ASME STS-1–2016
(Revision of ASME STS-1–2011)

Steel Stacks

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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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.

The last standard was approved as an American National Standard on March 11, 2011 and issued as STS-1–2011. ASME STS-1–2016 was approved as an American National Standard on September 23, 2016.

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Steel Stacks

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Secretary, STS Standards Committee
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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.

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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.

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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.

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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.

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 40CFR, 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. Formulas 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 formulas 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 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.

(b) Other geometrical shapes, such as octagonal, triangular, etc., must be considered special and particular attention given to dynamic stability as well as mechanical design. Unusual shapes for aesthetic appearance should be treated both structurally and mechanically as

unusual and basic engineering design standards should be followed.

1.4 Available Draft

The available draft without fan assistance equals the natural draft minus draft losses.

1.4.1 Natural Draft. The approximate natural draft of a stack is calculated from the following equation:

$$DR_N = 7.57\, H_E \left(\frac{1}{T_A} - \frac{1}{T_G}\right) \frac{B}{30} \tag{1-1}$$

where

B = barometric pressure; mercury absolute, in.
DR_N = stack natural draft; water gage, in.
H_E = stack height above centerline inlet, ft
T_A = absolute temperature of atmosphere, °R
T_G = average absolute temperature of gas, °R

Differences in gas absolute density due to composition and moisture have been neglected.

1.4.2 Draft Losses. Stack draft losses are entrance, friction, and exit losses. Draft losses are calculated from the following formula:

(a) Entrance loss

$$FL_{en} = 0.003\, KdV^2 \tag{1-2}$$

(b) Friction loss

$$FL_f = \left(\frac{2.76}{B}\right)(F)\,(T_g)\left(\frac{H_E}{Di^5}\right)\left(\frac{W}{10^5}\right)^2 \tag{1-3}$$

(c) Exit loss

$$FL_{ex} = \left(\frac{2.76}{B}\right)\left(\frac{T_g}{D_t^4}\right)\left(\frac{W}{10^5}\right)^2 \tag{1-4}$$

where

B = barometric pressure; mercury absolute, in.
d = gas density, lb/ft^3
D_i = inside diameter(s) of stack section, ft
D_t = inside diameter of stack at outlet, ft
F = friction factor based on Reynolds number (see Fig. A-1 in Nonmandatory Appendix A)
FL_{en} = stack entrance loss; water gage, in.
FL_{ex} = stack exit loss; water gage, in.
FL_f = stack friction loss; water gage, in.
H_E = stack height above centerline of inlet, ft
K = breeching inlet angle factor (see Nonmandatory Appendix A, Table A-1)
T_g = average absolute temperature of gas, °R
V = gas velocity at inlet, ft/sec
W = mass flow rate of gas, lb/hr

The total of the calculated losses comprises the total stack draft loss.

(d) Total loss

$$FL_{\text{total}} = FL_{en} + FL_f + FL_{ex} \text{ water gage, in.} \tag{1-5}$$

Consideration should be given to the possible gas expansion or compression draft loss in large or unusually shaped entrances. Consideration should also be given to stack draft losses caused by stack-mounted sound attenuators, stack dampers, or stack caps.

1.4.3 Approximate Stack Draft Losses and Size. See Nonmandatory Appendix A, Figs. A-10 through A-13.

1.5 Heat Loss (See Nonmandatory Appendix A, Figs. A-2 Through A-9)

1.5.1 Ambient Conditions. Since the heat loss through the walls of a stack varies with ambient conditions, it is necessary to establish the desired design criteria. The low ambient temperature expected should be specified, as well as an average normal wind speed.

1.5.2 Insulation and Linings. Insulation and linings affect total heat loss.

(a) Insulation is applied to outer surface of the stack or between the shells of a dual wall stack. A thickness is selected to reduce the stack heat loss to the desired level or to provide a maximum stack exterior surface temperature. Insulation should be selected for the maximum temperature to which it will be exposed. Insulation should be held to the stack shell as recommended by the insulation manufacturer for the job conditions. When thicknesses over 1½ in. are used, two layers should be specified so that joints can be staggered. An appropriate outer surface weather protection should be specified for external applied insulation. Metal lagging should be secured with metal bands on maximum 24-in. centers.

(b) Stack linings are used for either heat loss reduction, as a protective coating, or both. A thickness is selected for the job conditions. Specify a service temperature range. Lining reinforcing and attachments to stack shell should be per manufacturer's recommendation.

(c) Stack surface cladding, either internal or external, will affect heat loss and should be considered in heat loss calculations.

1.5.3 Film Coefficients. Internal and external film coefficients affect heat loss.

(a) The internal stack surface film coefficient varies with gas velocity, gas temperature, stack diameter, and surface roughness. The effect of both maximum and minimum gas flow velocity on film coefficients should be studied in heat loss calculations. Therefore, the range of expected gas flow should be specified.

(b) The external stack surface film coefficient varies with ambient wind speed and stack diameter. A wind speed of 15 mph is suggested for establishing a maximum heat loss unless field data can prove higher or lower average velocities.