad t = \frac{Pd}{2(S - P)}$$

$$P = \frac{2St}{D_o}$$

504.1.3 Straight Pipe Under External Pressure. (01)
To determine wall thickness and stiffening requirements for straight pipe under external pressure, the procedure outlined in the BPV Code, Section VIII, Division 1, UG-28 through UG-30 shall be followed, using as the design length L the running center line length between any two sections stiffened in accordance with UG-29. As an exception, for pipe with $D_o/t < 10$, the value of S to be used in determining P_{a2} shall be the lesser of the following values for pipe material at design temperature:

(a) 1.5 times the stress value from Table A-1 of this Code; or

(b) 0.9 times the yield strength tabulated in Section II, Part D, Table Y-1 for materials listed therein. (The symbol D_o in Section VIII is equivalent to D in this Code.)

504.1.4 DELETED (01)

504.2 Curved Segments of Pipe

504.2.1 Pipe Bends. Pipe after bending shall conform to the following.

(a) The minimum thickness after bending shall not be less than as required for straight pipe in accordance with para. 504.1.

(b) The difference between maximum and minimum diameters for pipe bends subjected to internal pressure should not exceed 8% of the nominal outside diameter of the pipe.

(c) The difference between maximum and minimum diameters for pipe bends subjected to external pressure should not be greater than 8% of the nominal outside diameter of the pipe.

(d) Bends made with greater flattening than indicated above shall meet the requirements of para. 504.7.

(01) *(e)* Bends for use on heat transfer components such as U-Bends (return bends) shall be designed in accordance with the requirements of para. 504.3 and/or para. 504.7.

504.2.2 Elbows. Elbows manufactured in accordance with the standards listed in Table 526.1 shall be considered suitable for use at the pressure-temperature ratings specified by such standards, and in the case of standards under which elbows are made to a nominal pipe thickness, the elbows shall be considered suitable for use with pipe of the same nominal thickness unless otherwise stated by the fittings standard. Commercially manufactured elbows not made in accordance with the standards listed in Table 526.1 shall meet the requirements of para. 504.7.

504.3 Intersections

504.3.1 Branch Connections

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

Branch connections in which the smaller angle between the axes of the branch and the run is less than 45 deg impose special design and fabrication problems; the rules given for angles greater than 45 deg may be used as a guide, but sufficient additional strength must be provided to assure safe and satisfactory service, and these branch connections shall be designed to meet the requirement of para. 504.7.

(b) Branch connections in piping may be made by the use of:

(1) fittings (tees, laterals, crosses, and multiple opening headers, qualified as fully reinforced in accordance with para. 504.7);

(2) welding outlet fittings, such as forged nozzles, couplings [maximum NPS 3 (DN 75)], or adaptors or similar items having butt welding, socket welding, threaded, or flanged ends for attachment of the branch pipe, such welding outlet fittings being attached to the main pipe by welding; or (01)

(3) by attaching the branch pipe directly to the run pipe by welding (acceptable methods of making welded pipe-to-pipe branch connections are contained in para. 527.4.6) or by threading.

(c) Right angle branch connections may be made by attaching the branch pipe directly to the run pipe by socket welding provided:

(1) the nominal size of the branch does not exceed NPS 2 (DN 50) or one-fourth the nominal size of the run, whichever is lesser; (01)

(2) the depth of the socket in the run is at least $^3/_8$ in. (10 mm) deep with a minimum shoulder or $^1/_{16}$ in. (1.5 mm) between the bottom of the socket and the inside diameter of the run pipe. [Weld metal may be deposited on the run pipe to provide the required socket depth and to provide any reinforcement required by (d) and (e) below.] (01)

(3) the size of the fillet weld is not less than 1.25 times the nominal branch wall thickness.

(d) Right angle branch connections may be made by threading the branch pipe directly to the run pipe provided:

(1) the nominal size of the branch does not exceed NPS 2 (DN 50) or one-fourth the nominal size of the run, whichever is lesser; and (01)

(2) minimum thread engagement is 6 full threads for NPS $^1/_2$ (DN 15) and NPS $^3/_4$ (DN 20) branches, 7 for NPS 1 (DN 25) and NPS $1^1/_2$ (DN 40) branches, and 8 for NPS 2 (DN 50) branches. [Weld metal may be deposited on the run to provide sufficient thickness for the required thread engagement and to provide any reinforcement required by paras. 504.3.1(d) and (e). In interpreting paras. 504.3.1(d) and (e) for connections threaded directly into the run pipe, no part of the branch pipe may be counted in calculating the reinforcement area, and the value of d_1 shall be taken as the nominal outside diameter of the branch pipe.] (01)

(e) A pipe having a branch connection is weakened by the opening that must be made in it, and unless the wall thickness of the pipe is sufficiently in excess of that required to sustain the pressure, it is necessary to provide reinforcement. The amount of reinforcement

required shall be determined in accordance with paras. 504.3.1(d) and (e). There are, however, certain branch connections for which no supporting calculations are required. It may be assumed without calculation that a branch connection has adequate strength to sustain the internal and external pressure that will be applied to it if:

(1) the branch connection is made by the use of a fitting (tee, lateral, or cross) manufactured in accordance with a standard listed in Table 526.1 and used within the limits of pressure-temperature ratings given in the standard. (A butt welding fitting made in accordance with ASME B16.9 shall be of a nominal thickness not less than the nominal thickness required for the adjoining pipe.)

(01) *(2)* the branch connection is made by welding a threaded or socket welding coupling or half coupling directly to the main pipe using an appropriate type of minimum size weld (see Chapter V) and the nominal diameter of the branch does not exceed DN 50 (NPS 2) pipe size and does not exceed one-fourth the nominal diameter of the run. The minimum wall thickness of the coupling anywhere in the reinforcement zone shall be not less than that of the branch pipe, and in no case shall the coupling have a rating less than Class 3000 per ASME 16.11.

(3) the branch connection is made by welding a threaded, socket, or butt weld outlet integrally reinforced branch connection fitting to the main pipe, provided the fitting is made from materials in accordance with Table 523.1 and provided the fitting has demonstrated by full-scale internal pressure destructive tests that the branch fitting is as strong as the main or branch pipe. See para. 504.7.

(f) Reinforcement of Welded Branch Connections. Additional reinforcement is required when it is not provided inherently in the components of the branch connection. This subparagraph gives rules governing 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.

(01) *(1) Notation.* The notations described below are used in the pressure design of branch connections. The notations are illustrated in Fig. 504.3.1-A. Note the use of subscripts b for branch and h for header. Note also that Fig. 504.3.1-A does not indicate details of construction or welding.

C = corrosion allowance, in. (mm)

T = actual thickness of pipe, in. (mm), by actual measurement, or minimum thickness permissible under purchase specification

$\bar{T}$ = nominal thickness of pipe, in. (mm)

b = subscript referring to branch

h = subscript referring to run or header

t = pressure design thickness of pipe, in. (mm), according to the appropriate wall thickness equation or procedure in para. 504.1. When the branch does not intersect the longitudinal weld of the run, use S from para. 502.3.1 and Table 502.-3.1, not SE, in determining t for the purpose of reinforcement calculation only. The allowable stress SE of the branch shall be used in calculating t_b.

β = angle between axes of branch and run, deg

D_0 = outside diameter of pipe, in. (mm)

L_4 = height of reinforcement zone outside of run pipe, in. (mm)
= $2.5\ (T_h - C)$ or $2.5\ (T_b - C) + t_r$, whichever is lesser

d_1 = actual corroded length removed from run pipe, in. (mm)
= $[D_b - 2\ (T_t - C)] / \sin \beta$

d_2 = half-width of reinforcement zone, in. (mm)
= d_1 or $[(T_b - C) + (T_h - C) + d_1/2]$, whichever is greater, but in any case not more than D_oh

t_r = nominal thickness or reinforcing ring or saddle in. (mm)
= 0, if there is no reinforcement pad or saddle

(2) Required Area A_1

(a) For Internal Pressure. The quantity t_hd_1 $(2 - \sin \beta)$ is known as the required area; in the case of right angle nozzles, the required area becomes t_hd_1 sq in. (sq mm). The branch connection must be designed so that reinforcement area defined in (3) below is not less than the required area. (01)

(b) For External Pressure. The reinforcement area required for the branch connections subject to external pressure need be only $0.5\ t_hd_1\ (2 - \sin \beta)$.

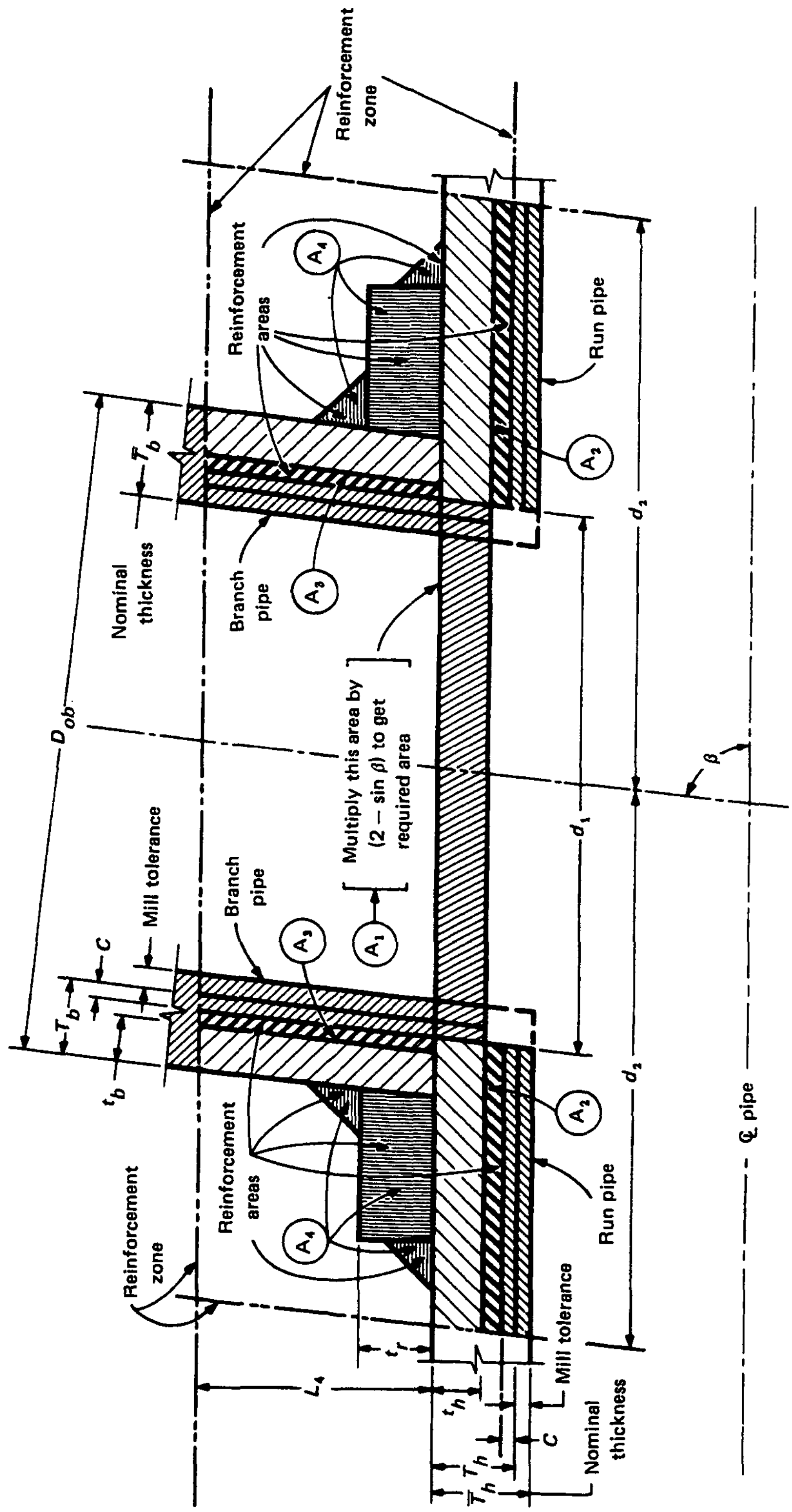
(3) Reinforcement Area. The reinforcement area shall be the sum of areas $A_2 + A_3 + A_4$ and shall not be less than the required area.

(a) Areas A_2 and A_3. The area lying within the reinforcement zone [defined in (f)(4) below] resulting from any excess thickness available in the main run pipe wall (A_2) and branch pipe wall (A_3) over that required by the proper wall thickness equations, i.e., the thickness $T_h - t_h - C$ and $T_b - t_b - C$ multiplied by appropriate lengths, i.e.,

$$A_2 = (2d_2 - d_1)\ (T_h - t_h - C) \qquad (4)$$

$$A_3 = [2L_4\ (T_b - t_b - C)] / \sin \beta \qquad (5)$$

(b) Area A_4. The area of all other metal within



GENERAL NOTE: This figure is merely to illustrate the notation of para. 504.3.1(f) and does not indicate complete welding details, or a preferred method of construction. For typical weld details, see Fig. 527.4.6-D.

FIG. 504.3.1-A REINFORCEMENT OF BRANCH CONNECTIONS

the reinforcement zone [defined in (f)(4) below] provided by weld metal and other reinforcement metal properly attached to the run or branch. In computing area of weld metal deposits, the minimum dimensions required by Chapter V shall be used unless a definite procedure is employed to instruct the welder to provide specific larger dimensions, in which case the latter dimensions may be used in calculations. Deduct mill tolerance from t_r when computing area or reinforcement pad.

Portions of the reinforcement area may be composed of materials other than those of the main run pipe but if the allowable stress of these materials (see para. 502.3.1 and Table 502.3.1) is less than that for the main run pipe, the calculated area for such portions must be reduced in the ratio of the allowable stress values before being credited to the reinforcement area. No additional credit shall be taken for materials having higher allowable stress values than for the main run pipe.

(4) Reinforcement Zone. The reinforcement zone is a parallelogram whose length shall extend a distance d_2 on each side of the center line of the branch pipe and whose width shall start at the actual corroded inside surface of the main run pipe and extend to a distance L_4 from the outside surface of the main pipe measured perpendicular to this outside surface.

(5) Reinforcement of Multiple Openings. When any two or more adjacent openings are so closely spaced that their reinforcement zones overlap, the two or more openings shall be reinforced in accordance with (f)(2) above 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 1.5 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.

(6) Rings and Saddles. Additional reinforcement provided in the form of rings or saddles shall not be appreciably narrower in the transverse direction than in the longitudinal direction.

(g) Extruded Outlet Headers

(1) The above principles of reinforcement are essentially applicable to extruded outlet headers. An extruded outlet header is defined as a header in which the outlet is extruded using a die (or dies) which controls the radii of the extrusion. The extruded lip at the outlet has a height 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., $h_x \geq r_x$). [See (3) below for notation and Fig. 504.3.1-B.]

(2) When the design meets the limitations of geometry outlined below, the rules herein established are valid. These rules cover minimum requirements and are designed to assure satisfactory performance of extruded outlet headers subjected to pressure. 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.

(3) Notations. The notations used herein are illustrated in Fig. 504.3.1-B. Note the use of subscript x for extruded outlet. Refer to (f) above for notations not listed here. **(01)**

L_5 = height of reinforcement zone, in. (mm) $= 0.7\sqrt{D_{ob} T_x}$

T_x = corroded finished thickness of extruded outlet measured at a height equal to r_x above the outside surface of the run, in. (mm)

d_x = the design inside diameter of the extruded outlet, in. (mm), measured at the level of the outside surface of the run

d_2 = half-width of reinforcement zone, in. (mm) (equal to d_x)

h_x = height of the extruded outlet, in. (mm). This must be equal to or greater than r_x [except as shown in sketch (b) in Fig. 504.3.1-B].

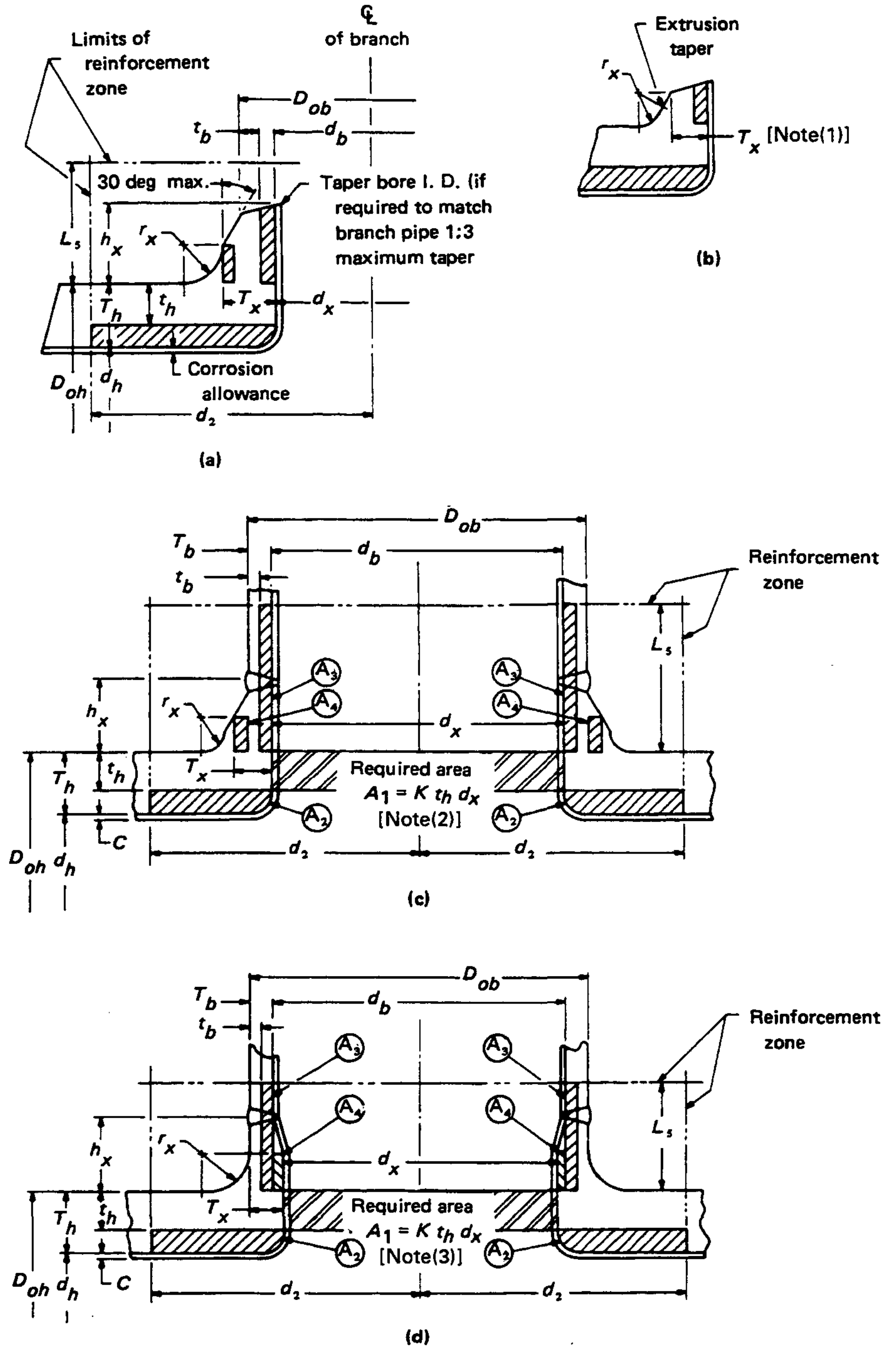
r_x = radius of curvature of external contoured portion of outlet measured in the plane containing the axis of the run and branch, in. (mm). This is subject to the following limitations.

(a) Minimum Radius. This dimension shall not be less than 0.05 D_{ob} except that on branch diameters larger than NPS 30 (DN 750) it need not exceed 1.50 in. (38 mm). **(01)**

(b) Maximum Radius. For outlet pipe sizes NPS 8 (DN 200) and larger, this dimension shall not exceed 0.10 D_{ob} + 0.50 in. (12.7 mm) For outlet pipe sizes less than NPS 8 (DN 200) this dimension shall not be greater than 1.25 in. (32 mm). **(01)**

(c) When the external contour contains more than one radius, the radius of any arc sector of approximately 45 deg shall meet the requirements for maximum and minimum radii.

(d) Machining shall not be employed in order to meet the above requirements.



GENERAL NOTE: This figure is merely to illustrate the notations of para. 504.3.1(g) and does not indicate complete welding details, or a preferred method of construction.

NOTES:

(1) Sketch to show method of establishing T_x when the taper encroaches on the crotch radius.
(2) Sketch is drawn for condition where $K = 1.00$.
(3) Sketch is drawn for condition where $K = 1.00$ and $d_x < d_b$.

FIG. 504.3.1-B EXTRUDED OUTLET HEADER NOTATION

(4) Required Area. The required area is defined as $A_1 = Kt_h d_x$ where K shall be taken as follows.

(a) For D_{ob}/D_{oh} greater than 0.60, $K = 1.00$.

(b) For D_{ob}/D_{oh} greater than 0.15 and not exceeding 0.60,

$$K = 0.6 + \tfrac{2}{3}\, D_{ob}/D_{oh} \qquad (6)$$

(c) For D_{ob}/D_{oh} equal to or less than 0.15, $K = 0.70$.

The design must meet the criteria that the reinforcement area defined in (g)(5) below is not less than the required area A_1.

(5) Reinforcement Area. The reinforcement area shall be the sum of areas $A_2 + A_3 + A_4$ as defined below.

(a) Area A_2. The area lying within the reinforcement zone resulting from any excess thickness available in the run wall.

$$A_2 = d_x(T_h - t_h) \qquad (7)$$

(b) Area A_3. The area lying within the reinforcement zone resulting from any excess thickness available in the branch pipe wall.

$$A_3 = 2L_5(T_b - t_b) \qquad (8)$$

(c) Area A_4. The area lying within the reinforcement zone resulting from any excess thickness available in the extruded outlet lip.

$$A_4 = 2r_x(T_x - t_b) \qquad (9)$$

(6) Reinforcement of Multiple Openings. The rules of (f)(5) above shall be followed except that the required area and reinforcement area shall be as given in para. 504.3.1(g).

(7) In addition to the above, the manufacturer shall be responsible for establishing and marking, on the header containing extruded outlets, the design pressure and temperature and this Code Section. The manufacturer's name or trademark shall be marked on the header.

(h) Mechanically Formed Tee Connections in Copper Materials (Type K, L, M)

(1) These mechanically formed connections shall be perpendicular to the axis of the run tube (header). They shall be formed by drilling a pilot hole and drawing out the tube surface to form a collar having a height of not less than three times the thickness of the branch wall. The collaring device shall be such as to assure proper fit up of the joint.

(2) The inner branch tube end shall conform to the shape of the inner curve of the run tube. Insertion of the branch tube shall be controlled to assure alignment with specified depth into the collar without extending into the flow stream so as to provide internal reinforcement to the collar as illustrated in Fig. 504.3.1-C.

(3) Branches can be formed up to the run tube size. Manufacturing procedures shall be in accordance with tool manufacturer's recommendations.

(4) These types of connections may not be used in other than Group A1 refrigerant service.

(5) All joints shall be brazed in accordance with paras. 528.1 and 528.2.

(i) Other Designs. Components to which design rules given in (c) and (d) above are not applicable shall meet the requirements of para. 504.7.

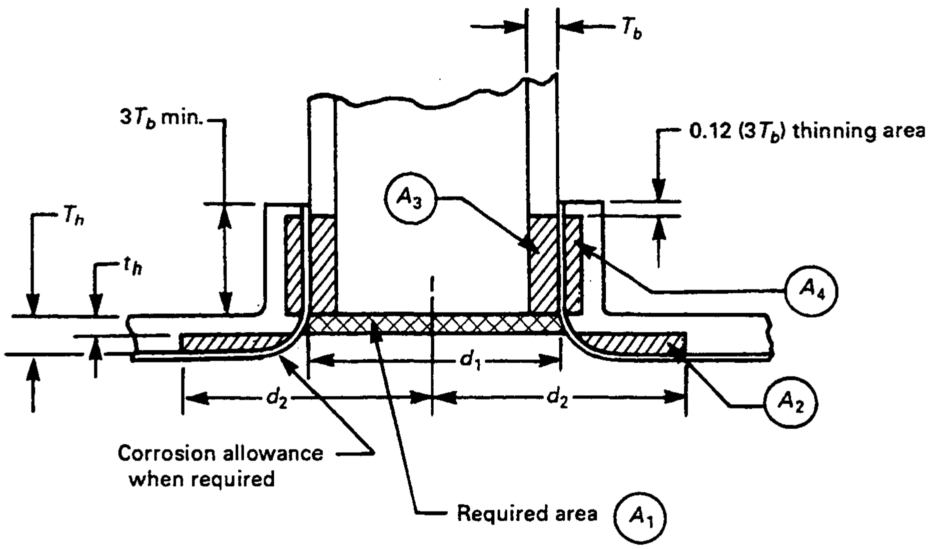
(j) The requirements of the preceding subparagraphs are designed to assure satisfactory performance of a branch connection subjected only to pressure. However, in addition, external forces and moments are usually applied to a branch connection by such agencies as thermal expansion and contraction, by dead weight of piping, valves and fittings, covering and contents, and by earth settlement. Special consideration shall be given to the design of a branch connection to withstand these forces and moments.

Where the ratio of branch diameter to run diameter is large or where repetitive stresses may be imposed on the connection due to vibration, pulsating pressure, temperature cycling, etc., it is recommended that the design be rather conservative and that consideration be given to the use of tee fittings or complete encirclement types of reinforcement.

Use of ribs, gussets, and clamps is permissible to stiffen the branch connection but their areas cannot be counted as contributing to the reinforcement area defined in (d)(3) above. Consideration should be given to stress arising from a temperature gradient between the piping and gussets during a sudden change in temperature of the fluid in the piping.

It is not practicable to give definite rules for design to accommodate the effects mentioned in this subparagraph. The purpose is to call them to the attention of the engineer so that from experience and judgment he may adequately provide for them.

Attention is especially directed to the design of small branches out of large and relatively heavy runs. Adequate flexibility must be provided in the smaller line to accommodate thermal expansion and other movements of the larger line.



A_1 = required area, sq in. (sq mm) = $t_h d_1$
A_2 = area lying within the reinforcement zone resulting from any excess thickness available in the header wall
A_3 = area lying within the reinforcement zone resulting from any excess thickness in the branch tube wall
A_4 = area lying within the reinforcement zone resulting from any excess thickness available in the extruded lip

$A_2 + A_3 + A_4 \geq A_1$

T = actual thickness of tube wall
b = branch
d_1 = opening size in header tube
d_2 = d_1 = reinforcement zone
h = header
t = pressure design thickness

FIG. 504.3.1-C MECHANICALLY FORMED TEE CONNECTIONS IN COPPER MATERIALS (01)

504.3.2 Openings in Closures

(01) *(a)* The rules of this paragraph are intended to apply to openings in closures in which the size of the opening is not greater than 50% of the inside diameter of the closure (as defined in para. 504.4). Larger openings should be designed as reducers, or in the case of flat closures, the closure shall be designed as a flange in accordance with para. 504.5.

(01) *(b)* A closure is weakened by an opening and unless the thickness of the closure is sufficiently in excess of that required to sustain pressure, it is necessary to provide reinforcement. The need for, and amount of reinforcement required, shall be determined in accordance with the subparagraph below except that it shall be considered that the opening has adequate reinforcement if:

The outlet connection is made by welding a threaded or socket welding coupling or half-coupling directly to the closure (using an appropriate weld as given in Fig. 527.4.6-D for branch connections) and if the nominal diameter of the outlet pipe does not exceed NPS 2 (DN 50) and does not exceed 25% of the nominal diameter of the closure. The minimum wall thickness of the coupling anywhere in the reinforcement zone shall not be less than that of the branch pipe and in no case shall a coupling have a rating less than Class 3000 per ASME B16.11.

(c) Reinforcement shall be provided for openings in closures in amount and distribution such that the area requirements for distribution are satisfied for all planes passing through the center of the opening and normal to the surface of the closure.

(d) The total cross section area required for reinforcement in any given plane passing through the center of the opening shall be not less than the quantity $d_5 t$ (see Note below) (01)

where

t = the pressure design thickness for the closure according to the equations and procedures specified in para. 504.4, in. (mm), except that a lesser thickness may be used where applicable in accordance with the provisions contained in Section VIII, Division 1, of the ASME BPV Code relative to openings in pressure vessel heads

d_5 = the diameter, in the plane under consideration, of the finished opening in the corroded condition, in. (mm)

NOTE: Flat heads that have an opening with a diameter that does not exceed one-half the head diameter as defined in UG-34 may have a total cross section of required reinforcement not less than that given by the formula $A = 0.5\ d_5t$.

(e) The reinforcement area and reinforcement zone shall be calculated in accordance with para. 504.3.1 considering the subscript h and other references to main run pipe to apply to the closure rather than to the run or header. Likewise, where the closure is curved, the boundaries of the reinforcement zone shall follow the contour of the closure, and dimensions of the reinforcement zone shall be measured parallel to and perpendicular to the closure surface.

(f) When two or more openings are to be located in a closure, the rules given in para. 504.3.1 for the reinforcement of multiple openings shall apply.

(g) Attention is directed to the general considerations for the design of branch connections discussed in para. 504.3.1(f) as they are equally applicable to openings in closures.

504.3.3 Miters. When the maximum stress due to internal pressure [Eq. (3)] does not exceed 50% of the allowable hoop stress, miters may be used subject to the following limitations.

(a) The number of full pressure or thermal cycles shall not exceed 7,000 during the expected life of the piping system.

(b) The direction change for any single assembled miter weld should not exceed 45 deg.

(c) The center line distance between adjacent miters should not be less than one nominal pipe diameter.

(d) Full penetration welds shall be used in joining miter segments.

(e) Miter joints with greater directional changes and closer center line distances shall conform to para. 504.7. Deflections caused by misalignments up to 3 deg are not considered miters.

504.3.4 Attachments. External and internal attachments to piping shall be designed so they will not 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.

504.4 Closures

504.4.1 General

(a) The required thickness of closures, considering pressure and mechanical, corrosion, and erosion allowances, shall be determined in accordance with Eq. (10). (01)

$$t_m = t + c \tag{10}$$

The minimum thickness for the closure selected, considering the manufacturer's minus tolerances shall not be less than t_m.

Closure fittings manufactured in accordance with the standards listed in Table 526.1 shall be considered suitable for use at the pressure-temperature ratings specified by such standards, and in the case of standards under which closure fittings are made to a nominal pipe thickness, the closure fittings shall be considered suitable for use with pipe of the same nominal thickness. Commercially manufactured closures not made in accordance with the standards listed in Table 526.1 and for which design rules are not given in this paragraph (para. 504.4) shall meet the requirements of para. 504.7.

(b) The notations described below are used for determining the pressure design of closures: (01)

P = internal design pressure (see para. 501.2.2), psig, or external design pressure (see para. 501.2.3), psi (kPa)

S = applicable allowable stress in accordance with para. 502.3.1 and Table 502.3.1, ksi (MPa)

c = the sum of the mechanical allowances, thread depth, groove depth, and the corrosion and erosion allowances, in. (mm) (See para. 504.4.)

t = pressure design thickness as calculated for the given closure shape and direction of pressure loading from the appropriate equations and procedures in Section VIII, Division 1, of the ASME BPV Code, in. (mm) (Certain symbols used in these equations, namely, P and S shall have the meanings described in this subparagraph instead of those given in ASME BPV Code. All other symbols shall be as defined in the ASME BPV Code.)

t_m = minimum required thickness, satisfying requirements for pressure, mechanical, corrosion and erosion allowances, in. (mm)

(01) **504.4.2 Flat Plate Closures.** The minimum required thickness t_m for a flat plate closure (shown in Fig. 527.4.7-A) shall be determined in accordance with Eq. (11).

$$t_m = d\sqrt{CP/S} + c \qquad (11)$$

where

C = 0.33 $[t_r/(t_s - c)]$ but not less than 0.20
P = as defined in para. 504.4.1(b)
S = as defined in para. 504.4.1(b)
c = as defined in para. 504.4.1(b)
d = inside diameter of pipe, in. (mm)
t_r = required or calculated thickness of pipe wall, in. (mm)
t_s = actual or measured thickness of pipe wall, exclusive of corrosion allowance, in. (mm)

504.5 Pressure Design of Flanges and Blanks

504.5.1 General

(01) *(a)* Flanges manufactured in accordance with the standards listed in Table 526.1 shall be considered suitable for use at the pressure-temperature ratings specified by such standards. Flanges not made in accordance with the standards listed in Table 526.1 shall be designed in accordance with Section VIII, Division 1, of the ASME BPV Code except that the requirements for fabrication, assembly, inspection, and testing, and the pressure and temperature limits for materials of this Code shall govern. Also, certain notations used in the ASME BPV Code, namely, P, S_a, S_b, and S_f shall have the meanings described in this paragraph instead of those given in the ASME BPV Code. All other notations shall be as defined in the ASME BPV Code.

P = internal design gage pressure (see para. 501.2.2), psi (kPa). (Flanges subject to external pressure should be designed for an internal pressure equal to the external design pressure.)
S_a = bolt design stress, ksi (MPa), at 100°F (38°C) (from Section VIII, Division 1, of the ASME BPV Code)
S_b = bolt design stress, ksi (MPa), at design temperature (from Section VIII, Division 1, of the ASME BPV Code)
S_f = allowable stress, ksi (MPa), for flange material or pipe (from para. 502.3.1 and Table 502.3.1)

(b) The flange design rules presented in (a) above are not applicable to designs employing flat faced flanges used with full-face gaskets that extend beyond the bolts, usually to the outside diameter of the flange. The forces and reactions in such a joint are very different from those found on ring-gasketed joints, and the flange should be designed to meet the requirements of para. 504.7.

504.5.2 Blind Flanges. Blind flanges manufactured in accordance with the standards listed in Table 526.1 shall be considered suitable for use at the pressure-temperature ratings specified by such standards.

(a) The required thickness of blind flanges not manufactured in accordance with standards in Table 526.1 shall be calculated in accordance with Eq. (12), considering pressure and mechanical, corrosion, and erosion allowances. The minimum thickness for the blind flange selected, considering manufacturer's minus tolerance, shall not be less than t_m. (01)

$$t_m = t + c \qquad (12)$$

(b) The notations described below are used for the determining of pressure design of blind flanges: (01)

P = internal design gage pressure (see para. 501.2.2), psig (kPa), or external design gage pressure (see para. 501.2.3), psi (kPa)
S = applicable allowable stress in accordance with para. 502.3.1 and Table 502.3.1, ksi (MPa)
c = sum of the corrosion and erosion allowances, in. (mm)
t = pressure design thickness, in. (mm), as calculated for the given closure shape and direction of pressure loading from the appropriate equations and procedures in Section VIII, Division 1, of the ASME BPV Code. (Certain symbols used in these equations, namely P and S, shall be considered to have the meanings described in this subparagraph instead of those given in the ASME BPV Code. All other symbols shall be as defined in the ASME BPV Code.)
t_m = minimum required thickness, in. (mm), satisfying requirements for pressure, mechanical, corrosion, and erosion allowances

504.5.3 Blanks (01)

(a) The pressure design thickness of permanent blanks (see Fig. 504.5.3) shall be calculated in accordance with Eqs. (12) and (13).

$$t = d_g\sqrt{\frac{3P}{16S}} \qquad (13)$$

where

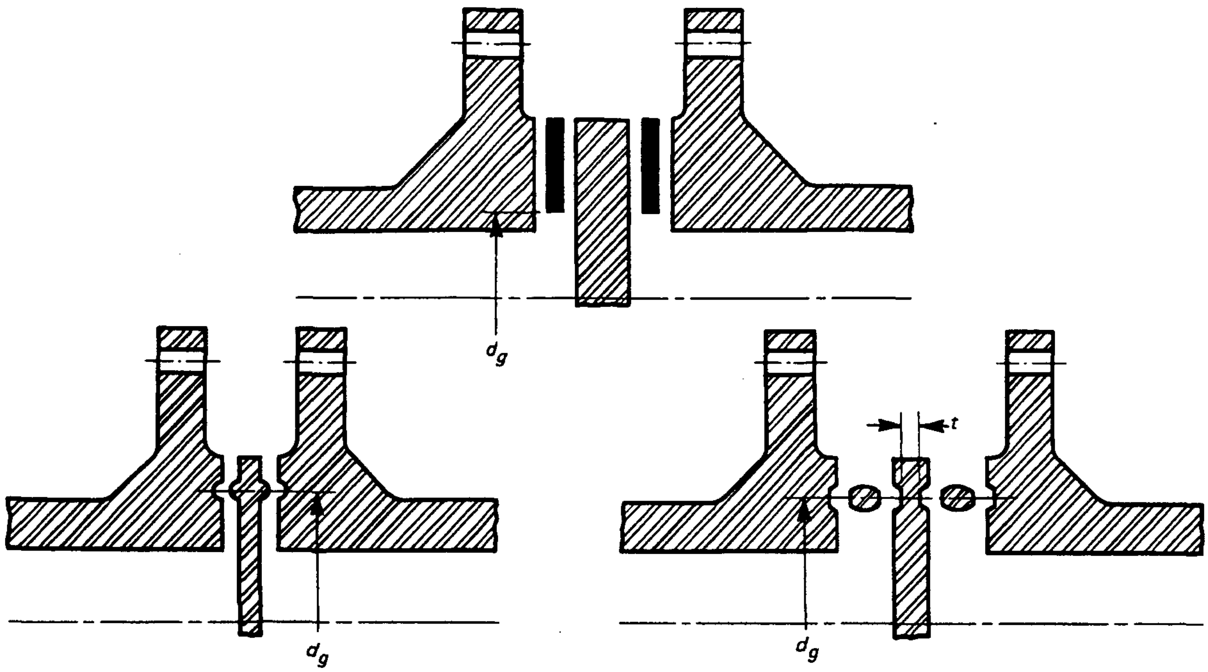


FIG. 504.5.3 BLANKS

P = internal design gage pressure (see para. 501.2.2), psig (kPa), or external design gage pressure (see para. 501.2.3), psi (kPa)
S = applicable allowable stress in accordance with para. 502.3.1 and Table 502.3.1, ksi (MPa)
d_g = inside diameter of gasket for raised or flat (plain) face flanges, or the gasket pitch diameter for retained gasketed flanges, in. (mm)

(b) Blanks to be used for test purposes only shall be designed in accordance with Eq. (13), except that P shall be at least equal to the test pressure and S may be as great as 95% of the specified minimum yield strength of the blank material. (This applies only if the test fluid is incompressible.)

(01) **504.6 Headers**

Headers used on heat transfer components shall be designed in accordance with para. 504.3 and/or shall meet the requirements of para. 504.7.

(01) **504.7 Design of Other Pressure-Containing Components**

Other pressure-containing components manufactured in accordance with the standards listed in Table 526.1 shall be considered suitable for use at the pressure-temperature ratings specified by such standards. Pressure-containing components not covered by the standards listed in Table 526.1 and for which design formulas or procedures are not given in this paragraph (para. 504), may be used where they have been proven satisfactory by successful performance under comparable service conditions. (Where such satisfactory service experience exists, interpolation may be made to other sized components with a geometrically similar shape.) In the absence of such service experience, the pressure design shall be based on an analysis consistent with the general design philosophy embodied in this Code Section and substantiated by at least one of the following:

(a) proof tests (as described in UG-101 of Section VIII, Division I, of the ASME BPV Code);

(b) experimental stress analysis; and/or

(c) for heat transfer components, proof test a sample at three times the design pressure of the component. (01)

PART 3
DESIGN APPLICATION OF PIPING COMPONENTS SELECTION AND LIMITATIONS

505 PIPE

(01) ### 505.1 General

Pipe, tubes, and other materials conforming to the standards and specifications listed in Tables 502.3.1 and 526.1 shall be used within the limitations of temperature and stress given in para. 502.3.1 and Table 502.3.1 and within the additional limitations contained in this Code.

(01) **505.1.1 Additional Limitations for Carbon Steel Pipe.** The wall thickness for refrigerant pipe sizes NPS 6 (DN 150) and smaller shall be no less than Schedule 40 (ASME B36.10), and for liquid refrigerants in Groups A2, A3, B2, and B3, pipe sizes smaller than NPS 2 (DN 50) shall be no less than Schedule 80.

ASTM A 53 Type F and API 5L furnace butt welded pipe is not permitted for use in refrigeration piping.

505.1.2 Additional Limitations for Cast Iron Pipe. Cast iron pipe shall not be used for refrigerant service.

(01) **505.1.3 Pressure Design of Other Piping Components.** Pressure design of other piping components shall meet the requirements of para. 504.7.

505.2 Nonferrous Pipe or Tube

505.2.1 Copper, copper alloy, aluminum, or aluminum alloy pipe and tube of any size may be used for any refrigerant service where compatible with the refrigerant used and when selected in accordance with the design rule in para. 504.1 and allowable stress values in Table 502.3.1.

(01) **505.2.2** Soft annealed copper tubing larger than $1^3/_8$ in. (35 mm) O.D. shall not be used for field assembled refrigerant piping, unless it is protected from mechanical damage.

506 FITTINGS, BENDS, AND INTERSECTIONS

506.1 Fittings

506.1.1 General. If fittings complying with applicable standards and specifications listed in Tables 523.1 and 526.1 are used, they shall be used within the limitations specified in this Code.

Other fittings, including those exceeding the range of sizes in the standards listed in Table 526.1, may be used provided the designs meet the requirements in para. 504.

506.1.2 Bell and Spigot Fittings. Bell and spigot fittings shall not be used for refrigerant service.

506.2 Bends and Intersections

Bends, miters, and extruded branch connections may be used when they are designed in accordance with the principles in Chapter II, Part 2.

506.3 Limitation on Materials for Fittings (01)

Malleable iron and cast iron shall not be used in couplings or fittings for piping containing flammable or toxic fluids.

507 VALVES

(a) Valves complying with the standards listed in Table 526.1 may be used in accordance with the limitations listed in the specific standards and in this Code.

(b) Refrigerant gate valves, ball valves, and plug cocks shall not be used in liquid refrigerant lines unless consideration is given to the expansion of liquid trapped in the valve cavities when the valve or cock is closed.

508 FLANGES, BLANKS, FLANGE FACINGS, GASKETS, AND BOLTING

508.1 Flanges

508.1.1 General. If flanges complying with applicable standards and specifications listed in Tables 523.1 and 526.1 are used, they shall be used within the limitations specified in this Code.

Other flanges, including those exceeding the range of sizes in the standards listed in Table 526.1, may be used provided the designs meet the requirements of para. 504.

508.1.2 Screwed Flanges. Screwed flanges are subject to restrictions on threaded joints established in para. 514(e).

508.2 Blanks

Blanks shall conform to design requirements in para. 504.5.3.

508.3 Flange Facings (01)

Flange facings complying with standards listed in Table 526.1 are suitable for use under this Code. Other special facings may be used provided they meet the requirements of para. 504.7.

Class 150 steel flanges may be bolted to cast iron valves, fittings, or other cast iron piping components having either Class 125 cast integral or screwed flanges. If such construction is used, it is preferred that the $^1/_{16}$ in. (1.5 mm) raised face on steel flanges be removed. If the raised face is removed and a ring gasket extending to the inner edge of the bolt holes is used, or if the raised face is not removed, the bolting shall be carbon steel not stronger than ASTM A 307, Grade B. If a full-face gasket is used, the bolting may be alloy steel (ASTM A 193).

Class 300 steel flanges may be bolted to cast iron valves, fittings, or other cast iron piping components having either Class 250 cast iron integral or screwed flanges, without any change in the raised face on either flange. If such construction is used, the bolting shall be carbon steel not stronger than ASTM A 307, Grade B.

(01) **508.4 Gaskets**

Selection of suitable material for a given service is the responsibility of the user, and subject to any applicable code or jurisdictional regulation. The material selected shall be compatible with the fluid and suitable for the pressure-temperature conditions and shall meet the requirements of ASME B16.20 or ASME B16.21.

508.5 Bolting

508.5.1 General. If bolts, nuts, and washers complying with applicable standards and specifications listed in Tables 523.1 and 526.1 are used, they shall be used within the limitations specified in this Code and shall also be subject to the requirements of Chapter III and paras. 508.3 and 508.5.2(a) and (b).

508.5.2 Bolting for Cast Iron Flanges

(a) Classes 25 and 125 cast iron integral or screwed companion flanges may be used with a full-face gasket or with a flat ring gasket extending to the inner edge of the bolts. When using a full-face gasket, the bolting may be alloy steel (ASTM A 193). When using a flat ring gasket, the bolting shall be of carbon steel equal to or less than ASTM A 307, Grade B. Materials other than carbon steels may be used provided the physical properties are equal to or less than the requirements of ASTM A 307, Grade B.

(01) *(b)* When bolting together two Class 250 cast iron, integral, or screwed companion flanges having $^1/_{16}$ in. (1.5 mm) raised faces, the bolting shall be of carbon steel equal to or less than ASTM A 307, Grade B. Materials other than carbon steels may be used provided the physical properties are equal to or less than the requirements of ASTM A 307, Grade B.

PART 4
SELECTION AND LIMITATIONS OF PIPING JOINTS

510 PIPING JOINTS

510.1 General

The type of piping joint used shall be suitable for the pressure-temperature conditions, and shall be selected giving consideration to joint tightness and mechanical strength under the service conditions (including thermal expansion and vibration) and to the nature of the fluid handled with respect to corrosion, erosion, flammability, and toxicity.

The following limitations are in addition to applicable requirements in other portions of this Code Section.

511 WELDED JOINTS

511.1 General

Welded joints may be used with any materials for which it is possible to qualify welding procedures, welders, and welding operators in conformance with Chapter V.

511.2 Butt Welds

Butt welds shall be made in accordance with the applicable requirements of Chapter V and para. 500. When backing rings are used in services where their use will result in severe corrosion or erosion, the backing ring should be removed and the internal joint ground smooth. In such services where it is impractical to remove the backing ring, consideration shall be given to welding the joint without backing rings, or consumable inserts may be used.

511.3 Socket Welds

511.3.1 Socket welds shall be made in accordance with the applicable requirements of Chapter V and para. 500. Dimensions of socket welding piping joints shall conform to ANSI B16.5 for flanges and ANSI B16.11 for fittings, and the weld dimensions shall be not less than the minimum dimensions shown in Figs. 527.4.4-B and 527.4.4-C.

511.3.2 Socket welded connections inserted directly into the wall of the run pipe shall be in accordance with requirements of para. 504.3.1(c).

511.3.3 Drains and bypasses may be attached to a fitting or valve by socket welding, provided the socket depth, bore diameter, and shoulder thickness conform to the requirements of ASME B16.5.

511.4 Fillet Welds

Fillet welds shall be made in accordance with the applicable requirements of Chapter V and para. 500. Fillet welds shall not have dimensions less than the minimum dimensions shown in Figs. 527.4.4-B, 527.4.4-C, and 527.4.6-D.

511.5 Seal Welds

Seal welds may be used to avoid joint leakage; however, they shall not be considered as contributing any strength to the joint. (See also para. 527.4.5.)

512 FLANGED JOINTS

Flanged joints shall meet the requirements of para. 508.

513 EXPANDED JOINTS

Expanded joints may be used where experience or tests have demonstrated that the joint is suitable for the conditions and where adequate provisions are made in the design to prevent separations of the joints.

514 THREADED JOINTS

(a) Threaded joints may be used within the limits stated in (b) through (f) below.

(b) When used, all pipe threads shall be taper pipe threads where the tightness of joint depends upon the seating of the thread. Straight threads on pipe joints that depend upon a seating surface other than the thread are allowed within the limitations of para. 518 if the thread root is no deeper than a standard pipe thread and if the thread is sealed from the contained fluid.

(c) Threaded joints shall not be used for Group A2 or Class 3 refrigerants, unless suitably seal welded or brazed.

(01) *(d)* Threaded joints larger than NPS 1 (DN 25) should not be used for Group A2 or Class 3 refrigerants.

(01) *(e)* Threaded joints larger than NPS 6 (DN 150) should not be used for salt brines.

(f) Pipe with a wall thickness less than ASME B36.10M Standard Weight or Schedule 40 up to NPS 6 (DN 150) and Schedule 30 in NPS 8, 10, 12 (DN 200, 250, 300) should not be threaded. (01)

515 FLARED, FLARELESS, AND COMPRESSION JOINTS

515.1 Selection and Application (01)

In selecting and applying flared, flareless, and compression type tube fittings, the designer shall consider the adverse effects on the joints of such factors as assembly and disassembly, cyclic loading, vibration, shock, thermal expansion and contraction, and the problem of frost growth between the tube and fitting.

515.2 Piping Joints With Applicable Standards (01)

Piping joints using flared, flareless, or compression fittings may be used within the limitations of applicable standards or specifications listed in Table 526.1 and the following requirements.

(a) Fittings and their joints shall be suitable for the tubing with which they are to be used with consideration to minimum tubing wall thickness and method of assembly recommended by the manufacturer.

(b) Fittings shall not be used in services that exceed the manufacturer's maximum pressure-temperature recommendations.

515.3 Piping Joints Without Applicable Standards (01)

For piping joints using flared, flareless, or compression fittings for which there are no applicable standards or specifications listed in Table 526.1, the engineer shall determine that the type of fitting selected is adequate and safe for the design conditions and that it meets the requirements of paras. 515.2(a) and (b) and the following requirements.

(a) The pressure design shall meet the requirements of para. 504.7.

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

517 BRAZED AND SOLDERED JOINTS (01)

Brazed and soldered socket type joints may be used with the following limitations for the attachment of valves, fittings, and flanges to nonferrous pipe and tubing.

(a) Soldered joints shall not be used for piping containing other than Group A1 refrigerants or any other toxic or flammable fluid.

(b) Bores and depths of sockets of brazed and soldered fittings shall conform to the dimensions in ASME B16.18 or ASME B16.22. Depths of sockets for brazed fittings only may conform to MIL-F-1183J.

(c) Brazed socket type joints may be used provided it is determined that the fittings are adequate and safe for the design conditions in accordance with the requirements listed in paras. 515(a) through (d) for flared and flareless fittings.

(d) The piping systems should be kept free of flux and other foreign materials.

(e) Solder joints shall not be used for temperatures in excess of those given in ASME B16.22.

518 SLEEVE COUPLED AND OTHER NOVEL OR PATENTED JOINTS

Coupling type, mechanical gland type, and other patented or novel type joints may be used provided adequate provisions are made to prevent separation of the joints and provided a prototype joint has been subjected to performance tests to determine the safety of the joint under simulated service conditions. When vibration, fatigue, cyclic conditions, low temperature, thermal expansion, or hydraulic shock are anticipated, the applicable conditions shall be incorporated in the tests.

PART 5
EXPANSION, FLEXIBILITY, STRUCTURAL ATTACHMENTS, SUPPORTS, AND RESTRAINTS

519 EXPANSION AND FLEXIBILITY

519.1 General

The following clauses define the objectives of piping flexibility analysis and alternative ways in which these can be realized.

519.1.1 Objectives. Piping systems shall be designed to have sufficient flexibility to prevent thermal expansion from causing:

(a) failure of piping or anchors from overstress or overstrain;

(b) leakage at joints; or

(c) detrimental distortion of connected equipment (pumps, turbines, or valves) resulting from excessive thrusts and moments.

519.1.2 Expansion Strains. Expansion strains may be taken up in two ways, either primarily by bending or torsion in which case only the extreme fibers at the critical location are stressed to the limit, or by axial compression and tension in which case the entire cross-sectional area over the entire length is substantially equally stressed.

(a) Bending or torsional flexibility may be provided by the use of bends, loops, or offsets; or by swivel joints, ball joints, corrugated pipe, or expansion joints of the bellows type permitting angular movement. Suitable anchors, ties, or other devices shall be provided as necessary to resist end forces from fluid pressure, frictional, or other resistance to joint movement and other causes.

(b) Axial flexibility may be provided by expansion joints of the slip-joint or bellows types. Pipe running from anchors to the joints must be guided where necessary to keep the pipe from bowing because of end forces originating in the joint from fluid pressure, friction, and deformation of the bellows. Anchors must be adequate for these forces plus the force arising from friction in the guides. For design and selection of expansion joints of the bellows type, reference to the Standards of the Expansion Joint Manufacturers Association is recommended.

519.2 Concepts

Concepts peculiar to piping flexibility analysis and requiring special consideration are explained in the following paragraphs.

519.2.1 Stress Range. As contrasted with stresses from sustained loads (such as internal pressure or weight), stresses caused by thermal expansion in systems stressed primarily in bending and torsion are permitted to attain sufficient initial magnitude to cause local yielding or creep. The attendant relaxation or reduction of stress in the hot condition leads to the creation of a stress reversal when the component returns to the cold condition. This phenomenon is designated as self-springing of the line and is similar in effect to cold springing. The amount of self-springing depends on the initial magnitude of the expansion stress, the material, the temperature, and the elapsed time. While the expansion stress in the hot condition tends to diminish with time, the arithmetic sum of the expansion stresses in the hot and cold conditions during any one cycle remains substantially constant. This sum, referred to as the stress range, is the determining factor in the thermal design of piping.

519.2.2 Expansion Range. In computing the stress range, the full thermal expansion range from the minimum to maximum metal temperature normally expected during installation and operation shall be used, whether the piping is cold sprung or not. Linear or angular movements of the equipment to which the piping is attached shall be included. For values of the unit thermal expansion range, refer to para. 519.3.1.

Where substantial anchor or terminal movements are anticipated as a result of tidal changes (unloading dock piping) or wind sway (piping attached to slender towers), these effects shall be considered analogous to terminal movements caused by thermal expansion.

519.2.3 Cold Spring. Cold spring is recognized as beneficial in that it serves to balance hot and cold stresses without drawing on the ductility of the material, for which reason it is recommended in particular for materials of relatively low ductility. In addition, it helps assure minimum departure from as-erected hanger settings. Inasmuch as the life of a system under cyclic conditions depends primarily on the stress range rather than the stress level at any one time, no credit for cold spring is given for stress range calculations. In calculating end thrusts and moments where actual reactions at any one time rather than their range are considered significant, cold spring is credited. (See para. 519.4.6.)

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

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

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

(c) in a system of uniform size, by use of a line configuration for which the neutral axis (actually, the wrench axis) is situated close to the major portion of the line with only a very small portion projecting away from it absorbing most of the expansion strain.

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

519.3 Properties

The following paragraphs deal with materials and geometric properties of pipe and piping components and the manner in which they are to be used in piping flexibility analysis.

519.3.1 Unit Thermal Expansion Range. The thermal expansion range e in./100 ft (mm/m) shall be determined from Table 519.3.1 as the algebraic difference between the unit expansion shown for the maximum normal-operating metal temperature and that for the minimum normal-operating metal temperature. For materials not included in this Table, reference shall be made to authoritative source data, such as publications of the National Institute of Standards and Technology. (01)

519.3.2 Moduli of Elasticity. The cold and hot moduli of elasticity, E_c and E_h, respectively, shall be taken from Table 519.3.2 for the minimum and maximum normal-operating metal temperatures in Table 519.3.2. For materials not included in these Tables, reference shall be made to authoritative source data, such as publications of the National Institute of Standards and Technology.

519.3.3 Poisson's Ratio. Poisson's Ratio is the ratio of the unit deformation at right angles to the direction of the load to the unit deformation in the direction of the load, and may be taken as 0.3 at all temperatures for all metals. However, more accurate data may be used if available.

519.3.4 Allowable Expansion Stress Range. The allowable basic expansion stress range S_A and permissible additive stresses shall be as specified in paras. 502.3.2(c) and (d) for systems primarily stressed in bending or torsion.

519.3.5 Dimensions. Nominal dimensions of pipe and fittings, and cross-sectional areas, moments of inertia, and section moduli based thereon shall be used in flexibility calculations, including the permissible additive stresses.

(01) **TABLE 519.3.1 THERMAL EXPANSION DATA (IP and SI)**

Linear Thermal Expansion (IP), in./100 ft

Material	Temperature Range 70°F to -325	-150	-50	70	200	300	400
Carbon steel, carbon moly	-2.37	-1.45	-0.84	0.00	0.99	1.82	2.70
Nickel steel ($3\frac{1}{2}$Ni)	-2.25	-1.48	-0.84	0.00	1.01	1.84	2.69
Nickel steel (9Ni)	-2.27	-1.43	-0.81	0.00	0.98	1.77	2.57
Austenitic stainless steels	-3.85	-2.27	-1.24	0.00	1.46	2.61	3.80
Ductile iron	. . .	-1.29	-0.77	0.00	0.94	1.72	2.56
Monel (67Ni-30Cu)	-2.62	-1.79	-0.98	0.00	1.22	2.21	3.25
Copper (99.90Cu) C12000, C12200	-3.70	-2.28	-1.28	0.00	1.51	2.67	3.88
Red brass (85Cu) C23000	-3.88	-2.24	-1.29	0.00	1.52	2.76	4.05
Copper nickel (90Cu-10Ni) C70600	-4.10	-2.26	-1.29	0.00	1.49	2.62	3.77
Copper nickel (70Cu-30ni) C71500	-3.15	-1.95	-1.13	0.00	1.33	2.40	3.52
Aluminum	-4.68	-2.88	-1.67	0.00	2.00	3.66	5.39
Copper silicon (3Si) C65500	-4.21	-2.31	-1.32	0.00	1.51	2.67	3.88

Linear Thermal Expansion (SI), mm/m

Material	Temperature Range 21°C to -198	-101	-46	21	93	149	204
Carbon steel, carbon moly	-1.97	-1.21	-0.70	0.00	0.82	1.52	2.25
Nickel steel ($3\frac{1}{2}$Ni)	-1.87	-1.23	-0.70	0.00	0.84	1.53	2.24
Nickel steel (9Ni)	-1.89	-1.19	-0.68	0.00	0.82	1.48	2.14
Austenitic stainless steels	-3.21	-1.89	-1.03	0.00	1.22	2.18	3.17
Ductile iron	. . .	-1.07	-0.64	0.00	0.78	1.43	2.13
Monel (67Ni-30Cu)	-2.18	-1.49	-0.82	0.00	1.02	1.84	2.71
Copper (99.90Cu) C12000, C12200	-3.08	-1.90	-1.07	0.00	1.26	2.22	3.23
Red brass (85Cu) C23000	-3.23	-1.87	-1.07	0.00	1.27	2.30	3.37
Copper nickel (90Cu-10Ni) C70600	-3.42	-1.88	-1.07	0.00	1.24	2.18	3.14
Copper nickel (70Cu-30Ni) C71500	-2.62	-1.62	-0.94	0.00	1.11	2.00	2.83
Aluminum	-3.90	-2.40	-1.39	0.00	1.67	3.05	4.49
Copper silicon (3Si) C65500	-3.51	-1.92	-1.10	0.00	1.26	2.22	3.23

519.3.6 Flexibility and Stress Intensification Factors. Calculations shall take into account stress intensification factors found to exist in components other than plain straight pipe. Credit may be taken for the extra flexibility of such components. In the absence of more directly applicable data, the flexibility and stress intensification factors shown in Table 519.3.6 may be used. For piping components or attachments (such as valves, strainers, anchor rings or bands) not covered in the Table, suitable stress intensification factors may be assumed by comparison of their significant geometry with that of the components shown.

519.4 Analysis for Bending Flexibility

The following paragraphs establish under what circumstances and in what manner piping flexibility analyses are to be made where the system primarily derives its flexibility from bending or torsional strains.

519.4.1 Formal calculations or model tests shall be required only where reasonable doubt exists as to the adequate flexibility of a system.

519.4.2 Adequate flexibility may generally be assumed to be available in systems that:

(a) are duplicates of successfully operating installations or replacements of systems with a satisfactory service record;

(b) can be readily adjudged adequate by comparison with previously analyzed systems; and

(c) are of uniform size, have no more than two points of fixation and no intermediate restraints, are (01)

TABLE 519.3.2 MODULI OF ELASTICITY (IP and SI) (01)

Moduli of Elasticity (IP), psi [Note (1)]

Material	Temperature, °F						
	–325	–150	–50	70	200	300	400
Carbon steel, carbon 0.30 or less	31.4	30.5	30.0	29.5	28.8	28.3	27.7
Cast iron	...	...	...	13.4	13.2	12.9	12.6
Monel (67Ni-30Cu)	27.8	27.1	26.6	26.0	25.4	25.0	24.7
Copper (99.90Cu) C12000, C12200	18.0	17.6	17.3	17.0	16.6	16.3	16.0
Red Brass (85Cu) C23000	18.2	17.7	17.5	17.0	16.6	16.4	15.8
Copper nickel (90Cu-10Ni) C70600	19.0	18.6	18.3	18.0	17.6	17.3	16.9
Copper nickel (70Cu-30Ni) C71500	22.3	22.8	22.4	22.0	21.5	21.1	20.7
Aluminum	11.1	10.6	10.3	10.0	9.6	9.2	8.7
Copper silicon (3Si) C65500	15.9	15.5	15.3	15.0	14.6	14.4	14.1

Moduli of Elasticity (SI), kPa [Note (2)]

Material	Temperature, °C						
	–198	–101	–46	21	93	149	204
Carbon steel, carbon 0.30 or less	216	210	207	203	198	195	191
Cast iron	...	...	...	92.4	91.0	88.9	86.9
Monel (67Ni-30 Cu)	192	187	183	179	175	173	170
Copper (99.90Cu) C12000, C12200	124	121	119	117	114	112	110
Red Brass (85Cu) C23000	125	122	121	117	114	113	109
Copper nickel (90Cu-10Ni) C70600	131	128	126	124	121	119	117
Copper nickel (70Cu-30Ni) C71500	154	157	155	152	148	145	143
Aluminum	77	73	71	69	66	63	60
Copper silicon (3Si) C65500	110	107	105	103	101	99	97

NOTES:
(1) E in psi = tabulated values multiplied by 10^6.
(2) E in kPa = tabulated values multiplied by 10^6.

designed for essentially noncyclic service (less than 7,000 total cycles), and satisfy the following approximate criterion:

$$\frac{DY}{(L-U)^2} \leq \frac{30S_A}{E_c} \quad (14)$$

where

D = nominal pipe size, in. (mm)
L = developed length of piping between anchors, ft (m)
U = anchor distance (length of straight line joining anchors), ft (m)
Y = resultant of movements to be absorbed by pipeline, in. (mm)
E_c = modulus of elasticity of the piping material in the cold condition, psi (kPa)
S_A = allowable stress range, psi (kPa), include stress range reduction factor f where more than 7,000 cycles of movement are anticipated during the life of the installation (see Fig. 502.3.2)

519.4.3 Methods of Analysis. Systems that do not meet the requirements of para. 519.4.2 shall be analyzed by a method appropriate to the hazard entailed by failure of the line, the importance of maintaining continuous service, the complexity of the layout, and strain sensitivity of the pipe material. Simplified or approximate methods may be applied without correction only if they are used for the range of configurations for which their adequate accuracy has been demonstrated. Accompanying any flexibility calculation, there shall be an adequate statement of the method and any simplifying assumptions used.

519.4.4 Standard Assumptions. Standard assumptions specified in para. 519.3 shall be followed in all cases. In calculating the flexibility of a piping system

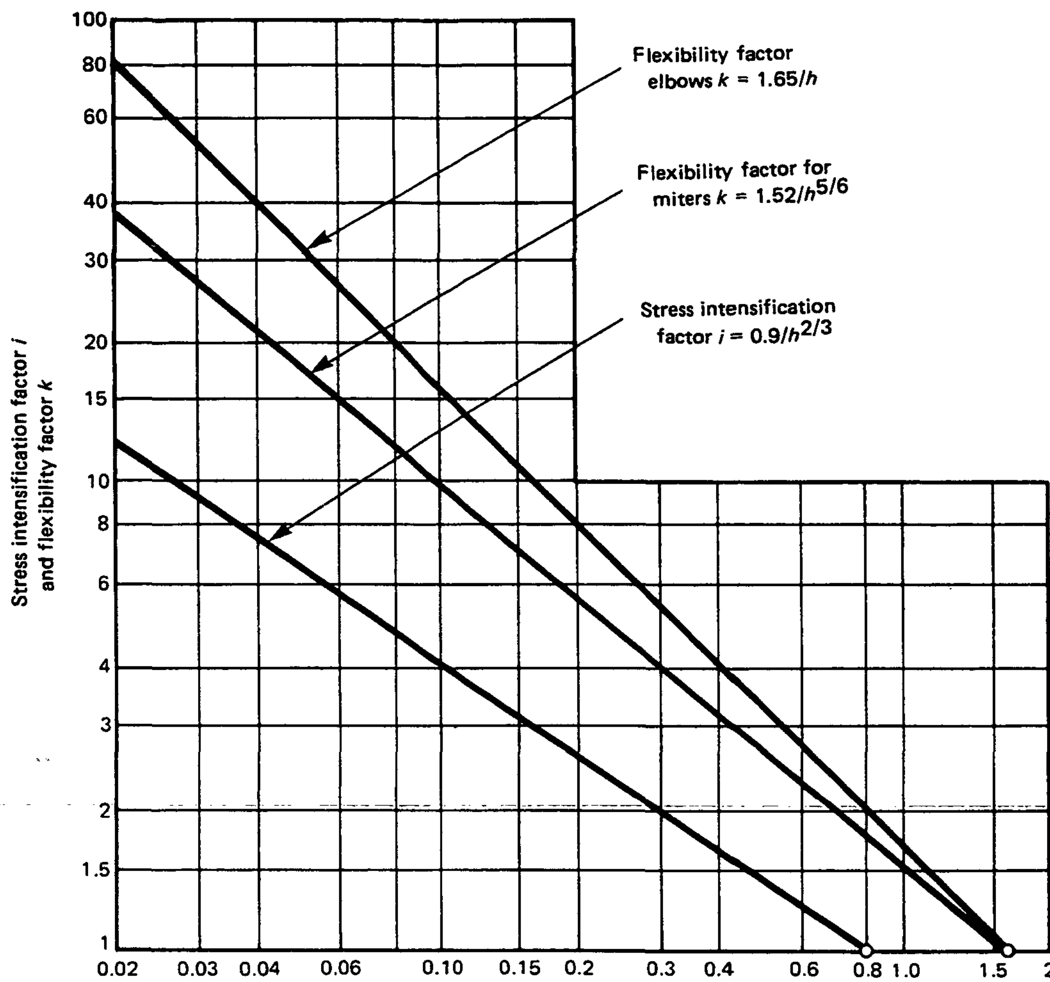


Chart A

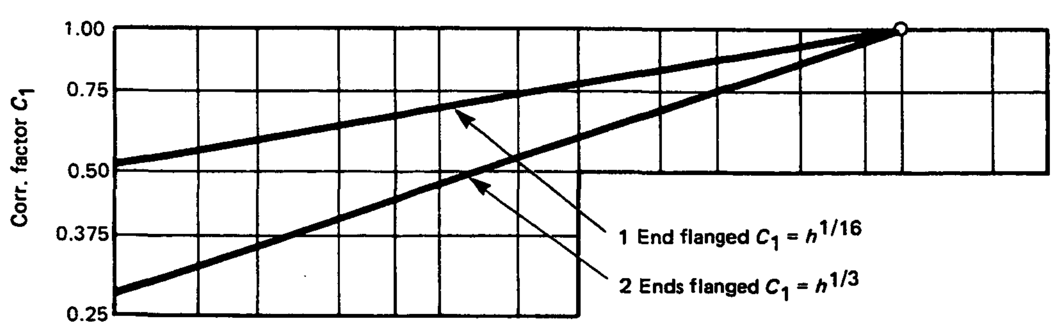
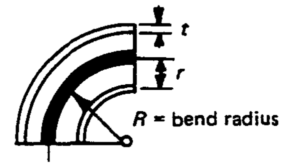
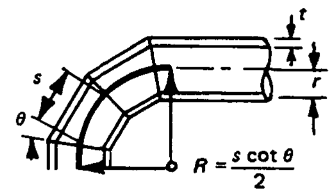
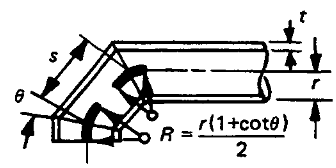
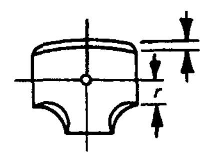
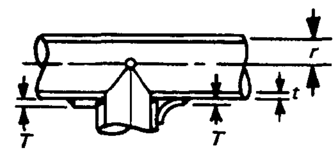
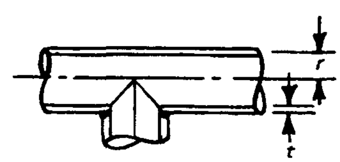


Chart B

(01) TABLE 519.3.6 ILLUSTRATION

TABLE 519.3.6 FLEXIBILITY FACTOR k AND STRESS INTENSIFICATION FACTOR i (01)

Description	Flexibility Characteristic h	Flexibility Factor k	Stress Intensification Factor i_i [Note (1)]	Stress Intensification Factor i_o [Note (2)]	Sketch
Welding elbow or pipe bend [Notes (3), (4), (5), (6), & (7)]	$\frac{tR}{r^2}$	$\frac{1.65}{h}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.75}{h^{2/3}}$	
Closely spaced miter bend [Notes (3), (4), (5), & (7)], $s < r(1 + \tan\theta)$	$\frac{ts}{r^2}\left(\frac{\cot\theta}{2}\right)$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.75}{h^{2/3}}$	
Widely spaced miter bend [Notes (3), (4), (7), & (8)], $s \geq r(1 + \tan\theta)$	$\frac{t}{r}\left(\frac{1 + \cot\theta}{2}\right)$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.75}{h^{2/3}}$	
Welding tee ASME B16.9 [Notes (3) & (4)]	$4.4\frac{t}{r}$	1	$0.75 i_o + 0.25$	$\frac{0.9}{h^{2/3}}$	
Reinforced fabricated tee with pad or saddle [Notes (3), (4), & (9)]	$\frac{(t + \frac{1}{2}T)^{5/2}}{t^{3/2} r}$	1	$0.75 i_o + 0.25$	$\frac{0.9}{h^{2/3}}$	 Pad saddle
Unreinforced fabricated tee [Notes (3) & (4)]	$\frac{t}{r}$	1	$0.75 i_o + 0.25$	$\frac{0.9}{h^{2/3}}$	
Butt welded joint, reducer, or welding neck flange	...	1	1.0		...
Double-welded slip-on flange	...	1	1.2		...

(continued)

(01) TABLE 519.3.6 FLEXIBILITY FACTOR k AND STRESS INTENSIFICATION FACTOR i (CONT'D)

Description	Flexibility Characteristic h	Flexibility Factor k	Stress Intensification Factor i_i [Note (1)]	Stress Intensification Factor i_o [Note (2)]	Sketch
Fillet welded joint (single-welded), socket welded flange, or single-welded slip-on flange	...	1	1.3	1.3	...
Lap flange (with ASME B16.9 lap-joint stub)	...	1	1.6	1.6	...
Threaded pipe joint, or threaded flange	...	1	2.3	2.3	...
Corrugated straight pipe, or corrugated or creased bend [Note (10)]	...	5	2.5	2.5	...

GENERAL NOTE: For reference, see Table 519.3.6 Illustration beginning on page 40.

NOTES:

(1) In-plane.

(2) Out-of-plane.

(3) For fittings and miter bends the flexibility factors k and stress intensification factors i in the Table apply to bending in any plane and shall not be less than unity; factors for torsion equal unity.

(4) Both factors apply over the effective arc length (shown by heavy center lines in the sketches) for curved and miter elbows and to the intersection point for tees. The values of k and i can be read directly from Chart A by entering with the characteristic h computed from the equations given where

- R = bend radius of welding elbow or pipe bend, in. (mm)
- r = mean radius of matching pipe, in. (mm)
- t = nominal wall thickness, in. (mm), of: part itself for elbows and curved or miter bends; mathing pipe for welding tees; run or header for fabricated tees (provided that if thickness is greater than that of matching pipe, increased thickness must be maintained for at least one run outside diameter to each side of the branch outside diameter).
- θ = one-half angle between adjacent miter axes, deg
- s = miter spacing at center line, in. (mm)
- T = pad or saddle thickness, in. (mm)

(5) Where flanges are attached to one or both ends, the values of k and T in the Table shall be corrected by the factors C_1 given below, which can be read directly from Chart B; entering with the computed h: one end flanged, $h^{1/6} \geq 1$; both ends flanged, $h^{1/2} \geq 1$.

(6) The engineer is cautioned that cast butt welding elbows may have considerably heavier walls than that of the pipe with which they are used. Large errors may be introduced unless the effect of these greater thicknesses is considered.

(7) In large-diameter thin-wall elbows and bends, pressure can significantly affect the magnitude of flexibility and stress intensification factors. To correct values obtained from the Table for the pressure effect, divide:

(a) flexibility factor k by

$$1 + 6\frac{P}{E_c}\left(\frac{r}{t}\right)^{1/3}\left(\frac{R}{r}\right)^{1/3}$$

(b) stress intensification factor i by

$$1 + 3.25\frac{P}{E_c}\left(\frac{r}{t}\right)^{5/2}\left(\frac{R}{r}\right)^{2/3}$$

where

- P = gage pressure, psi gage (kPa gage)
- E_c = cold modulus of elasticity, ksi (MPa)

(8) Also includes single-miter joint.

(9) When $T > 1.5t$, use $h = 4.05\ t/r$.

(10) Factors shown apply to bending; flexibility factor for torsion equals 0.9.

between anchor points, the system shall be treated as a whole. The significance of all parts of the line and of all restraints, such as solid hangers or guides, including intermediate restraints introduced for the purpose of reducing moments and forces on equipment or small branch lines, and also the restraint introduced by support friction, shall be recognized. Not only the expansion of the line itself, but also linear and angular movements of the equipment to which it is attached shall be considered.

519.4.5 Flexibility Stresses

(01) *(a)* Bending and torsional stress shall be computed using the as-installed modulus of elasticity E_j ($E_j = E_c$ at installation temperature) and then combined in accordance with Eq. (15) to determine the computed stress range S_E, which shall not exceed the allowable stress range S_A in para. 502.3.2.

$$S_E = \sqrt{S_b^2 + 4S_t^2} \qquad (15)$$

where

Z = section modulus of pipe, in.^{3} (mm^3)
M_t = torsional moment, in.-lb (N-m)
S_b = resultant bending stress, ksi (MPa)
S_t = torsional stress, ksi (MPa)
= $M_t/2Z$

(01) *(b)* The resultant bending stresses S_b, ksi (MPa), to be used in Eq. (15) for elbows and miter bends shall be calculated in accordance with Eq. (16), with moments as shown in Fig. 519.4.5-A.

$$S_b = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z} \qquad (16)$$

where

Z = sectional modulus of pipe, in.^{3} (mm^3)
M_i = inplane bending moment, in.-lb (N-m)
M_o = outplane bending moment, in.-lb (N-m)
i_i = inplane stress intensification factor from Table 519.3.6
i_o = outplane stress intensification factor from Table 519.3.6

(01) *(c)* The resultant bending stresses S_b to be used in Eq. (15) for branch connections shall be calculated in accordance with Eqs. (17) and (18) with moments as shown in Fig. 519.4.5-B.

(1) For header (Legs 1 and 2),

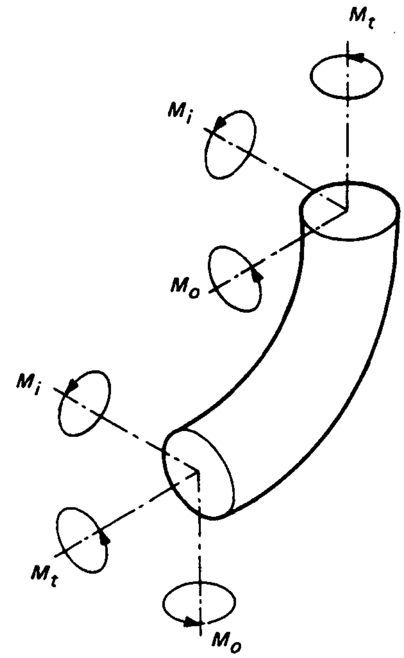


FIG. 519.4.5-A BENDS (01)

$$S_b = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z} \qquad (17)$$

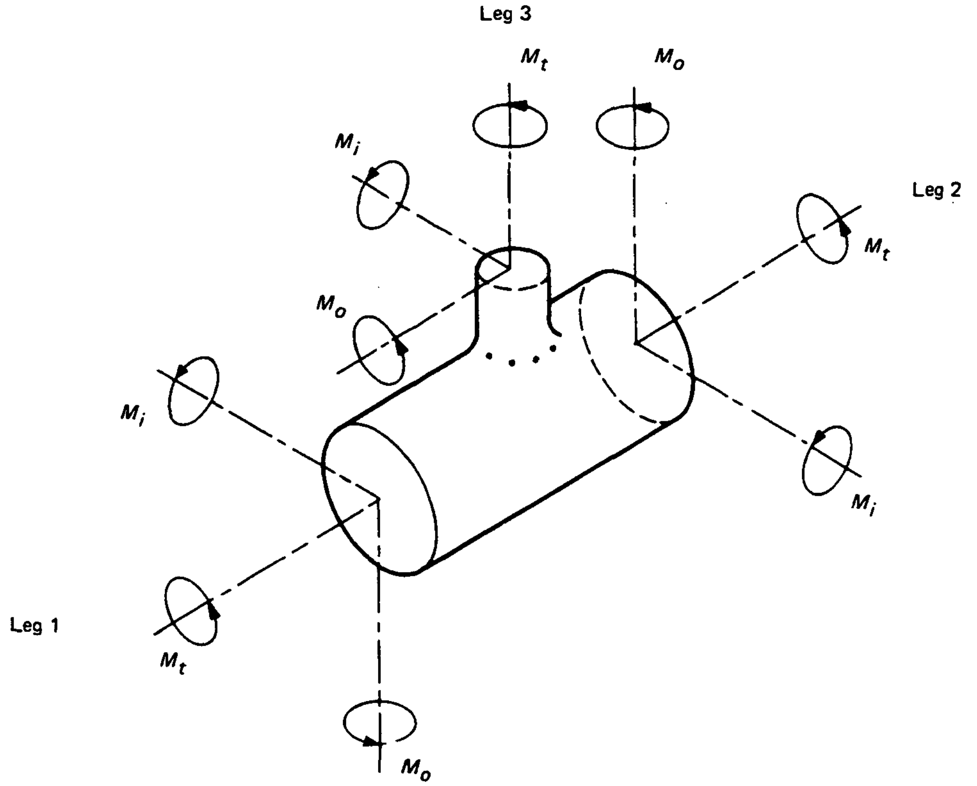
(2) For branch (Leg 3),

$$S_b = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z_e} \qquad (18)$$

where

S_b = resultant bending stress, ksi (MPa)
Z_e = effective section modulus for branch of tee, in.^{3} (mm^3)
= $\pi r_m{}^2 t_s$
i_i = inplane stress intensification factor
i_o = outplane stress intensification factor
t_h = thickness of pipe matching run of tee or header exclusive of reinforcing elements, in. (mm)
t_s = effective branch wall thickness, in. (mm) (lesser of t_n and $i_o t_o$)
r_m = mean branch cross-sectional radius, in. (mm)
t_b = thickness of pipe matching branch, in. (mm)

(d) Allowable stress range S_4 and permissible additive stresses shall be computed in accordance with paras. 519.2.1 and 519.2.2.



(01) FIG. 519.4.5-B BRANCH CONNECTIONS

(01) **519.4.6 Reactions.** The reactions (forces and moments) R_n and R_c in the hot and cold conditions, respectively, shall be obtained from the reaction range R derived from the flexibility calculations, using Eqs. (19) and (20).

In the design of anchors and restraints and in the evaluation of some mechanical effects of expansion on terminal equipment (such as pumps, heat exchangers, etc.) either reaction range R (see definition below) or instantaneous values of reaction forces and moments in the hot or cold condition may be of significance. Determination of the latter may be complicated by the difficulty of performing the desired cold spring and by other factors. Thus their determination may imply an elaborate engineering calculation, the basis of which should be clearly set forth. In the absence of a better procedure, in the case of one material uniform-temperature two anchor systems without intermediate constraints, the hot and cold reactions may be estimated by the formulas:

$$R_L = (1 - \tfrac{2}{3}C)\frac{E_h}{E_c}R \qquad (19)$$

$$R_c = CR \text{ or } C_1R\text{, whichever is greater} \qquad (20)$$

where

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

NOTE: Factor $\tfrac{2}{3}$ appearing in Eq. (19) accounts for observation that specified cold spring cannot be fully assured, even with elaborate precautions.

R = range of reaction forces or moments corresponding to the full expansion range based on E_c, lb (N) or in.-lb (N-m)

C_1 = estimated self-spring or relaxation factor; use zero if value becomes negative
= $1 - S_hE_c/S_EE_h$

E_c = modulus of elasticity in the cold condition, ksi (kPa)

E_h = modulus of elasticity in the hot condition, ksi (kPa)

R_c, R_h = maximum reaction forces or moments estimated to occur in the cold and hot conditions, respectively, lb (N) or in.-lb (N-m)

S_E = maximum computed expansion stress range at any point in the line, ksi (MPa) (see paras. 519.2.1 and 519.2.2)

S_h = basic material allowable stress at maximum (hot) normal temperature, ksi (MPa). (Use S, not SE, from para. 502.3.1 and Table 502.3.1.)

519.4.7 Reaction Limits. The computed reactions shall not exceed limits that connected equipment, specifically strain sensitive components, such as pumps, compressors, valves, strainers, tanks, and pressure vessels, can safely sustain.

519.4.8 Movements. Calculation of displacements and rotations at specific locations may be required where clearance problems are involved. In cases where small-size branch lines attached to stiff main lines are to be calculated separately, the linear and angular movements of the junction point must be calculated or estimated for proper analysis of the branch.

520 DESIGN OF PIPE SUPPORTING ELEMENTS

520.1 General

Loads on equipment supporting, bracing, guiding, or anchoring piping include, in addition to weight effects, loads due to service pressure and temperatures, vibration, wind, earthquake, shock, erection contingencies (including testing), thermal expansion and contraction, and differential settlement of foundations, all as defined in para. 501. The design of all elements supporting or restraining pipe shall have regard to the degree of probability of concurrence of loads and whether they are sustained or tend to relax themselves as defined in para. 519.2.1.

520.1.1 Objectives. Supporting elements shall be designed to prevent the loadings and deflections due to the influences delineated in para. 520.1 from causing:

(a) piping stresses in excess of those permitted in this Section of the Code;

(b) leakage at joints;

(c) detrimental distortion of connected equipment (such as pumps, turbines, valves, etc.) resulting from excessive forces and moments;

(d) excessive stresses in the pipe supporting (or restraining) elements themselves;

(e) resonance with imposed vibrations;

(f) excessive interference with the thermal expansion and contraction of a piping system which is otherwise adequately flexible;

(g) unintentional disengagement of the piping from its supports; and/or

(h) excessive piping sag in systems requiring drainage slope.

520.1.2 Allowable Stresses in Piping. The design of piping-support elements shall be such that the sustained piping stresses shall not exceed the allowable value as defined in paras. 502.3.2(d) and 523.2.2(f)(4).

520.1.3 Allowable Stresses in Piping Support and Restraint Components

(a) The allowable stress for the base material of all parts of supporting and restraint assemblies shall not exceed the appropriate S value taken from para. 502.3.1 and Table 502.3.1 including Notes except as permitted in 520.1.3(b). It is not necessary to include joint factors. The allowable stress shall be reduced 25% for threaded members and for welds in support assemblies or for attachments to piping. For threaded members stresses shall be based on the root area of the threads.

(b) An increase in allowable stress of 20% shall be allowed for short-time overloading conditions.

(c) For requirements pertaining to springs, see para. 521.3.2.

(d) For requirements pertaining to anchors and guides, see paras. 521.1.3 and 521.1.4.

(e) The principles in para. 502.3.1(d) are not applicable to design of springs.

(f) Pipe support and hanger components conforming to the requirements of para. 502.3.1 may have an increase in their working stress to 80% of minimum yield strength at room temperature for the period of hydrostatic testing. This applies only to supports that have been engineered by the designer and not to standard catalog items unless they have been carefully analyzed by the designer.

520.1.4 Materials — Steel. All equipment for permanent supports and restraints shall be fabricated from durable materials suitable for the service conditions. Unless otherwise permitted in para. 520.1.5, steel shall be used for pipe supporting elements. All materials shall be capable of meeting the respective standard specifications given in Table 523.1 with regard to the tests and physical properties.

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

520.1.5 Materials Other Than Those in Para. 520.1.4. Cast iron may be used for roller bases, rollers, anchor bases, brackets, and parts of pipe supporting elements upon which the loading will be mainly that of compression. Malleable or nodular iron castings may be used for pipe clamps, beam clamps, hanger flanges, clips, bases, swivel rings, and parts of pipe supporting elements. Treated wood may be used for pipe supporting elements which are primarily in compression when the metal temperatures are at or below ambient temperature. Materials other than those listed in Table 523.1 may be employed to take advantage of their superior properties, in specialty items such as constant support hangers. In such cases, allowable stresses shall be determined in accordance with the principles given in para. 502.3.1.

520.1.6 Protective Coatings

(a) Under conditions causing mild corrosion, such as atmospheric rusting, which are not of an intensity to warrant the use of corrosion resistant materials, a durable protective coating, such as hot-dipped galvanizing, weather resistant paint, or other suitable protection, should be applied to all parts after fabrication or after installation.

(b) Under any conditions, exposed screw threads on parts of the equipment where corrosion resistant materials are not used shall be greased immediately after fabrication. Paints, slushes, or other suitable protective coatings may be used instead of grease.

520.1.7 Threaded Components. Threads shall be in accordance with ASME B1.1. except that other thread forms may be used to facilitate adjustment under heavy loads. All threaded adjustments shall be provided with lock nuts or be locked by other positive means. Turnbuckles and adjusting nuts shall have the full length of thread in service. Means shall be provided for determining that full length of thread is in service.

521 DESIGN LOADS FOR PIPE SUPPORTING ELEMENTS

521.1 General

521.1.1 Forces and moments at pipe supporting elements caused by thermal expansion or contraction shall be determined as necessary.

521.1.2 Weight calculations for gas, vapor, or safety valve discharge piping should not include the weight of liquid if the possibility of these lines containing liquid is remote and provided the lines are not subjected to hydrostatic tests.

521.1.3 Restraints, such as anchors and guides, shall be provided where necessary to control movement or to direct expansion and/or other effects into those portions of the system that are adequate to absorb them for the purpose of protecting terminal equipment and/or other (weaker) portions of the system. The effect of friction in other supports of the system shall be considered in the design of such anchors and guides.

521.1.4 Anchors or guides for expansion joints of the corrugated or stip-type (or variants of these types) shall be designed to resist end forces from fluid pressure and frictional or other applicable resistance to joint movement, in addition to other loadings.

521.2 Resilient Variable-Support and Constant-Support Types

Reactions or load calculations for resilient or constant effort type supports, such as springs or weight loaded supports and braces, shall be based on the maximum working conditions of the piping. However, the support shall be capable of carrying the total load under test conditions, unless additional support is provided for the test period. The amount of variation that can be tolerated shall be determined by incorporating the change in supporting effect in the flexibility analysis or shall be based on such considerations as bending effect, control of piping elevation, allowable terminal reactions, etc.

521.3 Design Details

521.3.1 General

(a) Hanger Rods. Safe axial loads for threaded hanger rods shall be based on the root area of the threads and subject to 25% reduction in allowable stress as in para. 520.1.3(a). Pipe, straps, or bars of strength and effect area equal to the equivalent hanger rod may be used instead of hanger rods. See Table 521.3.1. (01)

(b) Chains. Chain may be used for pipe hangers and shall be designed in accordance with para. 521.3.1(a).

(c) Sliding Supports. Sliding supports (or shoes) and brackets shall be designed to resist the forces due to friction in addition to the loads imposed by bearing. The dimensions of the support shall provide for the expected movement of the supported piping.

TABLE 521.3.1 MINIMUM SIZES OF STRAPS, RODS, AND CHAINS FOR HANGERS (01)

Nominal Pipe Size NPS (DN)	Component (Steel)	Minimum Stock Size, in. (mm)	
		Exposed to Weather	Protected From Weather
1 and smaller [1 in. (25 mm)]	Strap	$\frac{1}{8}$ in. (3 mm) thick	$\frac{1}{16}$ in. (1.5 mm) thick × $\frac{3}{4}$ in. (19 mm) wide
Above 1 [1 in. (25 mm)]	Strap	$\frac{1}{4}$ in. (6 mm) thick	$\frac{1}{8}$ in. (3 mm) thick × 1 in. (25 mm) wide
2 and smaller [2 in. (50 mm)]	Rod	$\frac{3}{8}$ in. (10 mm) diameter	$\frac{3}{8}$ in. (10 mm) diameter
Above 2 [2 in. (50 mm)]	Rod	$\frac{1}{2}$ in. (13 mm) diameter	$\frac{1}{2}$ in. (13 mm) diameter
2 and smaller [2 in. (50 mm)]	Chain	$\frac{3}{16}$ in. (5 mm) diameter or equivalent area	$\frac{3}{16}$ in. (5 mm) diameter or equivalent area
Above 2 [2 in. (50 mm)]	Chain	$\frac{3}{8}$ in. (10 mm) diameter or equivalent area	$\frac{3}{8}$ in. (10 mm) diameter or equivalent area
All sizes	Bolted clamps	$\frac{3}{16}$ in. (5 mm) thick; bolts $\frac{3}{8}$ in. (10 mm) diameter	$\frac{3}{16}$ in. (5 mm) thick; bolts $\frac{3}{8}$ in. (10 mm) diameter

GENERAL NOTE: For nonferrous materials, the minimum stock area shall be increased by the ratio of allowable stress of steel to the allowable stress of the nonferrous material.

(d) At point of support subject to horizontal movement, the movement shall be provided for by the swing of long hanger rods or chains or by the use of trolleys, rollers, sliding or swinging supports.

(e) Covering on insulated piping shall be protected from damage at all hanger locations. Saddles, bases, or suitable shields properly constructed and secured to the covered pipe shall be used at points of roller, base, and trapeze support.

(f) Lugs, plates, angle clips, etc., used as part of an assembly for the support or guiding of pipe may be welded directly to the pipe provided the material is of good weldable quality and the design is adequate for the load. Preheating, welding, and postheating shall be in accordance with the rules of Chapter V.

(g) See MSS SP-58 for typical design details.

521.3.2 Spring Supports. Spring type supports shall be provided with means to prevent misalignment, buckling, or eccentric loading of the spring, and to prevent unintentional disengagement of the load. Materials shall be in accordance with the provisions of paras. 520.1.4 and 520.1.5. Constant support spring hangers shall be designed to provide a substantially uniform supporting force throughout the range of travel. All spring elements shall be provided with means of adjustment for the pipe position in the operating and nonoperating condition. Means shall be provided to prevent overstressing the spring due to excessive deflections. It is desirable that all spring hangers be provided with position indicators.

521.3.3 Counterweights. Counterweights when used instead of spring hangers shall be provided with stops to prevent overtravel. Weights shall be positively secured. Chains, cables, hanger and rocker arm details, or other devices used to attach the counterweight load to the piping, shall be subject to requirements of para. 521.3.1.

521.3.4 Hydraulic-Type Supports. An arrangement utilizing a constant hydraulic head may be installed to give a constant supporting effort. Safety devices and stops shall be provided to support the load in case of hydraulic failure.

521.3.5 Sway Braces or Vibration Dampeners. Sway braces and vibration dampeners may be used to limit the movement of piping due to vibration.

CHAPTER III
MATERIALS

523 MATERIALS — GENERAL REQUIREMENTS

523.1 Acceptable Materials and Specifications

The materials used shall conform to the specifications listed in Table 523.1 or shall meet the requirements of this Code for materials not so established.

Reclaimed pipe and piping components may be used provided they are properly identified as conforming to a specification listed in Table 523.1 and otherwise meet applicable requirements of this Code.

523.2 Limitations on Materials

(01) **523.2.1 General.** The materials listed in Table 502.3.1 shall not be used at design metal temperatures above those for which stress values are given in the Table. The materials shall not be used below the minimum temperature listed unless they meet the impact test requirements of para. 523.2.2.

(01) **523.2.2 Impact Tests.** Materials subject to design metal temperatures below the minimum temperature listed in Table 502.3.1 and in (f)(5), except for those exempted in (f)(4) and (f)(5), shall be impact tested as required by UG-84 of Section VIII, Division 1, of the ASME BPV Code, with the following substitution for UG-84(b)(2).

(a) A welded test section shall be prepared from a piece of plate, pipe, or tubing for each material specification certified by the manufacturer in accordance with UG-84(e).

(b) If the material to be used is not certified, test sections shall be prepared from each piece of pipe, plate, or tubing used.

(c) One set of impact-test specimens shall be taken across the weld (the metal tested is the weld metal) with the notch in the weld, and one set shall be taken similarly with the notch at the fusion line (the metal tested is the base metal).

(d) Impact test specimens shall be cooled to a temperature not higher than the lowest temperature to which the pipe, plate, or tubing may be subjected in its operating cycle.

(e) One set of impact-test specimens with the notch in the weld metal and one set with the notch at the fusion line, shall be made for each range of pipe thickness that does not vary by more than $\frac{1}{4}$ in. (6 mm) over and under the tested thickness for each material specification used on the job. (01)

(f) The following materials are exempted from the requirements for impact testing.

(1) Impact tests are not required for aluminum: Types 304 or CF8, 304L or CF3, 316 or CF8M, and 321 austenitic stainless steel; copper; red brass; copper-nickel alloys; and nickel-copper alloys.

(2) Impact tests are not required for bolting material conforming with A 193, Grade B7, for use at temperatures above −50°F (−46°C). (01)

(3) Impact tests are not required for bolting materials conforming with A 320, Grades L7, L10, and L43, at temperatures above −150°F (−101°C) or above −225°F (−143°C) for A 320, Grade L9. (01)

(4) Impact tests are not required for ferrous materials used in fabricating a piping system for metal temperatures between −50°F (−46°C) and −150°F (−101°C) provided the maximum circumferential or longitudinal tensile stress resulting from coincident pressure, thermal contraction, or bending between supports does not exceed 40% of the allowable stress for the materials as given in Table 502.3.1. See paras. 502.3.2, 519, and 520. (01)

(5) Impact tests are not required for ferrous materials used for fabricating a piping system for metal temperatures between −20°F (−29°C) and −50°F (−46°C) provided the minimum design metal temperature is above the allowable temperature determined from applying the temperature reduction due to the reduced pressure ratio from Fig. 523.2.2 to the listed minimum temperatures in Table 502.3.1. For minimum temperature listings of "A" or "B," use the minimum temperatures corresponding to the nominal thickness shown in Table 523.2.2. (01)

(01) **523.2.3 Cast Iron and Malleable Iron.** Cast iron and malleable iron shall not be used for piping components in hydrocarbon or other flammable fluid service at temperatures above 300°F (149°C), nor at gage pressures above 300 psi (2 070 kPa). Cast iron or malleable iron shall not be used at temperatures below −150°F (−101°C).

(01) **523.2.4 Nodular Iron.** Nodular iron shall not be used for piping components at gage pressures above 1,000 psi (6 895 kPa) or at temperatures below −150°F (−101°C).

523.2.5 Clad and Lined Materials. Clad and lined materials may be used in accordance with the applicable requirements in Part UCL of Section VIII, Division 1, of the ASME BPV Code.

(01) **523.2.6 Nonmetallic Pressure Containing Components.** Nonmetallic pressure containing components, such as plastics, glass, carbon, rubber, or ceramics, may be used even if not specifically listed in this Code. Materials and methods in Chapter VIII of B31.3 are acceptable. If stress data are not available for establishment of allowable stresses, the components may be qualified per para. 504.7. Consideration shall be given to the suitability of the material for the service temperature, its resistance to deterioration from the service fluid or environment, its flammability, its resistance to shock, its creep, and its proper support and protection from mechanical damage.

523.3 Deterioration of Materials in Service

The selection of materials to resist deterioration in service is outside the scope of this Code. It is the responsibility of the engineer to select materials suitable for the conditions of operation.

524 MATERIALS APPLIED TO MISCELLANEOUS PARTS

524.1 Gaskets

Limitations on gasket materials are covered in para. 508.4.

524.2 Bolting (01)

Limitations on bolting materials are covered in paras. 508.3, 508.5, and 523.2.2.

(01)

TABLE 523.1 ACCEPTABLE MATERIALS — SPECIFICATIONS

Component	Specification	Material
Bolting	ASTM A 193	Alloy steel and stainless steel bolting materials for high temperature service
	ASTM A 194	Carbon and alloy steel nuts for bolts for high pressure and high temperature service
	ASTM A 307	Carbon steel bolts and studs, 60 ksi (414 MPa) tensile
	ASTM A 320	Alloy steel bolting materials for low-temperature service
	ASTM A 325	Structured bolts, steel, heat treated, 120/105 ksi, min. tensile strength
	ASTM A 354	Quenched and tempered alloy steel bolts, studs, and other externally threaded fasteners
	ASTM B 21	Naval brass rod, bar, and shapes
	ASTM B 98	Copper-silicon alloy rod, bar, and shapes
	ASTM B 211	Aluminum and aluminum alloy bar, rod, and wire
Fittings, valves, flanges	ASTM A 47	Ferritic malleable iron castings
	ASTM A 48	Gray iron castings
	ASTM A 105	Forgings, carbon steel, for piping components
	ASTM A 126	Gray iron castings for valves, flanges, and pipe fittings
	ASTM A 181	Forgings, carbon steel for general purpose piping
	ASTM A 182	Forged or rolled alloy steel pipe flanges, forged fittings, and valves and part for high temperature service
	ASTM A 197	Cupola malleable iron
	ASTM A 216	Steel castings, carbon, suitable for fusion welding for high temperature service
	ASTM A 217	Steel castings, martensitic stainless and alloy, for pressure containing parts suitable for high temperature service
	ASTM A 234	Piping fittings of wrought carbon steel and alloy steel for moderate and elevated temperatures
	ASTM A 278	Gray iron castings for pressure containing parts for temperatures up to 650°F (345°C)
	ASTM A 350	Forgings, carbon and low alloy steel, requiring notch toughness testing for piping components
	ASTM A 351	Castings, austenitic, austenitic-ferritic (duplex) for pressure containing parts
	ASTM A 352	Steel castings, ferritic and martensitic, for pressure containing parts, suitable for low temperature service
	ASTM A 395	Ferritic ductile iron for pressure retaining castings for use at elevated temperatures
	ASTM A 403	Wrought austenitic stainless steel piping fittings
	ASTM A 420	Piping fittings of wrought carbon steel and alloy steel for low temperature service
	ASTM A 522	Forged or rolled 8% and 9% nickel alloy steel flanges, fittings, valves, and parts for low temperature service
	ASTM A 536	Ductile iron castings
	ASTM A 571	Austenitic ductile iron castings for pressure-containing parts suitable for low temperature service
	ASTM A 743	Castings, iron-chromium, iron-chromium-nickel, and nickel base, corrosion resistant, for general application
	ASTM A 744	Castings, iron-chromium-nickel and nickel base, corrosion resistant, for severe service
	ASTM B 16	Free-cutting brass rod, bar, and shapes for use in screw machines
	ASTM B 21	Naval brass rod, bar, and shapes
	ASTM B 26	Aluminum alloy sand castings
	ASTM B 61	Steam or valve bronze castings
	ASTM B 62	Composition bronze or ounce metal castings
	ASTM B 85	Aluminum alloy die castings
	ASTM B 124	Copper and copper alloy forging rod, bar, and shapes
	ASTM B 179	Aluminum alloys in ingot form for sand castings, permanent mold castings, and die castings
	ASTM B 247	Aluminum and aluminum alloy die forgings, hand forgings, and rolled ring forgings
	ASTM B 283	Copper and copper alloy die forgings (hot pressed)

TABLE 523.1 ACCEPTABLE MATERIALS — SPECIFICATIONS (CONT'D) (01)

Component	Specification	Material
Fittings, valves, flanges (cont'd)	ASTM B 361	Factory-made wrought aluminum and aluminum alloy welding fittings
	ASTM B 584	Copper alloy sand castings for general applications
	AWWA C110	Gray iron and ductile iron fittings NPS 2 (DN 50) through NPS 48 (DN 1200) for water and other liquids
Steel pipe	ASTM A 53 [Note (1)]	Pipe, steel, black and hot dipped, zinc coated, welded and seamless
	ASTM A 106	Seamless carbon steel pipe for high temperature service
	ASTM A 134	Pipe, steel electic-fusion (arc) welded [sizes NPS 16 (DN 400) and over]
	ASTM A 135	Electric-resistance welded steel pipe
	ASTM A 139	Electric-fusion (arc) welded steel pipe [sizes NPS 4 (DN 100) and over]
	ASTM A 312	Seamless and welded austenitic stainless steel pipe
	ASTM A 333	Seamless and welded steel pipe for low tempeature service
	ASTM A 358	Electric-fusion welded austenitic chromium-nickel alloy steel pipe for high temperature service
	ASTM A 376	Seamless austenitic steel pipe for high-temperature central-station service
	ASTM A 409	Welded large outside diameter austenitic steel pipe for corrosive or high temperature service
	ASTM A 587	Electric resistance-welded low carbon steel pipe for the chemical industry
	API FL [Note (1)]	Line Pipe
Nonferrous pipe	ASTM B 42	Seamless copper pipe, standard sizes
	ASTM B 43	Seamless red brass pipe, standard sizes
	ASTM B 165	Nickel-copper alloy (UNS N04400) seamless pipe and tube
	ASTM B 241	Aluminum and aluminum alloy seamless pipe and seamless extruded tube
	ASTM B 302	Threadless copper pipe
	ASTM B 315	Seamless copper alloy pipe and tube
	ASTM B 345	Aluminum and aluminum alloy seamless pipe and seamless extruded tube for gas and oil transmission and distribution piping systems
	ASTM B 466	Seamless copper-nickel alloy pipe and tube
	ASTM B 467	Welded copper-nickel pipe
Steel tube	ASTM A 178	Electric-resistance welded carbon steel boiler tubes
	ASTM A 179	Seamless cold-drawn low carbon steel heat exchanger and condenser tubes
	ASTM A 192	Seamless carbon steel boiler tubes for high pressure service
	ASTM A 210	Seamless medium-carbon steel boiler and superheater tubes
	ASTM A 213	Seamless ferritic and austenitic alloy steel boiler, superheater, and heat exchanger tubes
	ASTM A 214	Electric-resistance welded carbon steel heat exchanger and condenser tubes
	ASTM A 226	Electric-resistance welded carbon steel boiler and superheater tubes for high pressure service
	ASTM A 249	Welded austenitic steel boiler, superheater, heat exchanger and condenser tubes
	ASTM A 254	Copper brazed steel tubing
	ASTM A 269	Seamless and welded austenitic stainless steel tubing for general service
	ASTM A 271	Seamless austenitic chromium-nickel steel still tubes for refinery service
	ASTM A 334	Seamless and welded carbon and alloy steel tubes, for low temperature service
Nonferrous tube	ASTM B 68	Seamless copper tube, bright annealed
	ASTM B 75	Seamless copper tube
	ASTM B 88	Seamless copper water tube
	ASTM B 111	Copper and copper alloy seamless condenser tubes and ferule stock
	ASTM B 165	Nickel-copper alloy (UNS N04400) seamless pipe and tube
	ASTM B 210	Aluminum alloy drawn seamless tubes
	ASTM B 234	Aluminum and aluminum alloy drawn seamless tubes for condensers and heat exchangers
	ASTM B 280	Seamless copper tube for air conditioning and refrigeration field service
	ASTM B 315	Seamless copper alloy pipe and tube

(01)

TABLE 523.1 ACCEPTABLE MATERIALS — SPECIFICATIONS (CONT'D)

Component	Specification	Material
Nonferrous tube (cont'd)	ASTM B 466	Seamless copper-nickel pipe and tube
	ASTM B 743	Seamless copper tube in coil
Steel plate	ASTM A 36	Structural steel
	ASTM A 240	Heat-resisting chromium and chromium-nickel stainless steel plate, sheet, and strip for pressure essels
	ASTM A 283	Low and intermediate tensile strength carbon steel plates
	ASTM A 285	Pressure vesel plates, carbon steel, low and intermediate tensile strength
	ASTM A 353	Pressure vessel plates, alloy steel, 9% nickel, double-normalized and tempered
	ASTM A 414	Steel, sheet, carbon, for pressure vessels
	ASTM A 515	Pressure vessel plates, carbon steel, for intermediate- and higher-temperature service
	ASTM A 516	Pressure vessel plates, carbon steel, for moderate- and lower-temperature service
	ASTM A 553	Pressure vessel plates, alloy steel, quenched and tempered 8% and 9% nickel
	ASTM A 570	Steel sheet and strip, carbon hot-rolled, structural quality
	ASTM A 611	Steel sheet, carbon cold-rolled, structural quality
Nonferrous plate	ASTM B 96	Copper-silicon alloy plate, sheet, strip, and rolled bar for general purposes and pressure vessels
	ASTM B 152	Copper, sheet, strip, plate, and rolled bar
	ASTM B 171	Copper alloy plate and sheet for pressure vessels, condensers, and heat exchangers
	ASTM B 209	Aluminum and aluminum alloy sheet and plate
	ASTM B 248	General requirements for wrought copper and copper alloy plate, sheet, strip, and rolled bar
Welding electrodes and rods for steel and iron	ASME SFA-5.1 or AWS A5.1	Carbon steel electrodes for shielded metal arc welding
	ASME SFA-5.2 or AWS A5.2	Carbon and low alloy steel rods for oxyfuel gas welding
	ASME SFA-5.4 or AWS A5.4	Stainless steel electrodes for shielded metal arc welding
	ASME SFA-5.9 or AWS A5.9	Bars, strip, steel electrodes, and rods
Welding electrodes for nonferrous metals	AWS A5.3	Aluminum and aluminum alloy covered arc welding electrodes
	ASME SFA-5.6 or AWS A5.6	Copper and copper alloy covered electrodes
	ASME SFA-5.7 or AWS A5.7	Copper and copper alloy bare welding rods & electrodes
	ASME SFA-5.10 or AWS A5.10	Bare aluminum and aluminum alloy welding electrodes and rods
	AWS A5.12	Tungsten for arc welding electrodes
Solder and brazing metal	ASTM B 32	Solder metal
	ASME SFA-5.8 or AWS A5.8	Filler metals for brazing and braze welding
Springs	ASTM A 125	Steel springs, helical, heat treated
Chains	ASTM A 413	Carbon steel chain
	ASTM A 466	Weldless carbon steel chain
	ASTM A 467	Machine and boil chain
Bars	ASTM A 663	Steel bars, carbon, merchant quality, mechanical properties
	ASTM A 675	Steel bars, carbon, hot wrought, special quality, mechanical properties
	ASTM B 221	Aluminum alloy extended bar, rod, wire, shapes, and tube

(continued)

TABLE 523.1 ACCEPTABLE MATERIALS — SPECIFICATIONS (CONT'D) (01)

GENERAL NOTES:
(a) For specific edition of specifications referred to in this Code, see Appendix A and subsequent addenda.
(b) All ASME SFA specifications appear in Section II, Part C, of the ASME BPV Code.

NOTE:
(1) For buttweld type F, see para. 505.1.1.

(01) TABLE 523.2.2 IMPACT EXEMPTION TEMPERATURES

Thickness, in.	Curve A, °F [Note (1)]	Curve B, °F [Note (2)]
0.375	18	−20
0.4375	25	−13
0.5	32	− 7
0.5625	37	− 1
0.625	43	5
0.6875	48	10
0.75	53	15
0.8125	57	19
0.875	61	23
0.9375	65	27
1	68	31

GENERAL NOTE: For other nominal thickness, see Curves A and B in Fig. UCS-66 in Section VIII, Div. 1, ASME BPV Code.

NOTES:
(1) Curve A. All carbon and low alloy pipe, tube, plates, valves, fittings, and flanges listed for minimum temperature as "A" in Table 502.3.1. Use the minimum temperature under Curve A corresponding to the nominal material thickness in Table 523.2.2.
(2) Curve B. Specifications are ASTM unless otherwise noted. Use the minimum temperature under Curve B corresponding to the nominal material thickness in Table 523.2.2 for:
(a) A 285 Grades A and B;
(b) A 515 Grades 55 and 60;
(c) A 516 Grades 65, and 70 (if not normalized);
(d) API 5L Grades A25, A and B;
(e) A 139 Grades A, B, and C;
(f) A 135 Grades A and B;
(g) A 53 Grades A and B;
(h) A 106 Grades A and B;
(i) A 134 Grade B;
(j) A 234 Grade WPB;
(k) all materials of Curve A, if produced to fine grain practice and normalized; and
(l) all other product forms such as pipe, tube, and fittings, except for bolting, plates, structural shapes, and bars.

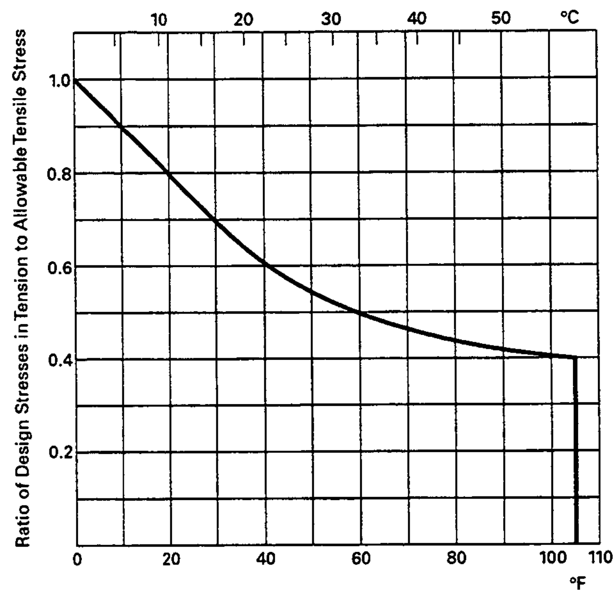


FIG. 523.2.2 REDUCTION IN MINIMUM DESIGN METAL TEMPERATURE WITHOUT IMPACT TESTING (01)

CHAPTER IV
DIMENSIONAL REQUIREMENTS

526 DIMENSIONAL REQUIREMENTS FOR STANDARD AND NONSTANDARD PIPING COMPONENTS

526.1 Standard Piping Components

Dimensional standards for piping components are listed in Table 526.1. Also, certain material specifications listed in Table 523.1 contain dimensional requirements which are requirements of para. 526. Dimensions of piping components shall comply with these standards and specifications unless the provisions of para. 526.2 are met.

526.2 Nonstandard Piping Components

The dimensions for nonstandard piping components shall, where possible, provide strength and performance equivalent to standard components, except as permitted under para. 504. For convenience, dimensions shall conform to those of comparable standard components.

526.3 Threads

The dimensions of all piping connection threads not otherwise covered by a governing component standard or specification shall conform to the requirements of applicable standards listed in Table 526.1.

TABLE 526.1 DIMENSIONAL STANDARDS (01)

Standard	Designation
Bolting	
Square and Hex Bolts and Screws	ASME B18.2.1
Square and Hex Nuts	ASME B18.2.2
Fittings Valves, Flanges, and Gaskets	
Cast Iron Pipe Flanges and Flanged Fittings, PN 3 (Class 25), PN 16 (Class 125), PN 40 (Class 250), PN 135 (Class 800)	ASME B16.6
Malleable Iron Threaded Fittings, PN 20 (Class 150), PN 50 (Class 300)	ASME B16.3
Gray Iron Threaded Fittings, PN 16 (Class 125), PN 40 (Class 250)	ASME B16.4
Pipe Flanges and Flanged Fittings	ASME B16.5
Factory-Made Wrought Steel Buttwelding Fittings	ASME B16.9
Face-to-Face and End-to-End Dimensions of Valves	ASME B16.10
Forged Fittings, Socket-Welding and Threaded	ASME B16.11
Ferrous Pipe Plugs, Bushings, and Locknuts With Pipe Threads	ASME B16.14
Cast Bronze Threaded Fittings, PN 16 (Class 125), PN 40 (Class 250)	ASME B16.15
Cast Copper Alloy Solder Joint Pressure Fittings	ASME B16.18
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings	ASME B16.22
Cast Copper Alloy Pipe Flanges and Flanged Fittings: PN 20 (Class 150), PN 50 (Class 300), PN 70 (Class 400), PN 110 (Class 600), PN 150 (Class 900), PN 260 (Class 1500), PN 420 (Class 2500)	ASME B16.24
Buttwelding Ends	ASME B16.25
Wrought Steel Buttwelding Short Radius Elbows and Returns	ASME B16.28
Valves-Flanged, Threaded, and Welding End	ASME B16.34
Ductile-Iron and Gray Iron Fittings, NPS 2 (DN 50) Through NPS 48 (DN 1200) for Water and Other Liquids	AWWA C110
Gate Valves NPS 3 (DN 80) Through NPS 48 (DN 1200) for Water and Sewage Systems	AWWA C500
Refrigeration Tube Fittings	ANSI/SAE J513
Flanged and Butt-Welded-End Steel Gate and Plug Valves for Refinery Use	API 600
Metallic Gaskets for Refinery Piping	API 601
Fittings, Tube, Cast Bronze, Silver Brazing	MIL-F-1183E
Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings	MSS SP-6
Spot Facing for Bronze, Iron, and Steel Flanges	MSS SP-9
Standard Marking System for Valves, Fittings, Flanges, and Unions	MSS SP-25
PN 20 (Class 150) Corrosion-Resistant Gate, Globe, Angle, and Check Valves With Flanged and Buttweld Ends	MSS SP-42
Wrought Stainless Steel Butt-Welding Fittings	MSS SP-43
Bypass and Drain Connections	MSS SP-45
PN 20LW (Class 150LW) Corrosion Resistant Cast Flanges and Flanged Fittings	MSS SP-51
Cast Iron Gate Valves, Flanged and Threaded Ends	MSS SP-70
Cast Iron Swing Check Valves, Flanged and Threaded Ends	MSS SP-71
Bronze Gate, Globe, Angle, and Check Valves	MSS SP-80
Pipe Hangers and Supports—Materials, Design and Manufacture	MSS SP-58
Pipe and Tube	
Welded and Seamless Wrought Steel Pipe	ASME B36.10M
Stainless Steel Pipe	ASME B36.19M
Miscellaneous	
Unified Screw Threads	ASME B1.1
Pipe Threads	ASME B1.20.1
Dryseal Pipe Threads	ASME B1.20.3
Mechanical Refrigeration, Safety Code for	ANSI/ASHRAE 15
Number Designation for Refrigerants	ANSI/ASHRAE 34

GENERAL NOTE: For specific edition of specifications referred to in this Code, see Appendix A and subsequent Addenda.

CHAPTER V
FABRICATION AND ASSEMBLY

527 WELDING

(01) ### 527.1 Material

(01) **527.1.1 Filler Material.** All filler material shall comply with the requirement of Section IX, ASME BPV Code.

(01) **527.1.2 Backing Rings.** The use of backing rings is not mandatory; however, when used, they shall conform to the following requirements. (Also, see para. 511.2.)

(a) Ferrous Rings. Backing rings shall be made from material of good weldable quality, and the sulfur content shall not exceed 0.05%. The backing ring material should preferably be of the same chemical composition as the parts to be joined.

Backing rings may be of the continuous machined, or split band type. Some acceptable split types are shown in Fig. 527.1.2.

(b) Nonferrous and Nonmetallic Rings. Backing rings of nonferrous or nonmetallic materials may be used provided they have no effect on the weld or the contained fluid. The satisfactory use of such materials shall be determined by the qualification of the welding procedure.

(01) ### 527.2 Preparation

(01) **527.2.1 Butt Welds**

(a) End Preparation

(1) Oxygen or arc cutting is acceptable only if the cut is reasonably smooth and true and all slag is cleaned from the flame cut surfaces. Discoloration that may remain on the flame cut surface is not considered to be detrimental oxidation.

(2) Butt welding end preparation dimensions contained in ASME B16.25 or any other angles that meet the requirements of the welding procedure are acceptable. (For convenience, the basic bevel angles taken from ASME B16.25 are shown in Fig. 527.2.1-A.)

(3) If piping component ends are bored for fitting backing rings, such boring shall not result in a finished wall thickness after welding less than the minimum design thickness plus corrosion and erosion allowances. Where necessary, weld metal may be deposited on the inside of the piping component to provide sufficient material for machining to insure satisfactory seating of the rings.

(4) If the piping ends are upset, they may be bored to allow for a completely recessed backing ring, provided the remaining net thickness of the finished ends is not less than the minimum design thickness plus corrosion and erosion allowance.

(b) Cleaning. Surfaces for welding shall be clean and shall be free from rust, scale, or other material that is detrimental to welding. Galvanizing must be removed from the weld zone of galvanized carbon steel.

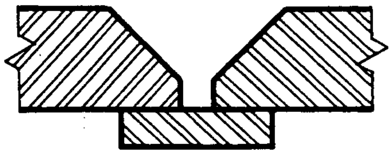
(c) Alignment. Misalignment of the inside surfaces of piping components to be joined by butt welding may result from out-of-roundness, outside diameter tolerance, wall thickness tolerance, or from the inclusion in the piping of components having wall thicknesses different from the wall thicknesses of most of the components. (01)

The inside surfaces of piping components to be joined by butt welding shall be aligned so that the misalignment at any point on the inside circumference does not exceed $^1/_{16}$ in. (1.6 mm) or one-fourth the nominal thickness of the component with the thinnest wall, whichever is smaller [see Fig. 527.2.1-B, sketch (a)].

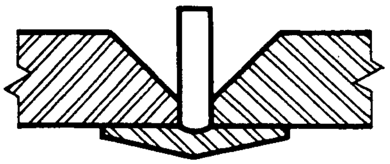
Where it is impossible to adhere to this limit by moving one component relative to the other, alignment shall be obtained by internally trimming the component extending internally by building up with welding, by expanding, or by swaging. It is preferred that these methods of adjustment be applied to such an extent that the adjoining internal surfaces are approximately flush [see Fig. 527.2.1-B, sketch (b)].

However, internal trimming shall not be applied to such an extent that it results in a piping component wall thickness less than the minimum design thickness plus corrosion and erosion allowance. Alignment shall be preserved during welding.

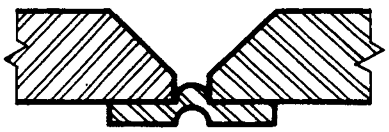
(d) Spacing. The root opening of the joint shall be as given in the welding procedure specification.



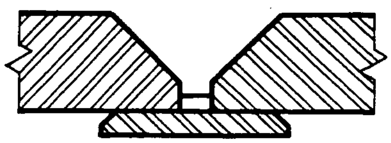
(a) Split Backing Ring



(b) Split Backing Ring and Knock-Off Spacer Pins



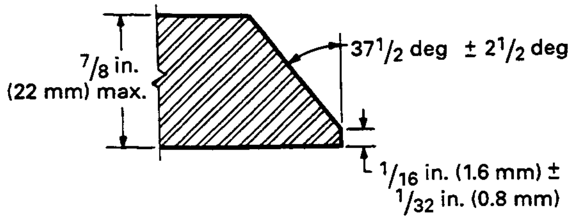
(c) Split Ridge Type Backing Ring



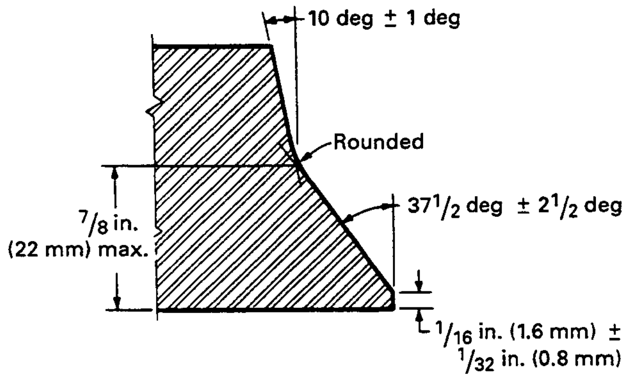
(d) Split Nub Type Backing Ring

GENERAL NOTES:
(a) Usual width of rings vary from $^3/_8$ in. (9.5 mm) and tubes to 1 in. (25.4 mm) for large pipes and tubes.
(b) Usual spacing at bottom of welds varies from $^3/_{32}$ in. (2.4 mm) to $^7/_{32}$ in. (5.6 mm) diameter and thickness.

(01) FIG. 527.1.2 TYPICAL JOINTS WITH BACKING RING

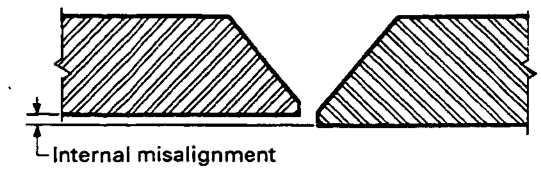


(a) PE Wall Thicknesses $^3/_{16}$ in. (5 mm) to $^7/_8$ in.(22 mm) Inclusive

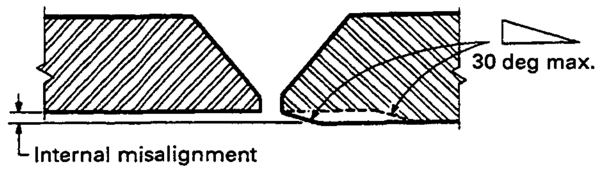


(b) PE Wall Thicknesses Above $^7/_8$ in. (22 mm)

FIG. 527.2.1-A BUTT WELDING END PREPARATION (01)



(a)



(b)

FIG. 527.2.1-B INTERNAL TRIMMING FOR BUTT WELDING OF PIPING COMPONENTS WITH INTERNAL MISALIGNMENT (01)

(01) **527.2.2 Fillet Welds.** Piping components that are joined by means of fillet welds shall be prepared in accordance with applicable provisions and requirements of para. 527.2.1. Details of typical fillet welds are shown in Figs. 527.3.3-A, 527.3.3-B, and 527.3.3-C.

(01) **527.3 Procedure**

(01) **527.3.1 General.** No welding shall be done if the weld area is wet or exposed to high wind or at a metal temperature below 32°F (0°C).

(01) **527.3.2 Butt Welds**

(a) Butt joints not made in accordance with the standards and specifications listed in Table 502.3.1 may be made with a single-V, double-V, or other suitable type of groove, with or without backing rings.

(b) Tack welds shall be made by a qualified welder or shall be removed. Tack welds that are not removed shall be made with a filler metal that is the same or equivalent to the electrode to be used for the first pass. Tack welds that have cracked shall be removed. Before assemblies are transferred from a location of fit-up to a location of welding, all joints shall have been adequately tack welded or partially welded, so as to prevent the cracking of these welds or the distortion of the assembly during such transfer. Piping that is to be welded in place shall be properly aligned and adequately supported during tack welding and subsequent welding in order to avoid the cracking of welds.

(c) If the external surfaces of the two components are not aligned, the weld shall be tapered between the surfaces.

(d) The welding shall be such as to assure that the following requirements are met.

(01) *(1)* The external surface of butt welds shall be free from undercuts greater than 1/32 in. (0.8 mm) deep, or one-half the weld reinforcement, whichever is smaller.

(01) *(2)* The thickness of weld reinforcement shall not exceed the following considering the thinner component being joined:

Pipe Wall Thickness, in. (mm)	Reinforcement Thickness, in. (mm)
1/4 (6) and under	1/16 (1.6)
Over 1/4 (6) through 1/2 (13)	3/32 (2.4)
Over 1/2 (13) through 1 (25)	1/8 (3)
Over 1 (25)	3/16 (5)

(3) Cracks. None permitted.

(01) *(4) Incomplete Penetration.* The total joint penetration shall not be less than the thinner of the two components being joined, except to the extent that incomplete root penetration is permitted for girth welds only. The depth of incomplete root penetration at the weld root of girth welds shall not exceed 1/32 in. (0.8 mm) or one-half the thickness of the weld reinforcement, whichever is smaller. The total length of such incomplete root penetration or at the root shall not exceed 1½ in. (38 mm) in any 6 in. (152 mm) of weld length.

(5) Lack of fusion. None permitted.

527.3.3 Socket and Fillet Welds. Fillet welds may vary from convex to concave. The size of a fillet weld is determined by the leg length of the largest inscribed right angle triangle as shown in Fig. 527.3.3-A. Typical fillet weld details for slip-on flanges and socket welding components are shown in Figs. 527.3.3-B and 527.3.3-C. The limitations as to imperfections of these socket and fillet welds shall be as set forth in para. 527.3.2(d) for butt welds. (01)

527.3.4 Seal Welds. Where seal welding of threaded joints is performed, external threads shall be entirely covered by the seal weld. Seal welding shall be done by qualified welders. (01)

527.3.5 Welded Branch Connections (01)

(a) Figures 527.3.5-A, 527.3.5-B, and 527.3.5-C show typical details of branch connections, with and without added reinforcement. However, no attempt has been made to show all acceptable types of construction and the fact that a certain type of construction is illustrated does not indicate that it is recommended over other types not illustrated. Whenever possible, branch connections shall be made in such a manner that the longitudinal seam of welded pipe is not pierced.

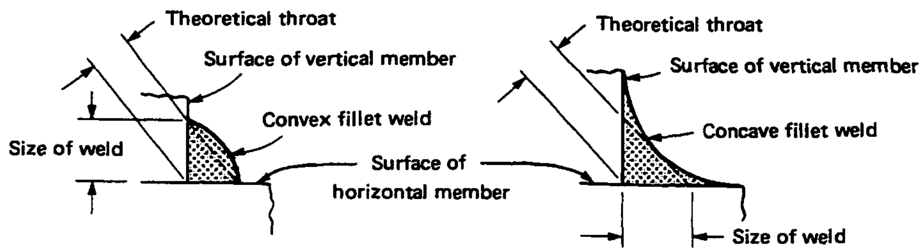
(b) Figure 527.3.5-D shows basic types of weld attachments used in the fabrication of branch connections. The location and minimum size of these attachment welds shall conform to the requirements of this paragraph. Welds shall be calculated in accordance with para. 504.3.1 but shall be not less than the sizes shown in Fig. 527.3.5-D. (01)

The notations and symbols used in this paragraph and in Fig. 527.3.5-D are as follows:

t_c = 0.7 t_n and not less than 1/4 in. (6 mm) except on thin material 1.4 t_n is acceptable

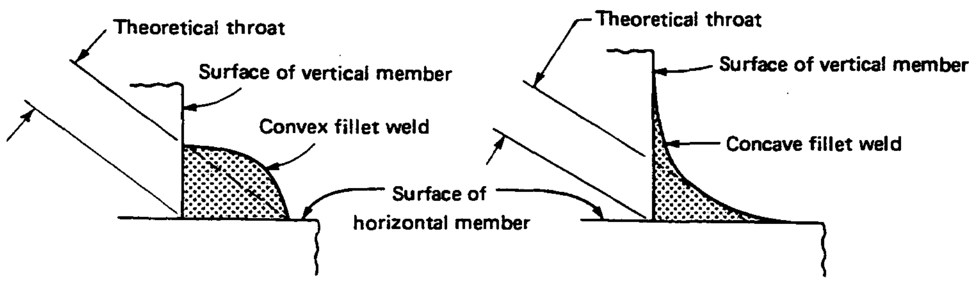
t_e = nominal thickness of reinforcing element (ring or saddle), in. (mm) (t_e = 0 if there is no added reinforcement.)

t_n = nominal thickness of branch wall less corrosion allowance, in. (mm)



GENERAL NOTE: The size of an equal leg fillet weld is the leg length of the largest inscribed right isosceles triangle. Theoretical throat = 0.707 × size of weld.

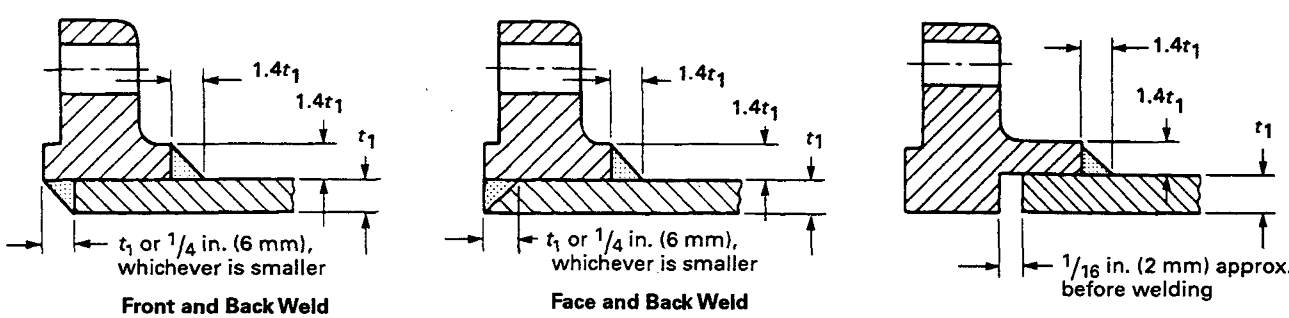
(a) Equal Leg Fillet Weld



GENERAL NOTE: The size of an unequal leg fillet weld is the leg length of the largest right triangle, which can be inscribed within the fillet cross section.

(b) Unequal Leg Fillet Weld

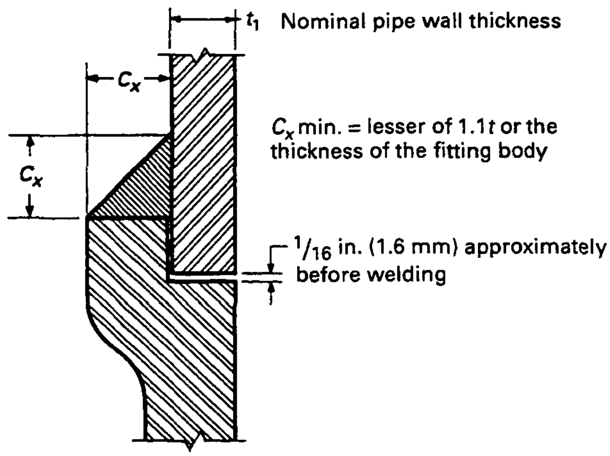
FIG. 527.3.3-A FILLET WELD SIZE (01)



(a) Slip-On Flange **(b) Socket Welding Flange**

GENERAL NOTE: t_1 = nominal pipe wall thickness.

FIG. 527.3.3-B WELDING DETAILS FOR SLIP-ON AND SOCKET WELDING FLANGES, AND SOME ACCEPTABLE TYPES OF FLANGE ATTACHMENT WELDS (01)



(01) FIG. 527.3.3-C MINIMUM WELDING DIMENSIONS REQUIRED FOR SOCKET WELDING COMPONENTS OTHER THAN FLANGES

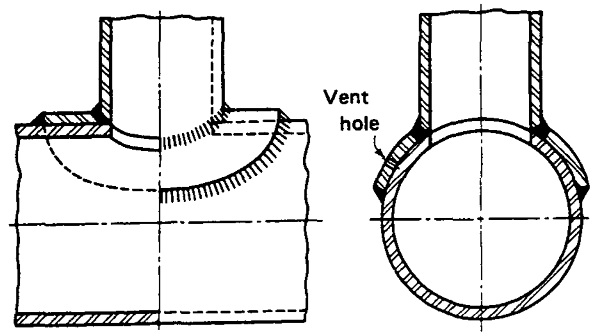
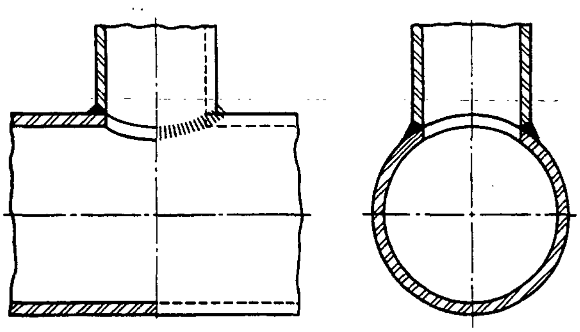


FIG. 527.3.5-B TYPICAL WELDED BRANCH CONNECTION WITH ADDITIONAL REINFORCEMENT (01)



(01) FIG. 527.3.5-A TYPICAL WELDED BRANCH CONNECTION WITHOUT ADDITIONAL REINFORCEMENT

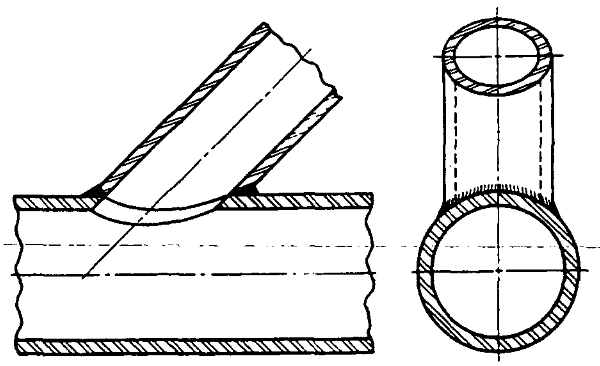


FIG. 527.3.5-C TYPICAL WELDED ANGULAR BRANCH CONNECTION WITHOUT ADDITIONAL REINFORCEMENT (01)

t_{min} = t_e or t_n, whichever is smaller

(c) Branch connections (including specially made integrally reinforced branch connection fittings) that abut the outside surface of the run (header) wall, or that are inserted through an opening cut in the run (header) wall, shall have opening and branch contour where necessary to provide a good fit and shall be attached by means of fully penetrated groove welds. The fully penetrated groove welds shall be finished with cover fillet welds having a minimum throat dimension not less than t_c [see Fig. 527.3.5-D sketches (a) and (b)]. The limitations as to imperfection of these groove welds shall be as set forth in para. 527.3.2(d) for butt welds.

(d) In branch connections having reinforcement pads or saddles, the reinforcement shall be attached by welds at the outer edge and at the branch periphery as follows.

(1) If the weld joining the added reinforcement to the branch is a fully penetrated groove weld, it shall be finished with a cover fillet weld having a minimum throat dimension not less than t_c; the weld at the outer edge, joining the added reinforcement to the run (header), shall be a fillet weld with a minimum throat dimension of 0.5 t_e [see Fig. 527.3.5-D sketches (c) and (d)].

(2) If the weld joining the added reinforcement to the branch is a fillet weld, the throat dimension shall not be less than 0.7 t_{min} [see Fig. 527.3.5-D sketch (e)]. The weld at the outer edge joining the outer

reinforcement to the run (header) shall also be a fillet weld with a minimum throat dimension of 0.5 t_c.

(e) When rings or saddles are used, a vent hole shall be provided (at the side and not at the crotch) in the ring or saddle to reveal leakage in the weld between branch and main run and to provide venting during welding and heat treating operations. Rings or saddles may be made in more than the one piece if the joints between the pieces have adequate strength and if each piece is provided with a vent hole. A good fit shall be provided between reinforcing rings or saddles and the parts to which they are attached.

(01) **527.3.6 Welded Flat Plate Closures.** Figures 527.3.6-A and 527.3.6-B show acceptable and unacceptable welds for flat plate closures in pipe. See para. 504.4.2 for nomenclature.

(01) **527.3.7 Heat Treatment for Welds.** Heat treatment of welds shall be in accordance with para. 531.

(01) 527.4 Qualification

(01) **527.4.1 General**

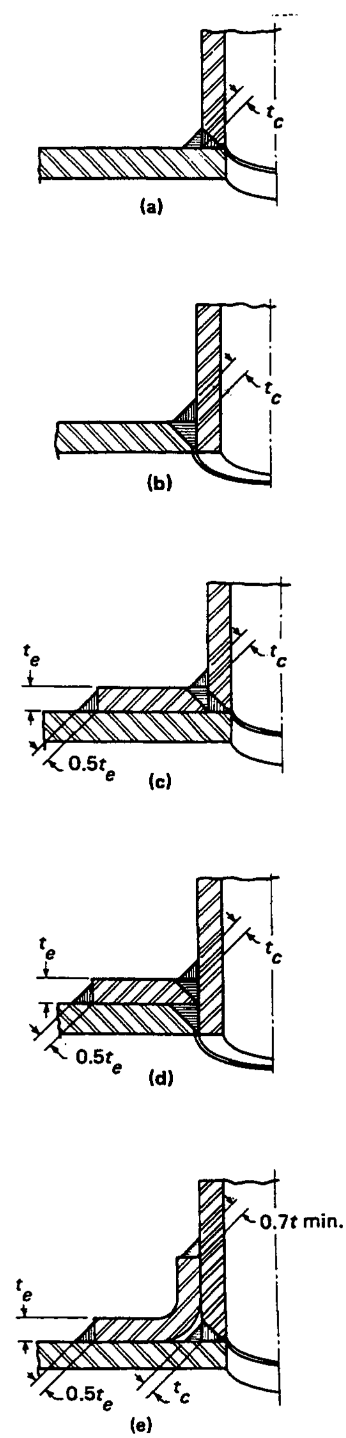
(a) The qualification of welding procedures and welders performance for both ferrous and nonferrous materials shall be in accordance with Section IX, ASME BPV Code, or with AWS welding procedure, AWS D10.9 Level AR-1 for refrigerant piping, Level AR-1 or AR-3 for nonvolatile brine piping.

(b) General Requirements

(1) The following rules shall apply to the qualification of welding procedures and welder performance for all types of manual, semiautomatic, and automatic arc and gas welding processes.

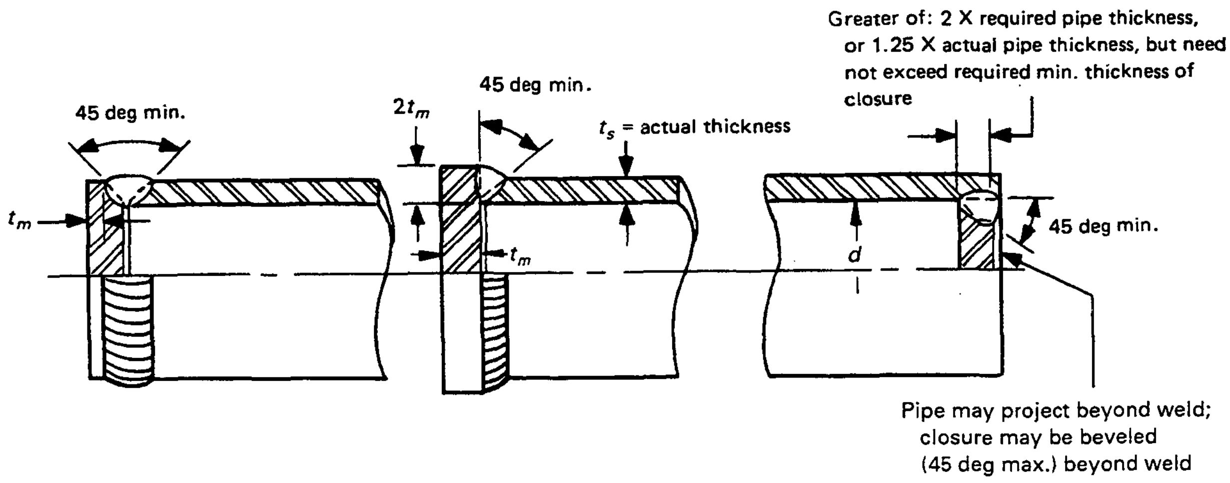
(2) Each employer is responsible for the welding done by personnel of its organization and shall conduct the tests required in Section IX, ASME BPV Code, or AWS D10.9, to qualify the welding procedures used in the construction of weldments constructed under this Code Section and to qualify welders and welding operators who apply these procedures, and the employer shall maintain records thereof.

(3) To avoid duplication of qualification tests of procedures, welders, or welding operators, the procedures, welders, or welding operators qualified as required above by one employer may be accepted by another employer on piping using the same or an equivalent procedure wherein the essential variables are within the limits established in Section IX, ASME BPV Code, or AWS D10.9. The contractor, fabricator, or purchaser may accept or reject qualification tests made



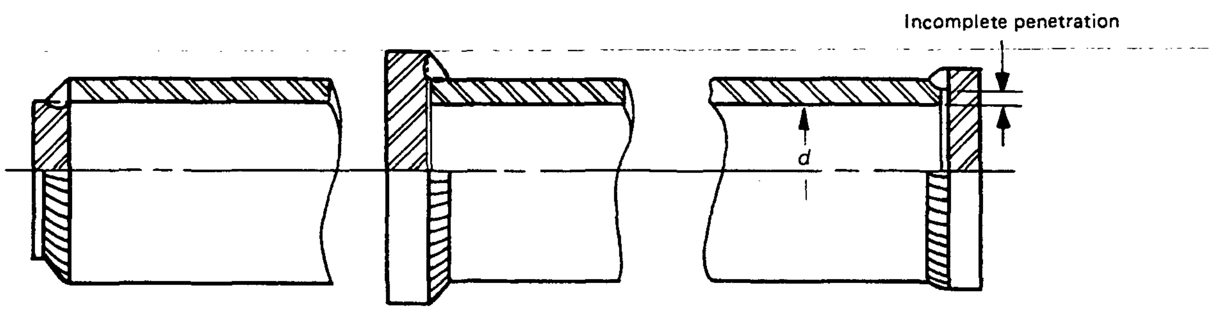
GENERAL NOTE: Weld dimensions may be larger than the minimum values shown here.

FIG. 527.3.5-D SOME ACCEPTABLE TYPES OF WELDED BRANCH ATTACHMENT DETAILS SHOWING MINIMUM ACCEPTABLE WELDS (01)



GENERAL NOTE: For other acceptable welds, see ASME BPV Code, Section VIII, Division 1. For nomenclature see para. 504.2.2.

(01) FIG. 527.3.6-A ACCEPTABLE WELDS FOR FLAT PLATE CLOSURES



(01) FIG. 527.3.6-B UNACCEPTABLE WELDS FOR FLAT PLATE CLOSURES

by others. An employer or code examiner accepting the qualification tests of welders or welding operators by another employer shall clearly indicate in his record of such welders or welding operators, the employer by whom the welders or welding operators were qualified, and the dates of such qualification. By so doing the employer accepts the responsibility for the welder's workmanship.

(c) Performance Requalification. Renewal of a Performance Qualification is required when:

(1) a welder has not used the specific process (within the essential variables of the ASME BPV Code, Secion IX, or AWS D10.9) to weld either ferrous or nonferrous piping materials for a period of 6 months or more, provided that the welder has been continually welding during that period; or

(2) there is a specific reason to question his ability to make welds that meet the Performance Qualification requirements. Renewal of qualification under stipulation (1) above need be made in only a single pipe wall thickness.

527.5 Records (01)

The employer shall maintain a record, certified by the employer, and available to the purchaser or the purchaser's agent and the inspector, of the procedures used and the welders or welding operators employed by the employer, showing the date and results of procedure and performance qualifications and the identification symbol assigned to each performance qualification. The identification symbol shall be used to identify the work performed by the welder or welding operator. After completing a welded joint, the welder or welding operator shall identify it as his or her work by applying his or her assigned symbol for permanent record in a manner specified by his or her employer.

(01) **527.6 Defect Repairs**

All defects in welds requiring repair shall be removed by flame or arc gouging, grinding, chipping, or machining. All repair welds shall be preheated and postheated as originally required and the basic principles of the same welding procedure initially used shall be employed as far as applicable. This recognizes that the cavity of the weld may not be of the same contour or dimensions as the original joint.

Preheating may be required on certain alloy materials of the air hardening type in order to prevent surface checking or cracking adjacent to the flame or arc gouged surface.

528 BRAZING AND SOLDERING

528.1 Brazing Materials

(01) **528.1.1 Filler Metal.** The filler metal used in brazing shall be a nonferrous metal or alloy having a melting point above 840°F (449°C) and below that of the metal being joined. The filler metal shall melt and flow freely with the desired temperature range and, in conjunction with a suitable flux or controlled atmosphere, shall wet and adhere to the surfaces to be joined. Brazing material containing other than residual phosphorous as an impurity is prohibited on joints made of ferrous materials.

528.1.2 Flux. Fluxes that are fluid and chemically active at the brazing temperature shall be used when necessary to prevent oxidation of the filler metal and the surfaces to be joined and to promote free flowing of the filler metal.

(01) **528.2 Brazing Preparation and Procedures**

(01) **528.2.1 Surface and Joint Preparation.** The surfaces to be brazed shall be clean and free of grease, oxides, paint, scale, and dirt of any kind, except as noted in para. 528.2.5. Any suitable chemical or mechanical cleaning method may be used to provide a clean wettable surface for brazing. The procedure for joints covered in para. 517 shall be as outlined in the Copper Tube Handbook, published by the Copper Development Association.

528.2.2 Joint Clearance. The clearance between surfaces to be joined shall be not greater than 0.004 in. (0.1 mm) or a diametral clearance of 0.008 in. (0.2 mm). (01)

528.2.3 Heating. The joint shall be brought uniformly to brazing temperature in as short a time as possible to minimize oxidation.

528.2.4 Brazing Qualification The qualification of brazing procedures and brazing operators shall be in accordance with the requirements of Part QB, Articles XII and XIII, Section IX, ASME BPV Code. (01)

528.2.5 Oil. Oil used for lubrication during mechanical expansion of tubing in coils need not be removed provided that sample(s) used for procedure qualification were in a similar condition and that the requirements of para. 528.2.4 are met. (01)

528.3 Soldering Materials

528.3.1 Solder. The solder metal used in soldering shall be a nonferrous metal or alloy having a solidus between 400°F (204°C) and 840°F (449°C) and below that of the metal being joined. The solder shall melt and flow freely within the desired temperature range and, in conjunction with a suitable flux, ASTM B 813, shall wet and adhere to the surface to be joined. (01)

528.3.2 Flux. Fluxes that are fluid and chemically active at the soldering temperature shall be used to prevent oxidation of the solder or filler metal and the surfaces to be joined and to promote the free flowing of the solder.

528.4 Soldering Preparation and Procedure

528.4.1 Surface Preparation. The surfaces to be soldered shall be clean and free from grease, oxides, paint, scale, and dirt of any kind. Any suitable chemical or mechanical cleaning method may be used to provide a clean wettable surface for soldering.

528.4.2 Joint Clearance. The average clearance between surfaces to be joined shall be not greater than 0.004 in. (0.1 mm), or a diametral clearance of 0.008 in. (0.20 mm). (01)

528.4.3 Heating. The joint shall be brought to soldering temperature in as short a time as possible to minimize oxidation without localized underheating or overheating.

(01) **528.4.4 Procedure.** Solderers shall follow the procedure as outlined in ASTM B 828.

529 BENDING — HOT AND COLD

529.1 Radii of Bends

Pipe and tube may be bent to any radius that will result in a bend surface free of cracks and substantially free of buckles. Out of the roundness and minimum finished thickness of bend shall be such that design requirements of para. 504 are met. This shall not prohibit the use of bends designed as creased or corrugated.

529.2 Procedure

Pipe and tube may be bent by any hot or cold method permissible by radii and material characteristics of the sizes being bent. Bending shall be done within a temperature range consistent with material characteristics and end use. Postheat treatment may be used to achieve this result.

529.3 Heat Treatment

Heat treatment shall be in accordance with paras. 531.1, 531.3.2, 531.3.3, and 531.3.5.

530 FORMING

530.1 Procedure

Piping components may be formed by any suitable method, including hot or cold pressing, rolling, forging, hammering, spinning, or drawing. Forming shall be done within a temperature range consistent with material characteristics and end use. Postheat treatment may be used to achieve this result.

530.2 Heat Treatment

Heat treatment shall be in accordance with paras. 531.1, 531.3.2, 531.3.3, and 531.3.5.

531 HEAT TREATMENT

531.1 Heating and Cooling Method

Heat treatment may be accomplished by a suitable heating method that will provide the required metal temperature, metal temperature uniformity, and temperature control, such as an enclosed furnace, local fuel firing, electric resistance, or electric induction. Cooling may be accomplished in a furnace, in air, with the aid of local thermal control, with the application of heat or insulation, or in any other manner required to achieve the desired cooling rate.

531.2 Preheating

531.2.1 Unless otherwise specified in the qualified procedure specification, preheating for welds in materials shall be as stipulated in Table 531.2.1 (see Section IX, ASME BPV Code, for P-Numbers of materials).

531.2.2 When welding dissimilar metals having different preheat requirements, the preheat temperature shall be that established in the welding procedure specification.

531.2.3 The preheat temperature shall be checked by use of temperature indicating crayons, thermocouple pyrometers, or other suitable methods to assure that the required preheat temperature is obtained prior to and maintained during the welding operation.

531.3 Postheat Treatment

531.3.1 Unless other postheat treatment is stipulated in the welding procedure to meet the requirements of para. 531.3.2, postheat treatment for the welds (except seal welds of threaded joints for P-Nos. 1 and 3 materials) shall be as stipulated in Table 531.2.1. Seal welds of threaded joints for P-Nos. 1 and 3 materials do not require postheat treatment.

531.3.2 Postheat treatment shall be performed as necessary to restore physical property requirements (such as strength, ductility, and corrosion resistance, or a combination thereof) with respect to material design, and end use requirements. Physical property requirements shall determine the treatment to be performed, such as stress relief, anneal, or normalize.

531.3.3 The heating method selected for restoration of physical properties desired for parts of any assembly shall be such as will accomplish this result without adversely affecting other components. Heating a fabri-

TABLE 531.2.1 HEAT TREATMENT OF WELDS (01)

ASME BPV Code, Section IX, P–Nos.	Material	Preheat Required: Min. Wall [Notes (1) & (2)]	Preheat Required: Min. Temp. °F (°C) [Note (3)]	Postheat Treatment Requirement [Notes (4) & (5)]: Min. Wall & Other [Notes (1) & (2)]	Postheat Treatment Requirement: Temp. °F (°C) [Notes (6)—(8)] Min.	Postheat Treatment Requirement: Temp. °F (°C) [Notes (6)—(8)] Max.
1	Mild steel	None	None required	Over ¾ in. (19 mm)	1,100 (595)	1,200 (650)
1	Mild steel	All walls	175 (80)	Over ¾ in. (19 mm)	1,100 (595)	1,200 (650)
3 [Note (10)]	Carbon moly ½Cr-½Mo	All walls	175 (80)	Over ½ in. (13 mm)	1,100 (650)	1,300 (705)
4 [Note (10)]	Cr-½Mo 1¼Cr-½Mo	Up to ¾ in. (19 mm) Over ¾ in. (19 mm)	300 (150) 400 (205)	Over ½ in. (13 mm) or over 4 in. (DN 100) nominal size; over 0.150 maximum	1,300 (705)	1,400 (760)
5 [Note (10)]	2½Cr-Mo	Up to ¾ in. (19 mm) Over ¾ in. (19 mm)	300 (150) 400 (205)	Over 1½ in. (13 mm) or over 4 in. (DN 100) nominal size, over 0.150 maximum	1,300 (705)	1,425 (775)
5 [Note (11)]	5Cr-½Mo 7Cr-½Mo 9Cr-Mo	Up to ¾ in. (19 mm) Over ¾ in. (19 mm)	300 (150) 400 (205)	All walls	1,300 (705)	1,425 (775)
6	High alloy martensitic TP-410 (12Cr)	All walls	300 (150) [Note (12)]	All walls	1,400 (760)	1,500 (825)
8	High alloy austenitic	All walls	None required	All walls	None required	
9	A 333 2½ & 3½Ni	All walls	300 (150)	Over ⅝ in. (16 mm)	1,100 (595)	1,200 (650)

NOTES:
(1) Wall thickness is defined as the thicker of the two abutting ends after end preparation including inside diameter machining.
(2) The thickness of socket, fillet, and seal welds is defined as the throat thickness for pressure and nonpressure retaining welds.
(3) Preheat temperatures shall be checked by use of temperature indicating crayons, thermocouple pyrometers, or other suitable methods.
(4) Not applicable to dissimilar metal welds.
(5) For materials not listed, preheat and postheat treatment shall be in accordance with the qualified Welding Procedure Specification.
(6) Postheat treatment temperatures shall be checked by use of thermocouple pyrometers or other suitable means.
(7) (a) The heating rate for furnace, gas, electric resistance, and other surface heating method shall be:
(1) 600°F (316°C)/hr maximum for thickness 2 in. (51 mm) and under; and
(2) 600°F (316°C)/hr divided by one half the thickness for thickness over 2 in. (51 mm).
(b) The heating rate for induction heating shall be:
(1) 600°F (316°C)/hr maximum for thickness less than 1½ in. (38 mm) at 60 Hz and 400 Hz; and
(2) 500°F (260°C)/hr maximum at 60 Hz and 400°F (205°C)/hr maximum at 400 Hz for thickness 1½ in. (38 mm) and over.

(01)

TABLE 531.2.1 HEAT TREATMENT OF WELDS (CONT'D)

ASME BPV Code, Section IX, P-Nos.	Postheat Treatment Requirement [Notes (4) & (5)] Time Cycle: hr/25 in./(mm) of Wall [Notes (1) & (2)]	Time Cycle: Min. Time, hr., Within Range	Other Limiting, Maximum, or Contingent Conditions, or Other	Approx. Lower Critical Temp., °F (°C)
1	1	1	No preheat for 0.30C maximum or 0.65 maximum C equivalent per applicable mateial specification [Note (9)]	1,375 (745)
1	1	1	Preheat required above 0.30C maximum and above 0.65 maximum C equivalent as per applicable material specification [Note (9)]	. . .
3 [Note (10)]	1	1	Brinell hardness 215 maximum [Note (11)]	1,400 (760) (½Cr-½Mo)
4 [Note (10)]	1	1	Lower preheat temperatures may apply for inert gas tungsten arc root pass welding; Brinell hardness 215 maximum [Note (11)]	1,430 (775) (Cr-½Mo) 1,430 (775) (1¼Cr-½Mo)
5 [Note (10)]	1	1	Lower preheat temperatures may apply for inert gas tungsten arc root pass welding; Brinell hardness 241 maximum [Note (11)]	1,400 (805) (2½Cr-Mo)
5 [Note (11)]	1	2	Lower preheat temperatures may apply for inert gas tungsten arc root pass welding; Brinell hardness 241 maximum [Note (11)]	1,515 (825) (5Cr-½Mo) 1,515 (825) (7Cr-½Mo) 1,515 (825) (9Cr-Mo)
6	1	2	Note (11)	12Cr
8	. . .	. . .	. . .	. . .
9	½	1	. . .	. . .

(8) Local postheat treatment of butt welded joints shall be performed on a circumferential band of the pipe. The minimum width of this band, centered on the weld, shall be the width of the weld plus 2 in. (51 mm). Local postheat treatment of welded branch connections shall be performed by heating a circumferential band of the pipe to which the branch is welded. The width of the heated band shall extend at least 1 in. (25 mm) beyond the weld joining the branch.

(9) 0.65 maximum C equivalent is defined as %C 1¼ % Mn.

(10) Welding on P-Nos. 3, 4, and 5 with 3Cr maximum may only be interrupted provided:

(a) a minimum of at least ⅜ in. (10 mm) thickness of weld deposit or 25% of welding groove is filled, whichever is greater; and

(b) the weld is allowed to cool slowly to room temperature.

(c) The required preheat must be resumed before welding is continued.

(11) The maximum Brinell hardness of welds in and of materials P-Nos. 3 through 6 shall be as listed. A minimum of 10% of welds that are furnace heat treated, and 100% of welds that are locally heat treated, shall be Brinell hardness tested at a point in the base metal as near as practical to the edge of weld metal and in the weld metal.

(12) 600°F (316°C) maximum interpass temperature, Brinell hardness 241 maximum.

cated assembly as a complete unit is usually desirable. However, the size or shape of the unit or the adverse effect of a desired heat treatment on one or more components where dissimilar materials are involved may dictate alternative procedures such as heating a section of the assembly before the attachment of others, or local circumferential band heating of welded joints in accordance with this Section. The hardness limitations of Table 531.2.1 are mandatory regardless of the heat treatment used.

531.3.4 Postheat treatment of welded joints between dissimilar metals having different postheat requirements shall be established in the welding procedure specification.

531.3.5 Postheat treatment temperatures shall be checked by the use of thermocouple pyrometers or other suitable equipment to assure that the desired treatment cycle has been accomplished.

531.3.6 If welding is interrupted before completed and allowed to cool prior to postheat treatment, adequate heat treatment or controlled rate of cooling shall be effected to assure that no detrimental effect to the work shall result.

531.3.7 Postheat treatment of welds shall be compatible with the analysis of the base materials being joined and the weld deposit. Postheat treatment of welded joints shall be established in the welding procedure specification.

531.3.8 Where Table 531.2.1 indicates thickness as a factor in determining the requirement for postheat treatment, nominal pipe wall thickness of the thicker pipe of the governing material that governs the weld size is intended. However, for lugs, supports, or other external nonpressure-containing attachments, the throat thickness of the attachment welds shall govern for those welds.

531.3.9 Local Postheat Treatment

(a) Local postheat treatment of welded joints shall require the entire band to be brought up to uniform temperature over the circumference of the heated pipe section with a gradual diminishing of temperature outward from the band.

(b) When local heat treating a circumferential weld, the minimum width of the band centered on the weld shall be the larger of

(1) twice the width of the weld reinforcement; or

(2) width of weld reinforcement plus 2 in. (51 mm). (01)

(c) When local heat treating welded branch connections or other attachments, a circumferential band of the pipe to which the branch or attachment is welded shall be heated to the desired temperature. The width of this band shall extend at least 1 in. (25 mm) beyond the weld joining the branch or attachment to the pipe. (01)

535 ASSEMBLY

535.1 General

The assembly of the various piping components, whether done in a shop or as field erection, shall be done so that the completely erected piping conforms with all requirements of this Code and with the specified requirements of the engineering design.

535.2 Bolting Procedure

535.2.1 All flanged joints shall be fitted up so that the gasket contact faces bear uniformly on the gasket. The joints shall then be progressively tightened in a diametrically staggered pattern. (01)

535.2.2 In bolting gasketed flanged joints, the gasket shall be properly compressed in accordance with the design principle applicable to the type of gasket used.

535.2.3 Steel-to-cast-iron flanged joints shall be assembled with care to prevent damage to the cast-iron flange. See paras. 508.3 and 508.5.

535.2.4 Bolt threads shall extend completely through the mating nut.

535.2.5 In refacing flanges, dimensions must not be reduced below those shown in ASME B16.5.

535.3 Threaded Piping (01)

535.3.1 Threaded joints that are to be seal welded shall be made up without any thread compound.

535.3.2 Any compound used in threaded joints shall be suitable for the service conditions and shall not react unfavorably with the service fluid.

535.3.3 Threaded joints in ferrous metal pipe shall conform to ASME B1.20.1. Exposed threads should be coated to inhibit corrosion. See para. 514(f).

535.3.4 Threaded joints in copper or brass pipe of standard size shall conform to ASME B16.15.

535.3.5 All threaded joints shall be made up tight. Backing off for alignment is not permitted.

(01) **535.4 Welded Joints**

535.4.1 All welded joints shall be assembled in accordance with para. 527.

(01) **535.5 Brazed Sleeve Joints**

535.5.1 All brazed sleeve joints shall be assembled in accordance with paras. 528.1 through 528.2.4.

(01) **535.6 Soldered Sleeve Joints**

535.6.1 All soldered sleeve joints shall be assembled in accordance with paras. 528.3 and 528.4.

(01) **535.7 Flare Type Fitting Joints**

Ends of tubing shall be cut square and all burrs removed. No scratches, breaks, or other mars at sealing surface of flare shall be permitted. Assembly shall be performed in accordance with the fitting manufacturer's recommendation.

535.8 Flareless and Compression-Type Fitting Joints (01)

Ends of tubing shall be cut square and all burrs removed. No scratches, breaks, or mars at the outside of the tube at fitting shall be permitted. Flareless and compression-type fittings shall be of a design in which the gripping member or sleeve shall grip or bite into the outer surface of the tube with sufficient strength to hold the tube against pressure, but without appreciably distorting the inside tube diameter. The gripping member shall also form a pressure seal against the fitting body. Assembly shall be performed in accordance with the fitting manufacturer's recommendations.

535.9 Assembly of Hangers (01)

Threaded hanger connections shall be prevented from being loosened by vibration or by deforming threads by use of double nuts, by use of self-locking nuts, or by other means. Where hanger rods carry loads close to the maximum allowed by para. 520.1.3(a) and pass through and transfer their load to structural steel by means of a nut threaded on the rod, assembly shall be such that the load is not carried on one corner of the nut.

CHAPTER VI EXAMINATION, INSPECTION, AND TESTING (01)

536 EXAMINATION

536.1 Definition

Examination applies to visual examination and to nondestructive examination when specified in this code or in the engineering design. These quality control functions are performed by an examiner employed by the manufacturer, fabricator, or erector.

536.2 Responsibility

The manufacturer, fabricator, or erector is responsible for:

(a) providing materials, components, and workmanship in accordance with the requirements of the Code;

(b) performing the required examinations;

(c) performing the supplemental examinations when specified in the engineering design; and

(d) preparing suitable records of materials, examination and tests for the inspector's use when required in the Code.

536.3 Examination Personnel Qualification and Certification

Examiners shall have training and experience commensurate with the needs of the specified examinations. For this purpose, SNT-TC-1A, Recommended Practice for Nondestructive Testing Personnel Qualification and Certification, may be used as a guide. The owner shall determine whether examination by other than personnel performing the work is required.

536.4 Required Examination

536.4.1 Visual Examination. Prior to operation, visual examination is required in accordance with this paragraph for all refrigerant and secondary coolant piping.

(a) Definition. Visual examination is 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, mechanical joints, supports, assembly, and erection.

(b) Requirements. Visual examination shall be performed, as necessary, during the fabrication and erection of piping components to provide verification that the design and procedure specifications are met.

(c) Acceptance Criteria. The acceptance criteria shall be as stated in Chapter V of this Code; para. 527 for welded joints, para. 528 for brazed and soldered joints, and para. 535 for other mechanical joints and assembly of hangers.

536.4.2 Additional Examination for Group A3 and B3 Piping. In addition to visual examination per paragraph 536.4.1, the following examinations are required for Group A3 and B3 refrigerant piping.

(a) Not less than 5% of circumferential butt and miter groove welds shall be fully examined by random radiography. Welds to be examined shall be selected to ensure that the work product of each welder or welding operator doing production welding is included. Welds to be examined shall be selected to maximize coverage of intersections with longitudinal joints. At least $1\frac{1}{2}$ in. (38 mm) of the longitudinal welds shall be examined. In-process examination in accordance with para. 536.6.2 may be substituted for all or part of radiographic examination on a weld-for-weld basis if specified in the engineering design and specifically approved by the Inspector.

(b) Not less than 5% of all brazed joints shall be examined by in-process examination in accordance with para. 536.6.2. The joints to be examined shall be selected to ensure that the work of each brazer making production joints is included.

536.4.3 Defects

(a) If a defect (i.e., an imperfection of a type or magnitude exceeding the acceptance criteria of this Code) is revealed in an examination per para. 536.4.2, two additional items of the same kind (if welded or brazed joints, by the same welder, welding operator or brazer) shall be given the same type of examination; and

(b) if the items examined as required in (a) above are acceptable, the defective item shall be repaired or replaced and reexamined as specified in para. 536.6.1(a) and all items represented by this additional examination shall be accepted; but

(c) if any of the items examined as required in (a) above reveals a defect, two further samples of the same kind shall be examined for each defective item found by the examination; and

(d) if the items examined as required by (c) above are acceptable, the defective item(s) shall be repaired or replaced and reexamined as specified in para. 536.6.1(a) and all items represented by this additional examination shall be accepted; but

(e) if any of the items examined as required by (c) above reveals a defect, all items represented by the progressive examination shall be either:

(1) repaired or replaced and reexamined as specified in para. 536.6.1(a); or

(2) fully examined and repaired or replaced and reexamined as specified in para. 536.6.1(a).

536.5 Supplementary Examination

Any of the types of examination described in para. 536 may be specified in the engineering design to supplement the examination required by para. 536.4. The extent of supplementary examination and the acceptance criteria shall be specified in the engineering design.

536.6 Types of Examinations

536.6.1 General

(a) Items examined with one or more defects shall be repaired or replaced. The repaired or replaced work shall be examined by the same methods and to the same extent, and shall meet the same acceptance criteria as required for the original work.

(b) Welds and joints not included in the examinations required by para. 536.4 shall be deemed acceptable when they meet the testing requirements of para. 538.

536.6.2 In-Process Examination. In-process examination comprises visual examination of the following as applicable;

(a) joint preparation and cleanliness;

(b) preheating;

(c) fit-up, joint clearance and internal alignment prior to joining;

(d) variables specified by the joining procedure, including filler material; and

(1) (for welding) position and electrode;

(2) (for brazing) position, flux, brazing temperature, proper wetting, and capillary action;

(e) (for welding) external condition of the root pass after cleaning, and internal where accessible, aided by liquid penetrant or magnetic particle examination when specified in the engineering design.

(f) (for welding) slag removal and weld condition between passes; and

(g) appearance of the finished joint.

536.6.3 Radiographic Examination

(a) Definitions. The following definitions apply to radiography required by this Code:

(1) Radiography applies only to circumferential butt welds and miter groove welds unless otherwise specified.

(2) 100% Radiography requires complete radiography of all of a specified kind of item in a designated lot of piping.

(3) Random Radiography requires complete radiography of a percent of specified kind of item in a designated lot of piping.

(4) Spot Radiography requires a single exposure radiograph at a specified point within the weld of a percent of a specified kind of item in a designated lot of piping. For circumferential butt welds and miter groove welds the minimum requirement is:

(a) a single elliptical exposure encompassing the entire weld circumference for pipe up to NPS $2\frac{1}{2}$ (DN 65);

(b) the lesser of 25% of the inside circumference or 6 in. (150 mm) for pipe greater than NPS $2\frac{1}{2}$ (DN 65); or

(c) a minimum of 6 in. (150 mm) of weld length for longitudinal welds.

(b) Method. Radiographic examination shall be performed in accordance with Article 2 of Section V of the ASME BPV Code.

(c) Acceptance Criteria. The acceptance criteria shall be at least that specified for Normal Service Fluid in Table 341.3.2 of ASME B31.3.

537 INSPECTION

537.1 Definition

Inspection applies to functions performed by the owner's Inspector or the Inspector's Delegate.

537.2 Responsibility

Prior to operation, it is the owner's responsibility to inspect a piping system to the extent necessary to assure compliance with the engineering design, and with the material, fabrication, assembly, examination, and testing requirements of this Code. Systems shall be inspected visually after complete installation and before operation, except that parts of the system that would not be accessible after complete installation shall be inspected after completion of those parts.

537.3 Rights of Inspectors

The Inspector or Delegate shall have access to any place where work concerned with the piping is being performed. When the work is not performed on the owner's premises, the Inspector's access is subject to negotiation with the manufacturer or fabricator. This includes, but is not limited to, manufacture, fabrication, assembly, erection, examination, and testing of the piping. Inspectors shall have the right to review all records pertaining to the examination requirements of para. 536.

537.4 Qualifications of the Owner's Inspector

The Inspector shall be designated by the owner. The Inspector (or Delegate) shall be an employee of the owner or of a company acting as the owner's agent. The Inspector (or Delegate) shall not represent nor be an employee of the manufacturer, fabricator, or erector unless the owner is the manufacturer, fabricator, or erector. The Inspector (or Delegate) shall have at least five years experience in the design, fabrication, examination, testing, or inspection of industrial piping.

538 TESTING

538.1 Testing Before Erection or Assembly

When system components (including compressors, pumps, heat exchangers, valves, gauges, regulators, pipe, tube, and fittings) have been pressure tested by the component manufacturer or assembler according to standards or applicable specifications, no further pressure testing of these components, other than leak testing, is required.

538.2 Preparation for Testing

All joints to be tested shall be exposed, unpainted, and free of rust, dirt, oil, and other foreign materials. Joints previously tested in accordance with this Code may be painted and insulated or covered.

538.3 Factory Testing of Refrigerant Piping

(a) All factory-assembled refrigerant piping of every system shall be tested and proved tight by the manufacturer to at least 110% of the design pressure for which it is rated, in accordance with the applicable requirements of para. 538.

(b) A pneumatic pressure test applied to the piping of each factory-assembled refrigerating system shall not exceed 130% of the design pressure of any component.

538.4 Field Testing of Refrigerant Piping

538.4.1 General Requirements. Refrigerant piping erected on the premises, except piping components that are factory tested, shall be pressure tested and leak tested after installation and before operation in accordance with the applicable requirements of para. 538.4.

538.4.2 Pressure Test

(a) Piping shall be examined before pressure is applied to ensure that it is tightly connected. All items not subject to the pressure test shall be disconnected or isolated by valves, blanks, plugs, or other suitable means.

(b) A preliminary test at a gauge pressure of 25 psig (170 kPa) may be applied, prior to other testing, as a means of locating major leaks.

(c) The temperature of the piping system during testing shall be above the ductile-brittle transition temperature.

CAUTION: Take measures to protect personnel from the potential of rupture of piping components during pneumatic testing of systems.

(d) The means used to furnish the test pressure shall have either a pressure limiting device or a pressure reducing device and a pressure relief device and gage on the outlet side. The pressure relief device shall be set above the test pressure, but low enough to prevent permanent deformation of any of the system components.

(e) The pneumatic test pressure used shall be at least 110% of the design pressure. The test pressure shall not exceed 130% of the design pressure of any component in the system.

(f) For large systems that are not completely visible to the testing operator, the pressure in the system shall be gradually increased to one-half of the test pressure, after which the pressure shall be increased in steps of approximately one-tenth of the test pressure until the

required test pressure has been reached. The test pressure shall be continuously maintained for at least 10 min. It may then be reduced to the leak test pressure per para. 538.4.3 (c).

(g) Mechanical joints at which blanks or plugs are inserted to blank off or facilitate removal of equipment during the pressure test need not be pressure tested after removal of the blank or plug provided the joint passes a subsequent leak test.

538.4.3 Leak Test After the pressure test in para. 538.4.2 is completed, a leak test shall be performed.

(a) Examination for leaks shall be by the gas and bubble formation testing as detailed in Article 10, Section V of the ASME Boiler and Pressure Vessel Code, or by other methods of equal sensitivity.

EXCEPTION: Refrigerant vapor detection methods shall be used when refrigerant is used in the test medium. Comply with environmental regulations when venting refrigerants.

(b) Examination shall be made of all joints and connections. The piping system shall show no evidence of leaking.

(c) The pressure used for leak tests shall be either, the design pressure, or a pressure specified in the engineering design.

538.5 Testing Medium for Refrigerant Piping

(a) A suitable dry gas such as nitrogen or air shall be used for pressure testing per para. 538.4.2. Toxic gases shall not be used unless personnel are adequately protected from harmful exposure should leaks occur during testing.

(b) Oxygen or any medium with a lower flammable limit below 13% shall not be used for pressure testing.

(c) The system refrigerant may be used for leak testing per para. 538.4.3.

CAUTION: Comply with environmental regulations when testing with refrigerants.

(d) Water or water solutions should not be used in testing refrigerant piping.

538.6 Pressure Tests for Secondary Coolant Piping

(a) Piping for secondary coolants tested hydrostatically shall be proven tight at a pressure of 150% of the design pressure. The pressure at the bottom of vertical runs shall not exceed either 90% of the minimum yield strength or 1.7 times the allowable stress for brittle materials.

(b) Piping systems for secondary coolants tested pneumatically shall be tested as refrigerant piping.

(c) Piping for a refrigerant used as a secondary coolant shall be tested as refrigerant piping.

538.7 Pressure Gages

Pressure gages shall be checked for accuracy prior to use in testing, either by comparison with master gages or by setting the pointer as determined by a dead-weight pressure gage tester.

538.8 Repair of Joints

(a) All leaking joints shall be repaired.

(b) Solder joints that leak shall be disassembled, cleaned, re-fluxed, reassembled, and re-soldered. Solder joints shall not be repaired by brazing.

(c) Brazed joints that leak may be repaired by cleaning the exposed area, re-fluxing, and re-brazing.

(d) Welded joints that leak shall have the defective areas of the weld removed and rewelded.

(e) After joints have been repaired, the joints shall be retested in accordance with paras. 538.4 and 538.5.

539 RECORDS

539.1 Definition

Records are the reduction to writing or film image of performances, evaluations, or data required by the Code.

539.2 Responsibility

It is the responsibility of the piping designer, manufacturer, fabricator, and erector as applicable to prepare the records required by this Code.

539.3 Extent and Retention of Records

The following records shall be maintained for three years:

(a) procedure specification, procedure qualification, and performance qualification records;

(b) results of weld examinations other than visual; and

(c) records of the testing of each piping system, which shall include the following information:

(1) date;

(2) identification of piping system tested;

(3) testing medium;

(4) test pressure; and

(5) signature of examiner and inspector.

NONMANDATORY APPENDIX A REFERENCED STANDARDS

(01)

Standards incorporated in this Code by reference and the names and addresses of the sponsoring organizations are shown in this Appendix. It is not practical to refer to a specific edition of each standard throughout the Code text; instead, the specific edition reference dates are shown here. The Appendix will be revised as needed.

API Specifications

5L, 4th Edition, 1995
600, 9th Edition, 1997

ASCE Standards

A58.1-1982

ASHRAE Standards

15-94 With Addenda
34-92 With Addenda

ASME Codes and Standards

Boiler and Pressure Vessel Code, 1998 Edition, including Addenda
- Section II Part C
- Section VIII, Division 1
- Section IX

B1.1-1989
B1.20.1-1992
B1.20.3-1976 (R1991)
B2.1-1984
B16.1-1989

B16.3-1992
B16.4-1992
B16.5-1996
B16.9-1993
B16.10-1992

B16.11-1991
B16.14-1991
B16.15-1985(R1994)
B16.18-1984
B16.22-1995

ASME Codes and Standards (Cont'd)

B16.24-1991
B16.25-1992
B16.28-1994
B18.2.1-1996
B18.2.2-1993

B36.10M-1996
B36.19M-1985(R1994)

ASTM Specifications

A 36/36M-96
A 47-90(R1996)
A 48-94a
A 53-96
A 105/A 105M-96

A 106-95
A 126-95
A 134-93
A 135-96

A 139-93a
A 178/178M-90
A 179/A 179M-90a
A 181/A 181M-95b
A 182/A 182M-97c

A 192/A 192M-90
A 193/A 193M-96b
A 194/A 194M-96
A 197-87(R1992)
A 210/A 210M-95

A 211-75 (R85)
A 213/A 213M-90
A 214/A 214M-90
A 216/A 216M-93
A 217/A 217M-95

ASTM Specifications (Cont'd)

A 226/A 226M-90
A 234/A 234M-97
A 240-96a
A 249/A 249M-91
A 254-90

A 269-96
A 271-88
A 278-93
A 283/A 283M-93a
A 285/A 285M-90(R1996)

A 307-94
A 312/A 312M-95a
A 320/A 320M-95
A 325/A 325M-97
A 333/A 333M-94

A 334/A 334M-96
A 350/A 350M-96c
A 351/A 351M-94a
A 352/A 352M-93
A 353/A 353M-93

A 354-95
A 358/A 358M-95a
A 376/A 376M-96
A 395-88(R1993)
A 403/A 403M-96

A 409M-95a
A 413-80
A 420/A 420M-96a
A 450/A 450M-89
A 466-91

A 467-86a
A 515/A 515M-92
A 516/A 516M-90(R1996)
A 522/A 522M-90
A 536-84 (R93)

REFERENCED STANDARDS (CONT'D)

ASTM Specifications (Cont'd)

A 533/A 533M-90
A 570/A 570M-96
A 571/A 571M-84 (R92)
A 587-93
A 611-89

A 663-88
A 675/A 675M-95
A 743/A 743M-92a
A 744/A 744M-89

B 16/B 16M-85
B 21-83b/B 21M-96
B 26/B 26M-97
B 32-89
B 42-93

B 43-94
B 61-93
B 62-93
B 68/B 68M-92
B 75/B 75M-95

B 85-90
B 88/B 88M-95a
B 96-93
B-98-93
B 111-88/B 111M-88a

B 124-89
B 152/B 152M-94
B 165-93
B 171-89/B 171M-95
B 179-90

B 209/B 209M-96
B 210/B 210M-95

ASTM Specifications (Cont'd)

B 211/B 211M-95a
B 221/B 221M-96
B 234/B 234M-88
B 241/B 241M-96
B 247/B 247M-95a

B 248-91b/B 248-90
B 280-95
B 283-94
B 302-87
B 315-86

B 345-96
B 361-95
B 466/B 466M-92a
B 467-88
B 543-92

B 584-93b
B 828-92

D 93-90

AWS Specifications

A5.1-92
A5.2-92
A5.3-88
A5.4-92
A5.6-84
A5.7-84

A5.8-89
A5.9-93
A5.10-88
A5.12-80

AWWA Standards

C110-93
C111-95
C500-93

CDA Publications

Copper Tube Handbook, 1980

MIL Standards

MIL-F-1183J-5/87

MSS Standard Practices

SP-6-1996
SP-9-1997
SP-25-1993
SP-42-1990(R1995)
SP-43-1991(R1996)
SP-45-1992
SP-51-1991(R1995)
SP-58-1998
SP-97-1995

SAE Specifications

J 513f-1996

GENERAL NOTE: The issue date shown immediately following the hyphen after the number of the standard (e.g., A-36-81a, B16-83, and SP-6-1980) is the effective date of issue (edition) of the standard.

Specifications and standards of the following organizations, appear in this Appendix:

API American Petroleum Institute
1220 L Street, NW
Washington, DC 20005
Phone: 202 682-8000

ASCE American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, VA 20191
Phone: 800 548-2723

ASHRAE American Society of Heating, Refrigerating, and Air-Conditioning Engineers
1791 Tullie Circle, N.E.
Atlanta, GA 30329
Phone: 404 636-8400

ASME The American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990

ASME Order Department
22 Law Drive
Box 2300
Fairfield, NJ 07007-2300
Phone: 201 882-1167
800-THE-ASME (US & Canada)
Fax: 201 882-1717, 5155

ASTM American Society for Testing and Materials
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959
Phone: 610 832-9500
Fax: 610 832-9555

AWS American Welding Society
550 NW LeJeune Road
PO Box 351040
Miami, FL 33135
Phone: 305 443-9353

AWWA American Water Works Association
6666 W. Quincy Avenue
Denver, CO 80235
Phone: 303 794-7711

CDA Copper Development Association Inc.
260 Madison Avenue
New York, NY 10016
Phone: 212 251-7200

MIL Department of Defense (DOD) Single Stock Point
U.S. Naval Publications and Forms Center
5801 Tabor Avenue
Philadelphia, PA 19120-5099
Phone: 215 697-2000

MSS Manufacturers Standardization Society of the Valve and Fittings Industry, Inc.
127 Park Street, NE
Vienna, VA 22180
Phone: 703 281-6613

SAE Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096
Phone: 412 776-4841

NONMANDATORY APPENDIX B
PREPARATION OF TECHNICAL INQUIRIES

B1 INTRODUCTION

The ASME B31 Committee, Code for Pressure Piping, will consider written requests for interpretations and revisions of the Code rules, and develop new rules if dictated by technological development. The Committee's activities in this regard are limited strictly to interpretations of the rules or to the consideration of revisions to the present rules on the basis of new data or technology. As a matter of published policy, ASME does not approve, certify, rate, or endorse any item, construction, proprietary device, or activity, and, accordingly, inquiries requiring such consideration will be returned. Moreover, ASME does not act as a consultant on specific engineering problems or on the general application or understanding of the Code rules. If, based on the inquiry information submitted, it is the opinion of the Committee that the inquirer should seek professional assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

Inquiries that do not provide the information needed for the Committee's full understanding will be returned.

B2 REQUIREMENTS

Inquiries shall be limited strictly to interpretations of the rules or to the consideration of revisions to the present rules on the basis of new data or technology. Inquiries shall meet the following requirements:

(a) Scope. Involve a single rule or closely related rules in the Scope of the Code. An inquiry letter concerning unrelated subjects will be returned.

(b) Background. State the purpose of the inquiry, which would be either to obtain an interpretation of Code rules or to propose consideration of a revision to the present rules. Provide concisely the information needed for the Committee's understanding of the inquiry, being sure to include reference to the applicable Code Section, edition, addenda, paragraphs, figures, and tables. If sketches are provided, they shall be limited to the scope of the inquiry.

(c) Inquiry Structure

(1) Proposed Question(s). The inquiry shall be stated in a condensed and precise question format, omitting superfluous background information, and, where appropriate, composed in such a way that "yes" or "no" (perhaps with provisos) would be an acceptable reply. The inquiry statement should be technically and editorially correct.

(2) Proposed Reply(ies). Provide a proposed reply stating what it is believed that the Code requires.

If, in the inquirer's opinion, a revision to the Code is needed, recommended wording shall be provided in addition to information justifying the change.

B3 SUBMITTAL

Inquiries should be submitted in typewritten form; however, legible handwritten inquiries will be considered. They shall include the name and mailing address of the inquirer and be mailed to the following address: Secretary, ASME B31 Committee; Three Park Avenue, 20th Floor; New York, NY 10016-5990.

ASME B31.5 INTERPRETATIONS
VOLUME 6

Replies to Technical Inquiries
August 1, 1994 Through December 31, 2000
Interpretations 6-1 Through 6-5

It has been agreed to publish intepretations issued by the B31 Committee concerning B31.5 as part of the update service to the Code. The interpretations have been asssigned numbers in chronological order. Each interpretation applies either to the latest Edition or Addenda at the time of issuance of the interpretation or the Edition or Addenda stated in the reply. Subsequent revisions to the Code may have superseded the reply.

These replies are taken verbatim from the original letters, except for a few typographical and editorial corrections made for improved clarity.

ASME procedures provide for reconsideration of these interpretations when or if additional information that the inquirer believes might affect the interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. As stated in the Statement of Policy in the Code documents, ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

B31.5

Interpretation: 6-1

Subject: B31.5-1992 Edition, Secondary Coolant

Date Issued: December 6, 1995

File: B31-94-033

Question: Does the addition of an anti-freeze to water in a chilled water system make a "secondary coolant" that is included in the scope of B31.5?

Reply: Yes.

Interpretation: 6-2

Subject: B31.5-1992 Edition, Para. 523.2.2(f)(4)

Date Issued: April 24, 1996

File: B31-95-047

Question (1): Does para. 523.2.2(f)(4) of ASME B31.5-1992 apply to gray cast iron materials?

Reply (1): No.

Question (2): If the reply to Question (1) is no, are the allowable stresses for gray cast iron at -20°F applicable down to -150°F?

Reply (2): Yes.

Interpretation: 6-3

Subject: B31.5-1992 Edition, Use of Group A2, Class 3, and Ammonia in Refrigerant Piping

Date Issued: May 21, 1997

File: B31-96-059

Question (1): Is Group A2, Class 3, refrigerant piping in ASME B31.5-1992 the only refrigerant piping for which the inspection requirements of ASME B31.3, Chapter VI, are to be followed?

Reply (1): Yes.

Question (2): Is Group A2, Class 3, refrigerant piping in ASME B31.5-1992 the only refrigerant piping for which the testing requirements of ASME B31.3, Chapter VI, are to be followed?

Reply (2): Yes.

Question (3): What inspection and testing is recommended for ammonia refrigerant piping in ASME B31.5-1992?

Reply (3): The requirements are in Chapter VI of B31.5.

Interpretation: 6-4

Subject: B31.5-1992 Edition, Use of Bushings and Reducers in Refrigerant Piping

Date Issued: December 19, 1997

File: B31-97-031

Question (1): Does the prohibition of couplings made of cast iron or malleable iron in ASME B31.5-1992, para. 506.3, include bushings and reducers?

Reply (1): No.

Question (2): Can reducing bushings made of cast iron or malleable iron be used in ammonia piping?

Reply (2): Yes.

Interpretation: 6-5

Subject: Interpretation of Pressure Testing of Refrigerant Equipment or Piping in B31.5 (1992 Edition, 1994 Addenda)

Date Issued: December 8, 2000

File: B31-00-024

Question: Can you provide any information or direction with regard to new codes or standards for pressure testing of refrigeration equipment or piping that "downgrade" the test pressure requirements from 1.5 times the MAWP to a lower fraction of 1.1 times the MAWP?

Reply: No.