ASME B31J-2017

[Revision of ASME B31J-2008 (R2013)]

Stress Intensification Factors (*i*-Factors), Flexibility Factors (*k*-Factors), and Their Determination for Metallic Piping Components

ASME Code for Pressure Piping, B31

AN AMERICAN NATIONAL STANDARD

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The American Society of Mechanical Engineers
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FOREWORD

In 1990 The American Society of Mechanical Engineers (ASME) B31 Code for Pressure Piping Technical Committee on Mechanical Design (MDC) realized that there was a need for a standard method to develop stress intensification factors (SIFs or *i*-factors) for ASME piping components and joints. At the time, the B31 Code books provided SIFs for various standard fittings and joints but did not provide guidance on how to conduct further research on existing SIFs or how to establish SIFs for nonstandard and other standard fittings or joints.

In 2001 the Committee realized that SIFs and *k*-factors in the various B31 Code books were not consistent or up to date, and so ASME initiated a research project completed by the MDC to incorporate recent research and current manufacturing practices in the SIF and *k*-factor test procedures, to provide a consistent and up-to-date table of SIFs and *k*-factors for metallic piping components.

This document provides a standard approach for the development of SIFs, *k*-factors, and sustained stress multipliers for piping components and joints of all types, including standard, nonstandard, and proprietary fittings.

Sustained stress multipliers are used to multiply the nominal bending stress due to sustained loading and reflect the collapse capacity of the metallic piping component or joint. Multipliers of the nominal bending stress due to sustained loads currently exist explicitly in some, but not all, B31 books. Where more accurate sustained stresses are needed but an equation for the sustained stress is not given in the B31 Code book, nominal stresses due to sustained moments computed using the section modulus of the matching pipe should be multiplied by the appropriate sustained stress multiplier. Where the sustained stress is needed and an equation for the sustained stress is given in the Code book as a function of the SIF and provided in lieu of more applicable data, the sustained stress multipliers developed using the method in this Standard may be substituted as more applicable data and used with the nominal stress computed using the section modulus of the matching pipe.

The most applicable currently available stress intensification and flexibility factors compiled from test and analysis data for standard commercially available metallic components are included in Table 1-1 and should be used with the section modulus of the matching pipe (not an "effective" section modulus). Nonmandatory Appendix A provides the standard method to develop stress intensification factors. Nonmandatory Appendix B provides the standard method to develop branch connection flexibility factors. Nonmandatory Appendix C demonstrates how the new branch connection *k*-factors should be used in the elastic analysis of piping systems, and Nonmandatory Appendix D provides a standard method to develop sustained stress factors. A procedure to develop *k*-factors for bends, elbows, and straight pipe is available in WRC Bulletin 463, "Report 1: Standardized Method for Developing Flexibility Factors for Piping Components," E. C. Rodabaugh and E. A. Wais (July 2001).

In its development, this Standard has been reviewed by individuals and appropriate subcommittees of the Boiler and Pressure Vessel Code, B31, and B16 Committees. Comments resulting from the review have been considered and responded to, with revisions made to the Standard, as appropriate. The 2017 edition has been revised in its entirety. It was approved as an American National Standard by the American National Standards Institute on January 11, 2017.

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Code for Pressure Piping

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Secretary, B31 Standards Committee
The American Society of Mechanical Engineers
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New York, NY 10016-5990
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Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Interpretations. Upon request, the B31 Standards Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the B31 Standards Committee.

Requests for interpretation should preferably be submitted through the online Interpretation Submittal Form. The form is accessible at http://go.asme.org/InterpretationRequest. Upon submittal of the form, the Inquirer will receive an automatic e-mail confirming receipt.

If the Inquirer is unable to use the online form, he/she may mail the request to the Secretary of the B31 Standards Committee at the above address. The request for an interpretation should be clear and unambiguous. It is further recommended that the Inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry in one or two words.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. Please provide a condensed and precise question, composed in such a way that a "yes" or "no" reply is acceptable.
Proposed Reply(ies):	Provide a proposed reply(ies) in the form of "Yes" or "No," with explanation as needed. If entering replies to more than one question, please number the questions and replies.
Background Information:	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. The Inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in the format described above may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

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

Attending Committee Meetings. The B31 Standards Committee regularly holds meetings and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of the B31 Standards Committee.

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INTRODUCTION

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

Rules for each Section reflect the kinds of piping installations considered during its development, as follows:

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

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

(c) B31.4, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids: piping that transports products that are predominately liquid between plants and terminals, and within terminals and pumping, regulating, and metering stations

(d) B31.5, Refrigeration Piping: piping for refrigerants and secondary coolants

(e) B31.8, Gas Transportation and Distribution Piping Systems: piping that transports products that are predominately gas between sources and terminals, including compressor, regulating, and metering stations and gas gathering pipelines

(f) B31.9, Building Services Piping: piping typically found in industrial, institutional, commercial, and public buildings and multiunit residences that do not require the range of sizes, pressures, and temperatures covered by B31.1

(g) B31.12, Hydrogen Piping and Pipelines: piping in gaseous and liquid hydrogen service and pipelines for gaseous hydrogen service

Rules for each Standard provide guidance for a specific task found in one or more B31 Section publications, as follows:

(a) B31E, Seismic Design and Retrofit of Above-Ground Piping Systems, establishes a method for the seismic design of above-ground metallic piping systems in the scope of the ASME B31 Code for Pressure Piping.

(b) B31G, Remaining Strength of Corroded Pipelines, provides a simplified procedure to determine the effect of wall loss due to corrosion or corrosion-like defects on the pressure integrity in pipeline systems.

(c) B31H, Standard Method to Establish Maximum Allowable Design Pressure for Piping Components, provides a standardized method to perform a proof (burst) test for piping components and joints (under development).

(d) B31J, Stress Intensification Factors (*i*-Factors), Flexibility Factors (*k*-Factors), and Their Determination for Metallic Piping Components, provides a standardized method to develop the stress intensification factors (*i*-factors), flexibility factors (*k*-factors), and sustained stress factors used in ASME B31 piping analysis.

(e) B31T, Standard Toughness Requirements for Piping, provides requirements for evaluating the suitability of materials used in piping systems for piping that may be subject to brittle failure due to low-temperature service conditions.

This B31J Standard provides stress intensification factors (*i*-factors) and flexibility factors (*k*-factors), with procedures for their determination for metallic piping components and joints. Stress intensification and flexibility factor equations for common piping components are provided in Table 1-1. The sustained load test procedure can be used to determine more applicable nominal stress multipliers for use in sustained and occasional ASME B31 analyses. Hereafter, in this Introduction and throughout the text of this B31 Standard, where the word *Standard* is used without further identification, it means this B31J Standard.

This Standard sets forth stress intensification factors, flexibility factors, and engineering procedures deemed appropriate for the safe determination of the fatigue and sustained load capacity of metallic piping components or joints in typical services. The procedure cannot foresee all geometries and services possible, and the use of competent engineering judgment may be necessary to extend the procedure to cover unusual geometries and service conditions or to ensure a safe testing environment.

The ASME B31 Committee is organized and operates under procedures of The American Society of Mechanical Engineers, which have been accredited by the American National Standards Institute. The Committee is continuing and keeps all Code Sections and Standards current with new developments in methods, materials, construction, and industrial practice. New editions are published or reaffirmed at intervals of 3 years to 5 years.

It is intended that this edition of the B31J Standard not be retroactive. Unless agreement is specifically made between contracting parties to use another edition, or a regulatory body having jurisdiction imposes the use of another edition, the latest edition issued at least 6 months prior to the original contract date for the piping installation activity in which a component or joint qualified by this Standard is to be used shall be the governing document for the determination of SIFs and *k*-factors. Users of this Standard are cautioned against making use of Standard revisions without assurance that they are acceptable to the proper authorities in the jurisdiction where the piping component is to be installed.

Stress Intensification Factors (*i*-Factors), Flexibility Factors (*k*-Factors), and Their Determination for Metallic Piping Components

1 General

The ASME B31 Code for Pressure Piping and the ASME Boiler and Pressure Vessel Code, Section III, Nuclear Components, Subsections NC and ND piping rules require the use of stress intensification factors (SIFs or *i*-factors) and flexibility factors (*k*-factors) when checking the adequacy of components and joints (welded and nonwelded) in piping subject to various loads, including cyclic loads, that may produce fatigue failures. As used herein, where the word *Code* is used without specific identification, it means the Code that incorporates or references this Standard. Experimental methods to determine SIFs, flexibility factors, and sustained load factors are provided in the Nonmandatory Appendices. Compiled stress intensification and flexibility factor equations for common piping components are included in Table 1-1; see also Tables 1-2 and 1-3 and Figures 1-1 through 1-7.

2 Definitions

flexibility factor: for branch connections and reducers, a ratio that defines the rotation of one end of a zero- or negligible-length element with respect to the opposite end of the same element when equal and opposite moments are applied at each end; for bends, a factor based on an effective length of matching pipe that increases the element flexibility to simulate the effect of bend ovalization that applies over the entire arc length of the bend.

i-factor: same as the stress intensification factor.

k-factor: same as the flexibility factor.

pipe stress analyst: individual responsible for the accuracy of *i*-factors, *k*-factors, and sustained load factors used in the analysis of the piping system.

piping components: mechanical elements suitable for joining or assembly into pressure-tight, fluid-containing piping systems. Components include pipe, tubing, fittings, flanges, gaskets, bolting, valves, and devices such as expansion joints, flexible joints, pressure hoses, traps, strainers, in-line portions of instruments, and separators.

stress intensification factor (SIF): a piping component fatigue strength factor that is the ratio of the elastically calculated nominal stress in matching pipe that causes a through-wall crack to appear in a given number of cycles in a straight pipe butt weld to the elastically calculated nominal stress in the matching pipe used with the component that produces a through-wall crack in the same number of cycles in the component or attached pipe.

verified numerical analysis: typically, a finite element analysis of a particular piping system component whose results have been verified against existing test data.

3 Document Contents

(a) Several different types of tests are often conducted on metallic piping components by the manufacturer or user of a piping component to demonstrate Code adequacy. These tests include burst tests, load-deflection tests (*k*-factor tests), SIF tests (*i*-factor tests), and sustained load tests. Multiple tests may be performed on the same specimen. For example, SIF tests can follow multiple *k*-factor tests, and sustained load tests can often follow SIF tests when the specimen has been suitably repaired.

(b) Typical tests conducted as part of a piping component evaluation include, but are not limited to, the following:

(1) burst test

(2) SIF test (in accordance with Nonmandatory Appendix A)

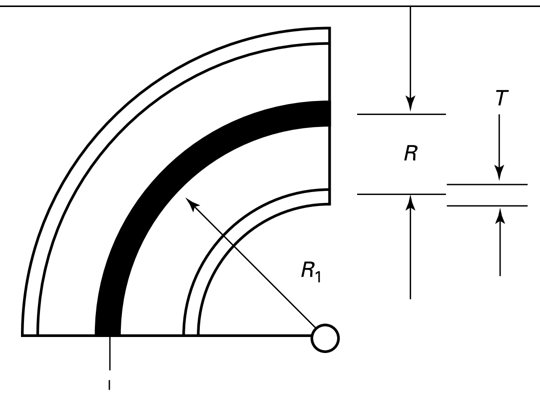
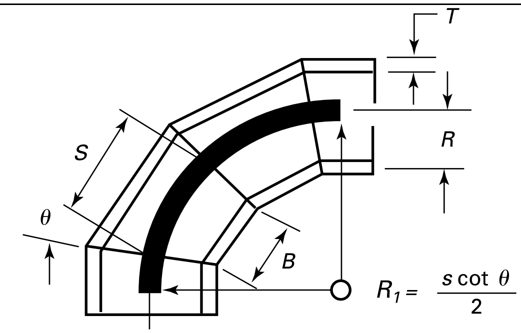
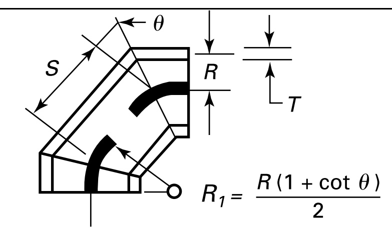
(3) *k*-factor test (in accordance with Nonmandatory Appendix B)

(4) sustained load test (in accordance with Nonmandatory Appendix D)

Procedures for the tests in subparas. (2) through (4) above are described in the Nonmandatory Appendices in this Standard.

(c) Stress intensification and flexibility factors for metallic piping components are included in Table 1-1 and were developed using the test procedures in this Standard and numerical methods.

Table 1-1 Flexibility and Stress Intensification Factors

Term	Equation	Sketch
1.1 Pipe Bend or Welding Elbow Meeting ASME B16.9 [Notes (1), (2), (3), (4)]		
Flexibility characteristic, h	TR_1 / R^2	
Flexibility factor in plane, k_i	$1.65/h$	
Flexibility factor out of plane, k_o	$1.65/h$	
SIF in plane, i_i	$0.9h^{2/3}$	
SIF out of plane, i_o	$0.75h^{2/3}$	
SIF torsional, i_t	1	
1.2 Closely Spaced Miter Bend, $s < R$ (1+ tan θ) [Notes (1), (2), (4)]		
Flexibility characteristic, h	$sT \cot \theta/(2R^2)$	
Flexibility factor in plane, k_i	$1.52/h^{5/6}$	
Flexibility factor out of plane, k_o	$1.52/h^{5/6}$	
SIF in plane, i_i	$0.9/h^{2/3}$	
SIF out of plane, i_o	$0.9/h^{2/3}$	
SIF torsional, i_t	1	
1.3 Widely Spaced Miter Bend, $s \geq R$ (1+ tan θ) [Notes (1), (4), (5)]		
Flexibility characteristic, h	$T (1 + \cot \theta)/(2R)$	
Flexibility factor in plane, k_i	$1.52/h^{5/6}$	
Flexibility factor out of plane, k_o	$1.52/h^{5/6}$	
SIF in plane, i_i	$0.9/h^{2/3}$	
SIF out of plane, i_o	$0.9/h^{2/3}$	
SIF torsional, i_t	1	