ASME B31Ea-2010

Addenda to ASME B31E-2008

Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems

ASME Code for Pressure Piping, B31

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Following approval by the ASME B31 Committee and ASME, and after public review, ASME B31Ea-2010 was approved by the American National Standards Institute on May 13, 2010.

SUMMARY OF CHANGES

This Addenda is published in its entirety for the user's convenience.

Changes given below are identified on the pages by a margin note, **(a)**, placed next to the affected area. The pages not listed are the reverse sides of the listed pages and contain no changes.

Page	*Location*	*Change*
2	3.1	Revised
	3.3.1	(1) Both equations revised (2) In the last paragraph, "238 MPa" revised to read "240 MPa"
3	Table 2	Revised
5	7	(1) First paragraph revised (2) References updated

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CONTENTS

FOREWORD

Seismic design of critical piping systems is often required by Building Codes or by regulation, or it may be voluntarily instituted for loss prevention and worker and public safety.

While seismic loads are mentioned in the various sections of the ASME B31 Pressure Piping Code, and allowable stresses are provided for occasional loads, there has been a need to provide more explicit and structured guidance for seismic design of new piping systems, as well as retrofit of existing systems. In order to respond to this need, this Standard was prepared by the ASME B31 Mechanical Design Technical Committee.

This 2010 Addenda was approved by the American National Standards Institute on May 13, 2010 and designated as ASME B31Ea-2010.

ASME B31 COMMITTEE
Code for Pressure Piping

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

CORRESPONDENCE WITH THE B31 COMMITTEE

General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions, and attending Committee meetings. Correspondence should be addressed to:

Secretary, B31 Standards Committee
The American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990

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 Mechanical Design Technical 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.

The request for 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 inquiry.
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. 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 this format will 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, which are open to the public. Persons wishing to attend any meeting should contact the Secretary of the B31 Standards Committee.

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 Committee B31, Code for Pressure Piping.

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

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

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

(c) B31J, Standard Test Method for Determining Stress Intensification Factors (*i*-Factors) for Metallic Piping Components, provides a standardized method to develop the stress intensification factors used in B31 piping analysis.

This is B31E, Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems. Hereafter, in this Introduction and in the text of this B31 Standard, where the word "Standard" is used without specific identification, it means this B31 Standard. It is expected that this Standard will be incorporated by reference into the appropriate sections of B31.

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STANDARD FOR THE SEISMIC DESIGN AND RETROFIT OF ABOVE-GROUND PIPING SYSTEMS

1 PURPOSE

This Standard establishes a method for the seismic design of above-ground piping systems in the scope of the ASME B31 Code for Pressure Piping.

1.1 Scope

This Standard applies to above-ground, metallic piping systems in the scope of the ASME B31 Code for Pressure Piping (B31.1, B31.3, B31.4, B31.5, B31.8, B31.9, B31.11). The requirements described in this Standard are valid when the piping system complies with the materials, design, fabrication, examination, testing, and inspection requirements of the applicable ASME B31 Code section.

1.2 Terms and Definitions

active components: components that must perform an active function, involving moving parts or controls during or following the earthquake (e.g., valves, valve actuators, pumps, compressors, and fans that must operate during or following the design earthquake).

axial seismic restraint: seismic restraint that acts along the pipe axis.

critical piping: piping system that must remain leak tight or operable (see definitions) during or following the earthquake.

design earthquake: the level of earthquake for which the piping system is to be designed for to perform a seismic function (position retention, leak tightness, or operability).

ductile piping system: in the context of this Standard for seismic qualification, ductile piping system refers to a piping system where the piping, fitting, and components are made of material with a minimum elongation at rupture of 15% at the temperature concurrent with the seismic load.

free-field seismic input: the ground seismic input at the facility location.

in-structure seismic input: the seismic excitation within a building or structure, at the elevation of the piping system attachments to the building or structure.

lateral seismic restraints: seismic restraints that act in a direction perpendicular to the pipe axis.

leak tightness: the ability of a piping system to prevent leakage to the environment during or following the earthquake.

noncritical piping: piping system other than critical piping that nevertheless must meet the requirements for position retention.

operability: the ability of a piping system to deliver, control (throttle), or shut off flow during or after the design earthquake.

position retention: the ability of a piping system not to fall or collapse in case of design earthquake.

seismic design: the activities necessary to demonstrate that a piping system can perform its intended function (position retention, leak tightness, operability, or a combination) in case of design earthquake.

seismic function: a function to be specified by the engineering design either as position retention, leak tightness, or operability.

seismic interactions: spatial or system interactions with other structures, systems, or components that may affect the function of the piping system.

seismic response spectra: a plot or table of accelerations, velocities, or displacements versus frequencies or periods.

seismic restraint: a device intended to limit seismic movement of the piping system.

seismic retrofit: the activities involved in evaluating the seismic adequacy of an existing piping system and identifying the changes or upgrades required for the piping system to perform its seismic function.

seismic static coefficient: acceleration or force statically applied to the piping system to simulate the effect of the earthquake.

1.3 Required Input

(a) The scope and boundaries of piping systems to be seismically designed or retrofitted.

(b) The applicable ASME B31 Code section.

(c) The classification of piping as critical or noncritical, and the corresponding seismic function (position retention for noncritical systems; degree of leak tightness, operability, or both for critical systems).

(d) The free-field seismic input (commonly in the form of accelerations) for the design earthquake.

(e) The responsibility for developing the in-structure seismic response spectra, where required.

(f) The operating conditions concurrent with the seismic load.

(g) The responsibility for qualification of the operability of active components, where required.

(h) The responsibility for the evaluation of seismic interactions.

(i) The responsibility for as-built reconciliation of construction deviations from the design documents.

2 MATERIALS

2.1 Applicability

This Standard applies to metallic ductile piping systems, listed in the applicable ASME B31 Code section.

2.2 Retrofit

The seismic retrofit of existing piping systems shall take into account the condition of the system and its restraints. As part of the seismic retrofit, the piping system shall be inspected to identify defects in the piping or its supports and current and anticipated degradation that could prevent the system from performing its seismic function.

3 DESIGN

(a) 3.1 Seismic Loading

The seismic loading to be applied may be in the form of horizontal and vertical seismic static coefficients, or horizontal and vertical seismic response spectra. The seismic input is to be specified by the engineering design in accordance with the applicable standard (such as ASCE 7) or site-specific seismic loading (para. 1.3).

When the seismic design force is computed based on para. 13.3.1 of ASCE 7, or a similar standard, the parameter a_p shall be 2.5 and the parameter R_p shall not exceed 3.5 when applying the stress limits of para. 3.4. When the alternative design methods of para. 3.5 are used, the derivation of seismic inputs shall be based on parameters compatible with the design method being utilized.

The seismic loading shall be specified for each of three orthogonal directions (typically plant east–west, north–south, and vertical). The seismic design should be based on either a three-directional excitation, east–west plus north–south plus vertical, combined by square-root sum of the squares (SRSS), or a two-directional design approach based on the envelope of the SRSS of the east–west plus vertical and north–south plus vertical seismic loading.

The seismic loading applied to piping systems inside buildings or structures shall account for the in-structure amplification of the free-field accelerations by the structure. The in-structure amplification may be determined based on applicable standards (such as the in-structure seismic coefficient in ASCE 7) or by a facility-specific dynamic evaluation.

The damping for design earthquake response spectrum evaluation of piping system shall be 5% of critical damping.

For the purposes of determining seismic loading, when applicable, the basis for design used in paras. 3.3 and 3.4 is allowable stress design.

3.2 Design Method

The method of seismic design is given in Table 1, and depends on

(a) the classification of the piping system (critical or noncritical)

(b) the magnitude of the seismic input

(c) the pipe size

In all cases, the designer may elect to seismically design the pipe by analysis, in accordance with para. 3.4.

3.3 Design By Rule

3.3.1 Where design by rule is permitted in Table 1, the seismic qualification of piping systems may be established by providing lateral seismic restraints at a maximum spacing given by the following: (a)

(a) For U.S. Customary units

$$L_{max} = \text{the smaller of } 1.94 \times \frac{L_T}{a^{0.25}} \text{ and } 0.0123 \times L_T \times \sqrt{\frac{S_y}{a}}$$

a = peak spectral acceleration, largest in any of the three directions, including in-structure amplification, g

L_{max} = maximum permitted pipe span between lateral seismic restraints, ft

L_T = reference span, the recommended span between weight supports, from ASME B31.1, Table 121.5 (reproduced in Table 2), ft

S_Y = material yield stress at operating temperature, psi

(b) For SI units

$$L_{max} = \text{the smaller of } 1.94 \times \frac{L_T}{a^{0.25}} \text{ and } 0.148 \times L_T \times \sqrt{\frac{S_y}{a}}$$

a = peak spectral acceleration, largest in any of the three directions, including in-structure amplification, g

L_{max} = maximum permitted pipe span between lateral seismic restraints, m

L_T = reference span, the recommended span between weight supports, from ASME B31.1, Table 121.5 (reproduced in Table 2), m

Table 1 Seismic Design Requirements, Applicable Sections

Acceleration	Noncritical Piping: NPS (DN) ≤ 4 (100)	Noncritical Piping: NPS (DN) > 4 (100)	Critical Piping: NPS (DN) ≤ 4 (100)	Critical Piping: NPS (DN) > 4 (100)
$a \leq 0.3\ g$	NR section 4 (interactions)	NR section 4 (interactions)	DR para. 3.3 (rule) para. 3.6 (mech. joints) para. 3.7 (restraints) section 4 (interactions)	DA para. 3.4/3.5 (analysis) para. 3.6 (mech. joints) para. 3.7 (restraints) para. 3.8 (components) section 4 (interactions)
$a > 0.3\ g$	NR section 4 (interactions)	DR para. 3.3 (rule) para. 3.6 (mech. joints) para. 3.7 (restraints) section 4 (interactions)	DA para. 3.4/3.5 (analysis) para. 3.6 (mech. joints) para. 3.7 (restraints) para. 3.8 (components) section 4 (interactions)	DA para. 3.4/3.5 (analysis) para. 3.6 (mech. joints) para. 3.7 (restraints) para. 3.8 (components) section 4 (interactions)

a = peak spectral acceleration, largest in any of the three directions, including in-structure amplification, g
DA = design by analysis
DR = design by rule
NPS = nominal pipe size, in.
NR = explicit seismic analysis is not required, provided the piping system complies with the provisions of the applicable ASME B31 Code section, including design for loading other than seismic

Table 2 Maximum Span, ft (m), Between Lateral Seismic Restraints for Steel Pipe With a Specified Minimum Yield Stress of 35 ksi (240 MPa), in Water Service at 70°F (21°C) (a)

NPS (DN)	Maximum Span, ft (m): L_T, ft (m)	0.1 g	0.3 g	1.0 g	2.0 g	3.0 g
1 (25)	7 (2.1)	24 (7.4)	18 (5.6)	14 (4.1)	11 (3.5)	9 (2.8)
2 (50)	10 (3.0)	34 (10.5)	26 (8.0)	19 (5.9)	16 (5.0)	13 (4.0)
3 (80)	12 (3.7)	41 (12.6)	31 (9.6)	23 (7.1)	20 (6.0)	16 (4.9)
4 (100)	14 (4.3)	48 (14.7)	37 (11.2)	27 (8.3)	23 (6.9)	19 (5.7)
6 (150)	17 (5.2)	59 (17.9)	45 (13.6)	33 (10.1)	28 (8.4)	23 (6.9)
8 (200)	19 (5.8)	66 (20.0)	50 (15.2)	37 (11.2)	31 (9.4)	25 (7.7)
12 (300)	23 (7.0)	79 (24.2)	60 (18.4)	45 (13.6)	37 (11.4)	31 (9.3)
16 (400)	27 (8.2)	93 (28.9)	71 (21.6)	52 (16.0)	44 (13.4)	36 (10.9)
20 (500)	30 (9.1)	103 (31.5)	79 (24.0)	58 (17.7)	49 (14.9)	40 (12.1)
24 (600)	32 (9.8)	110 (33.6)	84 (25.6)	62 (18.9)	52 (15.9)	43 (13.0)

S_Y = material yield stress at operating temperature, MPa

The maximum span L_{max} between lateral seismic restraints for steel pipe with a yield stress $S_Y = 35$ ksi (240 MPa), in water service, for several values of lateral seismic acceleration a, is provided in Table 2. Longer spans can be developed for gas and vapor service.

3.3.2 The maximum permitted span length L_{max} should be reduced by a factor of 1.7 for threaded, brazed, and soldered pipe.

3.3.3 Straight pipe runs longer than three times the span of Table 2 should be restrained longitudinally.

3.3.4 The piping system should be evaluated to be sufficiently flexible to accommodate the differential movement of attachment points to the structure or the movement of equipment or headers to which the piping is attached. This evaluation may be achieved by calculating the predicted seismic plus concurrent loads movement of the structure, equipment, or header to which the pipe is connected, and verifying that the pipe spans have sufficient flexibility to sustain these movements.

3.3.5 The distance between seismic restraints should be reduced for pipe spans that contain heavy in-line components.

3.3.6 Unrestrained cantilevered pipe shall be evaluated on a case-by-case basis.

3.3.7 The effect of seismic restraints on the expansion and contraction flexibility of the piping system shall be verified in accordance with the design rules of the applicable ASME B31 Code section.

3.3.8 The designer shall identify degradation in the piping or its supports and current and anticipated degradation that could prevent the system from performing its seismic function.

3.4 Design by Analysis

Where design by analysis is required in Table 1, or where it is applied by the designer as an alternative to the rules of para. 3.3, the elastically calculated longitudinal stresses due to the design earthquake (calculated by static or dynamic analysis) shall comply with the following equations:

$$\frac{PD}{4t} + 0.75i\,\frac{M_{\text{sustained}} + M_{\text{seismic}}}{Z} \le \min\,[2.4S;\ 1.5S_Y;\ 60\ \text{ksi}\ (408\ \text{MPa})]$$

$$\frac{F_{SAM}}{A} \le S_Y$$

A = pipe cross-sectional area, deducting corrosion/erosion allowance but not mill tolerance

D = outside pipe diameter

F_{SAM} = resultant force (tension plus shear) due to seismic anchor motion

i = stress intensification factor, from the applicable ASME B31 Code section, $0.75i$ cannot be less than 1

M_{seismic} = elastically calculated resultant moment amplitude due to seismic load, including inertia and relative anchor motion

$M_{\text{sustained}}$ = elastically calculated resultant moment amplitude due to sustained loads concurrent with the seismic load

P = system operating pressure

S = ASME B31 allowable stress, at the normal operating temperature; for ASME B31.4, use 0.80 S_Y, for ASME B31.8, use FTS_Y where F = location factor, T = temperature derating factor, as defined in B31.8

S_Y = specified minimum yield stress of the material (SMYS) at the normal operating temperature

t = pipe wall thickness, deducting corrosion allowance but not mill tolerance

Z = pipe section modulus, deducting corrosion/erosion allowance but not mill tolerance, in.^{3}

3.5 Alternative Design Methods

The piping system may be qualified by more detailed analysis techniques, including fatigue, plastic, or limit load analysis.

3.6 Mechanical Joints

For critical piping systems, the movements (rotations, displacements) and loads (forces, moments) at mechanical joints (nonwelded, nonbrazed, and nonsoldered joints) shall remain within the failure limits (for position retention) or leak tightness limits (for leak tightness and operability) specified by the owner.

3.7 Seismic Restraints

3.7.1 The seismic load on seismic restraints and their attachment to building structures or anchorage to concrete, shall be calculated by static or dynamic analysis, and added to concurrent operating loads.

3.7.2 The seismic adequacy of seismic restraints shall be determined on the basis of vendor catalogs, and the applicable design method and standard, such as MSS SP-58 or MSS SP-69 for standard support components, AISC or AISI for steel members, and ACI for concrete anchor bolts. The qualification of seismic restraints shall also address the prevention of buckling.

3.7.3 The seismic adequacy of nonseismic restraints shall also be verified if they are expected to perform a function after the earthquake. For example, spring hangers should not be permitted to pull off the wall if they are necessary to support the pipe weight after the earthquake.

3.7.4 For lateral seismic restraints, a total diametric gap equal to ½ in. (12 mm) is acceptable. A gap up to $0.1D$ or 2 in. (50 mm), whichever is smaller, is permitted, provided the seismic load, calculated on the basis of zero gap, is multiplied by an impact factor of 2. Larger gaps or smaller impact factors may be justified by analysis or test.

3.7.5 Short rod hangers [typically less than 12 in. (300 mm) long] may provide a restoring force that tends to limit side-sway of hung pipe, and may be considered as seismic restraints, provided they are designed to sustain the seismic loads and movements.

3.8 Equipment and Components

The seismic and concurrent loads applied by the pipe at equipment and component nozzles shall be qualified as part of the seismic design or retrofit of the piping system, to a degree commensurate with the required system function, as specified in para. 1.3.

For position retention, it is usually sufficient to show that the piping loads on equipment and components will not cause rupture. For leak tightness, the stress shall be maintained within yield or shown not to cause fatigue ruptures. For operability, the piping loads shall be kept within operability limits established by detailed analysis, testing, or similarity to seismically qualified equipment or components.

Components with unsupported extended structures, such as valves with heavy motor operators, shall be evaluated to insure that the extended structure does not fail during a seismic event. For components with unsupported extended structures, a natural frequency check shall be performed and shall be greater than 33 cps. When the natural frequency is less than 33 Hz, the component extended structure shall be stiffened as recommended by the component manufacturer.

4 INTERACTIONS

Piping systems shall be evaluated for seismic interactions. Credible and significant interactions shall be identified and resolved by analysis, testing, or hardware modification.

5 DOCUMENTATION

The engineering design shall specify the documentation to be submitted by the designer.

6 MAINTENANCE

The piping system shall be maintained in a condition that meets the seismic design requirements for the operating life of the system. In particular, changes to layout, supports, components, or function, as well as material degradation in service shall be evaluated to verify the continued seismic adequacy of the system.

(a) 7 REFERENCES

The following is a list of publications referenced in this Standard. The latest edition shall apply, unless otherwise noted.

ACI 318 Building Code Requirements for Reinforced Concrete

Publisher: American Concrete Institute (ACI), 38800 Country Club Drive, Farmington Hills, MI 48331 (www.aci-int.org)

AISC, Manual of Steel Construction

Publisher: American Institute of Steel Construction (AISC), One East Wacker Drive, Chicago, IL 60601-1802 (www.aisc.org)

AISI, Specification for the Design of Cold-Formed Steel Structural Members

Publisher: American Iron and Steel Institute (AISI), 2000 Town Center, Southfield, MI 48075 (www.steel.org)

ASCE 7-05, Minimum Design Loads for Buildings and Other Structures

Publisher: American Society of Civil Engineers (ASCE), 1801 Alexander Bell Drive, Reston, VA 20191 (www.asce.org)

ASME B31.1, Power Piping

ASME B31.3, Process Piping

ASME B31.4, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids

ASME B31.5, Refrigerant Piping and Heat Transfer Components

ASME B31.8, Gas Transmission and Distribution Piping Systems

ASME B31.9, Building Services Piping

ASME B31.11, Slurry Transportation Piping Systems

Publisher: The American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY 10016; Order Department: 22 Law Drive, P.O. Box 2900, Fairfield, NJ 07007-2900 (www.asme.org)

ICBO AC156, Acceptance Criteria for the Seismic Qualification Testing of Nonstructural Components

Publisher: International Conference of Building Officials (ICBO), ICC Evaluation Service, 5360 Workman Mill Road, Whittier, CA 90601

MSS SP-58, Pipe Hangers and Supports—Materials, Design, and Manufacture

MSS SP-69, Pipe Hangers and Supports—Selection and Application

Publisher: Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. (MSS), 127 Park Street NE, Vienna, VA 22180 (www.mss-hq.com)

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