ASME STS-1–2026
(Revision of ASME STS-1–2021)

Steel Stacks

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

ASME STS-1–2026
(Revision of ASME STS-1–2021)

Steel Stacks

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers
Two Park Avenue • New York, NY • 10016 USA

Date of Issuance: August 28, 2026

The next edition of this Standard is scheduled for publication in 2031.

This code or standard was developed under procedures accredited as meeting the criteria for American National Standards. The standards committee that approved the code or standard was balanced to ensure that individuals from competent and concerned interests had an opportunity to participate. The proposed code or standard was made available for public review and comment, which provided an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

ASME does not “approve,” “certify,” “rate,” or “endorse” any item, construction, proprietary device, or activity. ASME does not take any position with respect to the validity of any patent rights asserted in connection with any items mentioned in this document, and does not undertake to insure anyone utilizing a standard against liability for infringement of any applicable letters patent, nor does ASME assume any such liability. Users of a code or standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Participation by federal agency representatives or persons affiliated with industry is not to be interpreted as government or industry endorsement of this code or standard.

ASME accepts responsibility for only those interpretations of this document issued in accordance with the established ASME procedures and policies, which precludes the issuance of interpretations by individuals.

The endnotes and preamble in this document (if any) are part of this American National Standard.



ASME Collective Membership Mark

All rights reserved. “ASME” and the above ASME symbol are registered trademarks of The American Society of Mechanical Engineers. No part of this document may be copied, modified, distributed, published, displayed, or otherwise reproduced in any form or by any means, electronic, digital, or mechanical, now known or hereafter invented, without the express written permission of ASME. No works derived from this document or any content therein may be created without the express written permission of ASME. Using this document or any content therein to train, create, or improve any artificial intelligence and/or machine learning platform, system, application, model, or algorithm is strictly prohibited.

The American Society of Mechanical Engineers
Two Park Avenue, New York, NY 10016-5990

Copyright © 2026 by
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTENTS

Foreword vi
Committee Roster vii
Correspondence With the STS Committee viii
Introduction x
Summary of Changes xi

1 Mechanical Design 1
2 Materials 4
3 Linings and Coatings 7
4 Structural Design 13
5 Dynamic Wind Loads 23
6 Access and Safety 26
7 Electrical 35
8 Fabrication and Erection 36
9 Inspection and Maintenance 38
10 References 39

Mandatory Appendix
I Structural Design — Gust Effect Factor Calculation 43

Nonmandatory Appendices
A Mechanical Design 48
B Materials for Ambient and Elevated Temperature Service 62
C Linings and Coatings 79
D Structural Design 84
E Example Calculations 87
F Conversion Factors: U.S. Customary to SI (Metric) 96

Figures
6.2.6-1 Example of the General Construction of Cages 27
6.2.6-2 Minimum Ladder Clearances 29
6.3.6-1 Ladder Dimensions, Support Spacing, and Side Clearances 30
6.3.7-1 Length of Climb 31
6.3.9-1 Landing Platform Dimensions 33
I-1 Topographic Factor, K_{zt} 44
A-1 Friction Factor, f, as Related to Reynolds Number and Stack Diameter 48
A-2 External Heat Transfer Coefficient for Forced and Natural Convection 49
A-3 Effect of a Change in the Ambient Air-Free Stream Temperature on the External Heat Transfer Coefficient for Forced Convection 50

A-4 Heat Transfer Coefficient for the Air Gap Between Two Walls of a Double-Walled Metal Chimney (Mean Temperature 200°F Through 400°F) . . . 51
A-5 Heat Transfer Coefficient for the Air Gap Between Two Walls of a Double-Walled Metal Chimney (Mean Temperature 500°F and 600°F) . . . 52
A-6 Internal Heat Transfer Coefficient vs. Velocity at Film Temperature: 200°F . . . 53
A-7 Internal Heat Transfer Coefficient vs. Velocity at Film Temperature: 300°F . . . 54
A-8 Internal Heat Transfer Coefficient vs. Velocity at Film Temperature: 500°F . . . 55
A-9 Internal Heat Transfer Coefficient vs. Velocity at Film Temperature: 1,000°F . . . 56
A-10 Flue Size . . . 57
A-11 Natural Draft . . . 58
A-12 Friction Loss . . . 59
A-13 Exit Loss and Entrance . . . 60
C-1 Dewpoint Versus Sulfur Trioxide Concentration . . . 80
C-2 Sulfuric Acid Saturation Curve . . . 81

Tables

4.4.6-1 Minimum Fabricated Plate Thickness . . . 18
4.11.1.3-1 Cable Selection Criteria . . . 20
5.2.1.2-1 Representative Structural Damping Values, β_s . . . 24
I-1 Terrain Exposure Constants . . . 43
I-2 Risk Category of Buildings and Other Structures for Flood, Wind, Snow, and Earthquake Loads . . . 45
I-3 Velocity Pressure Exposure Coefficients, K_z . . . 46
I-4 Force Coefficients, C_f . . . 47
A-1 *K* Factors for Breeching Entrance Angle . . . 61
B-1 ASTM A36 Carbon Steel . . . 62
B-2 ASTM A387 Grade 11 Alloy Steel . . . 63
B-3 ASTM A387 Grade 12 Alloy Steel . . . 65
B-4 ASTM A242 Type 1, A606 Type 4 (Corten A) . . . 66
B-5 ASTM A588 Grade A, A709 (Corten B) . . . 67
B-6 ASTM A240 Stainless Steel Type 410 . . . 68
B-7 ASTM A240 Stainless Steel Type 304 . . . 69
B-8 ASTM A240 Stainless Steel Type 316 . . . 70
B-9 ASTM A240 Stainless Steel Type 304L . . . 71
B-10 ASTM A240 Stainless Steel Type 316L . . . 72
B-11 ASTM A240 Stainless Steel Type 317 . . . 73
B-12 ASTM A516 Grade 70 . . . 74
B-13 ASTM A240 Stainless Steel Type 309 . . . 75
B-14 ASTM A240 Stainless Steel Type 310 . . . 76
B-15 Other Stainless Steels, Nickel Alloys, and Titanium Used for Stacks and Chimney Liners 77
B-16 Thermal Coefficients of Expansion . . . 77
B-17 Maximum Nonscaling Temperature . . . 78
C-1 Suggested Suitability of Linings for Steel Stacks to Withstand Chemical and Temperature Environments of Flue Gases . . . 82
C-2 Suggested Stack Coating Characteristics and Classifications . . . 83
D-1 Allowable Creep Stress of Carbon Steel at Elevated Temperature . . . 85

D-2	Creep and Rupture Properties of Type 410 Stainless Steel	86
D-3	Creep and Rupture Properties of Type 304 Stainless Steel	86
D-4	Creep and Rupture Properties of Type 316 Stainless Steel	86
D-5	Creep and Rupture Properties of Type 317 Stainless Steel	86
E-1.1-1	Example 1: Velocity Pressure, q_z, Calculations	88
E-1.2-1	Example 2: Gust Effect Factor, G_f, Calculations	89
E-1.3-1	Example 3: Stack 1 Along Wind Loading	90
E-1.4-1	Example 4: Vertical Distribution of Horizontal Seismic Forces (Unfactored)	91
E-4-1	Mode Shape by Element	94
E-4-2	Equivalent Fatique and Static Loads by Element	94
F-1	Length	96
F-2	Area	96
F-3	Volume (Capacity)	96
F-4	Kinematic Viscosity (Thermal Diffusivity)	96
F-5	Force	96
F-6	Force/Length	96
F-7	Pressure or Stress (Force per Area)	96
F-8	Bending Moment (Torque)	97
F-9	Mass	97
F-10	Mass per Area	97
F-11	Mass per Volume	97
F-12	Temperatures	97
F-13	Heat	97
F-14	Velocity	97
F-15	Acceleration	97

FOREWORD

In early 1978, the American Society of Mechanical Engineers was approached by a group interested in formulating a standard for the design, fabrication, and erection of steel stacks and their appurtenances. They felt there was a need for such a Standard to establish a better level of standardization in the industry and for safeguarding the community. Because of the particular nature of stacks and their susceptibility to failures due to wind and seismic-induced vibrations, along with corrosion and erosion, the design process is a complex one. Additionally, recent regulations by the Environmental Protection Agency concerning emissions have placed a strong emphasis on the mechanical design of stacks. In the last several decades, much research has been done and many papers written on the subject. While investigation and research continued, it was the feeling of these persons that some formal guidelines needed to be established. Therefore, in April of 1979, a group composed of stack users, researchers, designers, fabricators, and erectors convened at the United Engineering Center in New York City under the auspices of the American Society of Mechanical Engineers to formulate such a code.

With the above in mind, the group subdivided and began gathering information to formulate guidelines for mechanical design, material selection, the use of linings and coatings, structural design, vibration considerations, access and safety, electrical requirements, and fabrication and construction. When these were established, a section on maintenance and inspection was added. The following is a result of their work and investigation. The initial document was approved as an American National Standard in August 1986 and published as ASME/ANSI STS-1-1986 in May 1988.

During the next 3 yr, the committee received comments from the public at large and from its own membership regarding the Standard's content. Several formulas needed correction, and some of the symbols needed clarification. Section 6.3.3 regarding Earthquake Response was also reviewed and revised to allow for static rather than dynamic analysis in certain cases and to correlate it with ASCE STD-7-88 (formerly ANSI A58-1). These changes were then submitted to the general membership and approved.

In 1994, the committee was reorganized to further review and update this steel stack Standard. Emphasis was given to the Structural Design and Vibrations chapters. Chapter 4, "Structural Design," was rewritten to be more compatible with the nomenclature, formulae, and symbols used in the Manual of Steel Construction — Allowable Stress Design (ASD), 9th Edition and Load and Resistance Factor Design (LRFD), 1st Edition. Chapter 5, "Vibrations," was revised to be more "user friendly." These and other chapters were updated to include the latest recognized applicable codes and standards.

The 2006 edition included changes and improvements to the Environmental Protection Agency regulation concerning emissions that have created a strong emphasis on the mechanical design of steel stacks, made necessary changes found through practical experience with the previous edition, expanded formulas as necessary, and provided both revised and new sections for steel stack design, fabrication, and erection. It revised sections on appurtenances to meet today's requirements for these items. A new section provided the fundamental concepts for guyed stacks. Revisions to the section on the physical properties of steel at elevated temperatures were made to match information available through a comprehensive review of current technical literature. Sections on vibration included minor changes but yielded a more workable standard. Also, a detailed example was included to provide a method for determining the magnitude of across wind loads. One method was included to address fatigue due to vibration. Fatigue can be a significant issue in steel stack design and needs to be considered in the design. Methods to determine across wind load and seismic loads were provided in the nonmandatory appendices. If fatigue requires close examination, the engineer is cautioned to review this issue with other design standards if necessary. There are several standards among them that can be helpful: AISC, CICIND, or ASME.

This Standard is available for public review on a continuing basis. Public review provides an opportunity for additional input from industry, academia, regulatory agencies, and the public-at-large.

ASME STS-1–2011 was approved as an American National Standard on March 11, 2011. ASME STS-1–2016 was approved as an American National Standard on September 23, 2016. ASME STS-1–2021 was approved by ANSI as an American National Standard on October 19, 2021. ASME STS-1–2026 was approved by ANSI as an American National Standard on March 30, 2026.

ASME STS COMMITTEE
Steel Stacks

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

STANDARDS COMMITTEE OFFICERS

R. S. Slay, *Chair*
M. Lathrop, *Vice Chair*
A. Dinizulu, *Staff Secretary*
L. Stanford, *Staff Secretary*

STANDARDS COMMITTEE PERSONNEL

S. Allen, J. T. Thorpe and Son, Inc.
A. Dinizulu, The American Society of Mechanical Engineers
J. Dorgan, Durr Universal, Inc.
H. K. Goel, Global Dominion Access, USA
M. Lathrop, Zeeco, Inc.
J. Maddock, Gerard Chimney Co.
D. C. Mattes, Hoffmann, Inc.
A. C. Olson, VAA, LLC
C. B. Reid, Industrial Environmental Systems, Inc.
W. Rosencutter, Meca Enterprises, Inc.
R. K. Simonetti, Consultant
R. S. Slay, Warren Environment, Inc.
L. Stanford, The American Society of Mechanical Engineers
N. Zarrabi, Associated Engineering Resources, Inc.
R. Lee, *Alternate,* Hoffmann, Inc.
I. Prunier, *Alternate,* Warren Environment, Inc.
J. Reid *Alternate,* Fox Equipment
E. Smith, *Alternate,* Meca Enterprises, Inc.

CORRESPONDENCE WITH THE STS COMMITTEE

General. ASME codes and standards are developed and maintained by committees with the intent to represent the consensus of concerned interests. Users of ASME codes and standards may correspond with the committees to propose revisions or cases, report errata, or request interpretations. Correspondence for this Standard should be sent to the staff secretary noted on the committee's web page, accessible at https://go.asme.org/STScommittee.

Revisions and Errata. The committee processes revisions to this Standard on a continuous basis 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 in the next edition of the Standard.

In addition, the committee may post errata on the committee web page. Errata become effective on the date posted. Users can register on the committee web page to receive email notifications of posted errata.

This Standard is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number, the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Standard

(4) to permit the use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Standard.

(c) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Standard and the paragraph, figure, or table number

(4) the editions of the Standard to which the proposed case applies

(d) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Approved cases are posted on the committee web page.

Interpretations. Upon request, the committee will issue an interpretation of any requirement of this Standard. An interpretation can be issued only in response to a request submitted through the online Inquiry Submittal Form at https://go.asme.org/InterpretationRequest. Upon submitting the form, the inquirer will receive an automatic email confirming receipt.

ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers can track the status of their requests at https://go.asme.org/Interpretations.

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.

Interpretations are published in the ASME Interpretations Database at https://go.asme.org/Interpretations as they are issued.

Committee Meetings. The STS Standards Committee regularly holds meetings that are open to the public. Persons wishing to attend any meeting should contact the secretary of the committee. Information on future committee meetings can be found on the committee web page at https://go.asme.org/STScommittee.

INTRODUCTION

The following Standard applies to steel stacks; i.e., those stacks where the primary supporting shell is made of steel. It applies to both single- and multiple-walled steel stacks, either of which can be lined or unlined. It also applies to steel stacks that are guyed or to certain aspects of tower stacks. The stack may be supported on a foundation or from another structure.

This Standard covers many facets of the design of steel stacks. It outlines the consideration that must be made for both the mechanical and structural design. It emphasizes what consideration must be taken for wind- and seismic-induced vibrations. It gives guidelines for the selection of material, linings, and coatings. It gives the requirements for lighting and lightning protection based upon existing building and federal codes. It gives the requirements for climbing and access based upon current Occupational Safety and Health Administration (OSHA) standards. It emphasizes the important areas regarding fabrication and construction. It outlines areas requiring maintenance and inspection following initial operation.

Although many of the topics within these guidelines may be used for all stacks, this Standard is intended to provide design guidelines for stacks containing nonflammable gases, such as combustion exhaust gases at low internal pressures. For stacks containing combustible gases under pressure, such as flare stacks and flammable vents, additional design considerations must be addressed, including design for internal pressure, design for internal deflagration pressure, and compatibility with adjoining piping design that is in accordance with piping and/or vessel design codes, such as ASME B31.3 and Section VIII of the ASME Boiler and Pressure Vessel Code (BPVC). In addition, the materials of construction referenced in this Standard may not be allowed for use with flammable gases under pressure per ASME B31.3 and Section VIII of the ASME BPVC; materials suitable for pressure containment of flammable gases are listed in these codes. No attempt is made within this Standard to define the need or the methods to be used to consider these additional design considerations.

The information presented has been prepared in accordance with established engineering principles utilizing state-of-the-art information. It is intended for general information. While every effort has been made to ensure its accuracy, the information should not be relied upon for any specific application without the consultation of a competent, licensed professional engineer to determine its suitability. It is therefore recommended that Engineering/Design drawings of the stack bear the Professional Engineer Seal, signature, and date.

Nothing in the Standard shall be construed to alter or subvert the requirements of any existing code or authority having jurisdiction over the facility. Furthermore, alternate methods and materials to those herein indicated may be used, provided that the engineer can demonstrate their suitability to all affected agencies and authorities.

ASME STS-1–2026
SUMMARY OF CHANGES

Following approval by the ASME STS Standards Committee and ASME, and after public review, ASME STS-1–2026 was approved by the American National Standards Institute on March 30, 2026.

ASME STS-1–2026 includes the following changes identified by a margin note, **(26)**.

Page	*Location*	*Change*
5	2.2.2	First paragraph, (a)(5), and (b)(e) revised
5	2.2.5	Revised
13	4.3.3.1	Last paragraph revised
14	4.3.4	Revised in its entirety
16	4.3.5	Former 4.3.5 deleted and subsequent paragraphs redesignated
18	4.4.6	Title and text revised
18	Table 4.4.6-1	Title and table revised
22	4.14	Revised in its entirety
25	5.4	Definition of β revised
35	7.2.2	Added
35	7.3.1	Revised
35	7.3.2	Revised
39	10	Updated
43	Mandatory Appendix I	After equation for Q, nomenclature revised
46	Table I-3	General Note (b) revised
84	Nonmandatory Appendix D	Figures D-1 and D-2 deleted; Tables D-1 and D-2 deleted, and subsequent tables redesignated
87	E-1.2	Dimensions B and h added
88	E-1.4	(1) Revised in its entirety (2) E-1.5 and Table E-1.5-1 deleted
91	Table E-1.4-1	Added
93	E-4	Revised
94	Table E-4-1	Note (1) added
94	Table E-4-2	Last two columns revised

INTENTIONALLY LEFT BLANK

STEEL STACKS

1 MECHANICAL DESIGN

1.1 Scope

Mechanical design includes sizing of the gas passage, both in diameter and height, and the drop in gas temperature as heat is transferred through the stack wall. Methods for calculating draft, draft losses, and heat losses are given. Differential expansion of stack components is discussed. Design considerations for stack appurtenances are established.

1.2 General

The purpose of a stack is to vent process exhaust gases to the atmosphere. The mechanical design of stacks is now controlled in part by air pollution rules and regulations. Heights and diameters are set by a balance between structural stability and function, while at the same time meeting the requirements for air pollution control dispersion of the gases to the atmosphere. The heights of steel stacks have increased to satisfy ambient air quality, and stack inlet gas temperatures have decreased as more heat energy is recovered. The importance of attention to stack heat losses has therefore increased. Stack minimum metal temperature should be held above the acid dew point of the vented gases, if possible. Stacks are being designed with many appurtenances to monitor the gases and make stack inspections.

1.3 Size Selection (Height, Diameter, and Shape)

1.3.1 Height. Stack height may be set by one or more factors.

(a) Environmental Protection Agency (EPA) regulations may set the required stack height for downwash due to local terrain or adjacent structures or to disperse pollutants at a minimum height above the site. Refer proposed stack location and purposes to the proper EPA authorities for the minimum height requirement under controlling air pollution control regulations. See Federal Register part II, EPA 40 CFR, Part 51, Stack Height Regulation (July 8, 1985).

(b) The National Fire Protection Association (NFPA) sets minimum height of high-temperature stacks above building roofs and structures for fire protection and human safety. Local codes are often more stringent and must be followed. A minimum of 8 ft of height above a roof surface or roof-mounted structure within 25 ft of a stack emitting gases above 200°F (93°C) should be maintained.

(c) The draft requirement of the process to be vented may establish stack height. Equations to calculate available draft are presented in subsequent paragraphs.

(d) The effective height of a stack considering plume rise may be increased by installing a nozzle or truncated cone at the top to increase the exit velocity of the gases. Several plume rise equations are available, but in actual practice, plume rise can be essentially negated by high wind velocities, low temperatures, and site conditions.

1.3.2 Diameters. The stack diameter may be set by one or more factors.

(a) Gas passage diameter is usually established by the volume of process gas flowing and available draft (natural draft minus draft losses). Velocities in a round stack between 2,400 ft/min and 3,600 ft/min are most common. Stacks venting saturated gases sometimes limit maximum stack velocities between 1,800 ft/min and 2,400 ft/min to reduce entrained or condensed moisture from leaving the stack exit. Tests by Electric Power Research Institute (EPRI) give different ranges for each type of inner surface (see EPRI Wet Stack Design Guide TR-107099-1996).

(b) Stack shell diameters may be controlled by transportation shipping limitations. Caution should be taken to ensure that mechanical performance and structural stability are maintained.

(c) Structural stability may control a stack shell diameter selection, and therefore, any size selection based on mechanical criteria must be maintained as tentative until a structural analysis can confirm its acceptability.

(d) Future increases in stack gas volume should be considered as well as future changes in process gas temperatures and gas quality in the diameter selection.

(e) EPA regulations may set stack exit diameter because of plume rise considerations. EPA requirements have sometimes set stack diameters in the test zone to provide optimum velocities for testing.

1.3.3 Shape. The shape of the stack varies with designers' preferences.

(a) Stacks generally are cylindrical in shape for efficiency in structural stability and economy in fabrication. Cylindrical shapes may vary in diameter throughout the height of the stack; however, diameter changes shall occur at an angle not exceeding 30 deg from the vertical.