

Flare Details for Petroleum, Petrochemical, and Natural Gas Industries

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Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

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Notice

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The American Petroleum Institute maintains this standard under continuous maintenance procedures. These procedures establish a document program for regular publication of addenda or revisions, including timely and documented consensus action on requests for revisions to any part of the standard. Proposed revisions shall be submitted to the Director, Standards Department, American Petroleum Institute, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

Introduction

A flare is a critical mechanical component of a complete system design intended for the safe, reliable, and efficient discharge and combustion of hydrocarbons from pressure-relieving and vapor-depressurizing systems.

The high-level safety and operating goals of a flare are summarized as follows:

- to provide safe, reliable, and efficient discharge and combustion of hydrocarbons with a high combustion efficiency;
- to ensure that the discharged hydrocarbons burn with stable combustion over the entire defined operating range;
- to ensure a continuity of the flare flame under severe weather conditions;
- to ensure that ground-level concentrations of specified compounds do not exceed environmental limits;
- to ensure that the back pressure does not exceed the maximum allowable;
- to ensure that velocity throughout the flare piping and the flare burner does not exceed the maximum specified;
- to ensure that the opacity limit at the smokeless flow rate range does not exceed that defined;
- to ensure that the flare radiation intensity does not exceed the maximum allowable;
- to ensure that noise levels do not exceed the maximum permissible.

For new designs, the development of a design can be advanced using the guidance and examples of good engineering practice that are identified in this standard.

A flare design basis is developed in consideration of the performance expectations, the functional requirements, and mechanical details required to fulfill the safety and operating goals established for each application. Section 4 provides the basis for design and functional requirements related to the primary components critical to fulfilling these safety and operating goals. Section 5 and Section 6 provide requirements more specific to the arrangement and mechanical details of design.

The functional requirements in this standard are supported by the technical guidance provided in Annex A, Annex B, Annex C, and Annex D. The technical guidance provided in the informative annexes addresses alternative designs or techniques and provides good practices on the basis of which, through sound engineering judgment, the practitioner can make appropriate design decisions and selections.

Datasheets are provided in Annex F in order to properly communicate and preserve the finalized basis of design and requirements. Annex E provides instructions for completing the flare datasheets in Annex F.

Users of this standard should be aware that further or differing requirements may be needed for individual applications. This standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this standard and provide details.

The International System of Units (SI) is used in this standard. Where practical, United States customary (USC) units are included in brackets for information.

A bullet (●) at the beginning of a section or subsection indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on datasheets (see examples in Annex F) or stated in the inquiry or purchase order.

The Fourth Edition of API Standard 537 contains the completed migration and integration of technical content from API Standard 521, Sixth Edition, initiated with API Standard 537, Third Edition, Addendum 1. In the Fourth Edition of API Standard 537, the subject matter previously contained in Annex G (added in Addendum 1) is incorporated throughout the standard under the appropriate subject headings.

Annex G is completely revised relative to Addendum 1 and now contains new subject matter related to flame properties. Three additional annexes have been provided (Annex H, Annex I, and Annex J) together with revised datasheets that now include multi-point staged ground flares (Annex F) and instructions for their use (Annex E). Annex H continues the migration of technical content, however now from the Seventh Edition of API Standard 521. Annex I provides informative content on the use of unmanned aerial systems for flare inspections, and Annex J contains a new component to the standard; a purchaser's checklist which is complementary to the datasheets for the purchaser's specification of requirements.

Flare Details for Petroleum, Petrochemical, and Natural Gas Industries

1 Scope

This standard specifies requirements and provides guidance for the selection, design, specification, operation, and maintenance of flares and related combustion and mechanical components used in pressure-relieving and vapor-depressurizing systems for petroleum, petrochemical, and natural gas industries. Although this standard is primarily intended for onshore facilities, guidance related to offshore applications is included.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Recommended Practice 2A-WSD:2000, *Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design*

API Standard 521, *Pressure-relieving and Depressuring Systems*

API Standard 560, *Fired Heaters for General Refinery Service*

ASME B16.5 ¹, *Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard*

ASME STS-1, *Steel Stacks*

ASTM A123/A123M ², *Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*

ASTM A143/A143M, *Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement*

ASTM A153/A153M, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*

ASTM A384/A384M, *Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies*

ASTM A385/A385M, *Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip)*

ASTM A475-03, *Standard Specification for Zinc-Coated Steel Wire Strand*

ASTM A586-04a, *Standard Specification for Zinc-Coated Parallel and Helical Steel Wire Structural Strand*

ASTM B633, *Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel*

EN 1092-1:2007 ³, *Flanges and their joints—circular flanges for pipes, valves, fittings and accessories, PN designated—Part 1: Steel flanges*

¹ ASME International, Two Park Avenue, New York, New York 10016, www.asme.org.

² ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

³ CEN European Committee for Standardization, Rue de la Science 23, B-1040 Brussels, Belgium, www.cencenelec.eu.

EN 10264-2:2002, *Steel wire and wire products—Steel wire for ropes—Part 2: Cold drawn non alloy steel wire for ropes for general applications*

EN 12385-10, *Steel wire ropes—Safety—Part 10: Spiral ropes for general structural applications*

ISO 2408:2017 ⁴, *Steel wire ropes—Requirements*

NACE MR0103 ⁵/ISO 17945, *Petroleum, Petrochemical and Natural Gas Industries—Metallic Materials Resistant to Sulfide Cracking in Corrosive Petroleum Refining Environments*

NACE MR0175/ISO 15156, *Petroleum, Petrochemical, and Natural Gas Industries—Materials for Use in H₂S-Containing Environments in Oil and Gas Production*, Parts 1, 2, and 3

SSPC SP 6 ⁶/NACE No. 3, *Joint Surface Preparation Standard: Commercial Blast Cleaning*

3 Terms, Definitions, Acronyms, and Abbreviations

For the purposes of this document, the following terms and definitions apply.

3.1 Terms and Definitions (General)

NOTE 1 The following general terms and definitions are provided to better define and distinguish the multi-disciplined workforce and the typical areas of responsibility involved in the specification, design, and supply work processes required in the overall procurement process for flare burners. These are intended to build upon the typical definitions of purchaser and vendor normally used in API standards.

NOTE 2 Recognizing that the work process and areas of responsibility may differ between projects and owner organizations, the terms and definitions contained in the purchaser's procurement documentation take precedence over definition of parties of the multi-disciplined workforces and their respective areas of responsibility.

3.1.1

owner

purchaser

The party with responsibility for all or part of the process and thermal design/definition, the mechanical specification, procurement, and installation of the purchased equipment.

NOTE The owner or purchaser, may at times, work through an engineering contractor (contractor) as an agent undertaking owner's requirement for the engineering, procurement, and/or installation phases of work including representation of the owner on decisions related to operation and maintenance as may be required. The term "purchaser" within this document will be considered synonymous with the term "contractor" or "owner."

3.1.2

vendor

The party that supplies the design, manufacturing, equipment, and any services required as specified by the purchaser.

⁴ International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

⁵ NACE International (now Association for Materials Protection and Performance), 15835 Park Ten Place, Houston, Texas 77084, www.ampp.org.

⁶ The Society for Protective Coatings (now Association for Materials Protection and Performance), 15835 Park Ten Place, Houston, Texas 77084, www.ampp.org.

NOTE 1 The vendor typically has the prime responsibility for the detailed engineering, material procurement, project management, and manufacturing processes involved in the physical supply of the equipment. Their responsibility includes all aspects of quality assurance, quality control for work of their own and others whom they qualify for providing work, products, or services on their behalf.

NOTE 2 The vendor, whether they directly produce the materials or are agents in supply of such components, have responsibility for the quality of the product to either recognized industry or other standards as directed by the purchaser, whomever they may be.

NOTE 3 A vendor may also provide specialty engineering services, such as computational fluid dynamics.

3.2 Specific Terms and Definitions

3.2.1

air seal

purge reduction device

Device used to reduce the amount of purge gas needed to protect against air infiltration into the flare stack.

NOTE Examples include buoyancy seal, orifice seal, and velocity seal.

3.2.2

assist gas

enrichment

supplemental gas

Flammable gas that is added to relief gas prior to the flare burner or at the point of combustion in order to raise the heating value.

NOTE In some designs, the assist gas can increase turbulence for improved combustion.

3.2.3

back blowing

Procedure by which the dry air seal drain line is blown back from the base of the drain into the buoyancy seal to ensure the line is clear.

3.2.4

barrel

Outer cylindrical portion of the flare burner.

3.2.5

blowoff

liftoff

The event that occurs when the fuel stream velocity exceeds the flame velocity, resulting in the flame front moving away from the flame stabilization point, which could lead to the flame being extinguished.

3.2.6

buoyancy seal

diffusion seal

density seal

Dry vapor seal that minimizes the required purge gas needed to protect from air infiltration.

NOTE The buoyancy seal functions by trapping a volume of light gas in an internal inverted compartment that prevents air from displacing buoyant light gas in the flare.

3.2.7

burnback

Internal burning within the burner.

NOTE Burnback can result from air backing down the flare burner at purge or low flaring rates.

3.2.8**burning velocity****flame velocity****flame speed**

Speed at which a flame front travels into an unburned combustible mixture.

3.2.9**burn pit flare**

Open excavation or bermed areas, normally equipped with a horizontal flare burner that can handle liquid and gaseous hydrocarbons.

3.2.10**Coanda flare**

Flare burner that is designed to employ the aerodynamic effect where moving fluids follow a curved or inclined surface over which they flow.

NOTE Flares of this type generally use steam or pressure to achieve smokeless performance.

3.2.11**combustion air**

Air required to combust the flare gases.

NOTE When the assist media for smoke control is air, it commonly provides only a fraction of the flow rate of air required for stoichiometric smokeless combustion.

3.2.12**combustion efficiency**

Percentage of the combustible fluid totally oxidized by the burner.

NOTE In the case of hydrocarbons, combustion efficiency is the mass percent of carbon in the original fluid that oxidizes completely to CO₂.

3.2.13**condensable gas**

Vapor that can condense at the temperature and pressure expected in a flare header during or after a flaring event.

3.2.14**cross-lighting**

Propagation of flame from burner exit to burner exit without aid of a flare pilot.

3.2.15**cryogenic service**

Systems that may be called upon to handle waste gas below $-29\text{ }^{\circ}\text{C}$ ($-20\text{ }^{\circ}\text{F}$).

3.2.16**derrick support**

Lattice based support system for the elevated flare stack, normally used for very tall flares or when plot space is limited.

3.2.17**design flare capacity**

The flare gas flow that is used for sizing calculations.

NOTE 1 The design flare capacity is normally expressed in kilograms per hour (pounds per hour) of a specific composition, temperature, and pressure.

NOTE 2 The flare design may depend on operating cases different from the design case and related to limitations such as composition (for maximum flame speed), radiation, and dispersion. Most commonly hydraulic limitations are based on available backpressure.

3.2.18**destruction efficiency**

Mass percent of the original combustible vapor that is no longer present in the combustion products.

NOTE In the case of a hydrocarbon, destruction efficiency is the mass percentage of carbon in the fluid vapor that oxidizes to CO or CO₂.

3.2.19**detached stable flame**

Flame that is not in contact with the flare burner itself, but burns with a stable flame in the vicinity of the flare burner.

3.2.20**direct ignition**

Initial combustion of a flare burner by a direct sparking energy source other than by a pilot flame.

NOTE Includes high-energy sparking or a pyrotechnic spark shower.

3.2.21**dispersion**

Distribution of vent stream or products of combustion as the fluids move through the atmosphere.

3.2.22**effective exit area****effective diameter****unobstructed cross-sectional area**

Actual flow area where flare gas exits.

NOTE Calculated by taking the ID of the flare burner and deleting areas blocking flare gas flow such as flame tabs, internal steam tubes, etc.

3.2.23**elevated flare**

Flare where the burner is raised high above ground level to reduce radiation intensity and to aid in dispersion.

3.2.24**enclosed flare**

A flare with one or more burners encapsulated with a mechanism and arranged in such a manner that the flame is not directly visible from grade.

3.2.25**endothermic flare**

Flare that utilizes supplemental energy, usually assist or enrichment gas, to maintain the combustion reaction.

3.2.26**excess air**

The amount of air above the stoichiometric requirement for complete combustion, expressed as a volume percentage.

3.2.27**exit velocity**

Speed at which the fluid exits the flare burner.

NOTE The exit velocity is usually expressed as meters per second (feet per second) or as the Mach number.

3.2.28**flame front generator****FFG**

Device used for lighting a pilot by means of a flame front.

NOTE A combustible gas-air mixture is created and allowed to fill an ignition line connecting the flame front generator and the pilot. Igniting the mixture allows the flame front to travel through the ignition line to the pilot.

3.2.29**flame retention device**

Physical device (retention tab) meant to prevent flame blowoff from a flare burner.

3.2.30**flare**

Device or system used to safely dispose of relief fluids in an environmentally compliant manner through the use of combustion.

3.2.31**flare burner****flare tip****tip**

Part of the flare where fuel, flare gases, and air are mixed at velocities, turbulence, and concentration required to establish and maintain proper ignition and stable combustion.

NOTE The name "flare burner" is considered more appropriate than "flare tip," given the engineered nature of design and inclusion of design measures for flame stabilization, that are most often of proprietary design.

3.2.32**flare gas****vent gas****waste gas**

Gas or vapor vented or relieved into a flare header for conveyance to a flare.

3.2.33**flare header**

Piping system that collects and delivers the relief gases to the flare.

3.2.34**flare stack**

A combined conduit and structure, upon which a flare burner is supported.

3.2.35**flashback**

Phenomenon occurring in a flammable mixture of air and gas when the local velocity of the combustible mixture becomes less than the flame velocity, causing the flame to travel back to the point of mixture.

3.2.36**ground flare**

Nonelevated flare.

NOTE A ground flare is normally an enclosed flare but may also refer to a ground multi-point flare or a burn pit.

3.2.37**guyed flare**

Elevated flare with the stack held in place using cables.

NOTE A typical guyed flare is shown in Annex A.

3.2.38**heat release**

Total heat liberated by combustion of the flare gas fluids from the flare burner.

NOTE 1 The heat release is expressed in kilowatts (British thermal units per hour).

NOTE 2 Commonly expressed based on the lower heating value (LHV) of the fluid.

3.2.39**higher heating value****HHV****gross heating value****upper heating value**

Total heat obtained from the combustion of a specified fuel at 16 °C (60 °F) expressed as unit of heat per mass or volume, which includes the latent heat of vaporization of water.

3.2.40**knockout drum**

Vessel in the effluent handling system designed to remove and store condensed and entrained liquids from the relief gases.

3.2.41**liquid seal****water seal**

Device that directs the flow of relief gases through a liquid (normally water) on their path to the flare burner, used to protect the flare header from air infiltration or flashback, to divert flow or to create backpressure for the flare header.

3.2.42**lower heating value****LHV****net heating value****NHV**

Higher heating value (HHV) minus the latent heat of vaporization of the water formed by the complete combustion of the hydrogen atoms in the fuel, expressed as unit of heat per mass or volume.

NOTE LHV is the more common term used in industry.

3.2.43**Mach number**

Actual fluid velocity divided by the velocity at which sound waves propagate through the fluid at the associated temperature.

3.2.44**manifold**

Piping system for the collection and/or distribution of a fluid to or from multiple flow paths.

3.2.45**muffler**

Device that mitigates noise.

3.2.46**multi-arm flare****multi-nozzle flare****multi-jet flare**

Single flare burner with multiple exit nozzles where flare gas flows to every exit based on the pressure drop of the path from the inlet to the exit, not through staging valves.

NOTE 1 These can be pressure assisted in high-pressure applications.

NOTE 2 These flare burners can be effectively staged utilizing variable exit orifices or slots on the nozzles.

3.2.47**multi-point flare
multi-burner flare**

Group of flare burners designed to burn all or a portion of the design flow capacity, where the flow to each burner (or set of burners) is controlled in stages to facilitate better combustion.

NOTE 1 Multi-point flares are capable of smokeless combustion at high flow rates with lower radiation levels.

NOTE 2 These can be pressure assisted in high-pressure applications.

3.2.48**nonreclosing pressure-relief device**

Pressure-relief device actuated by static differential or static inlet pressure.

NOTE Nonreclosing pressure device or any device approved by a recognized pressure-relief authority (e.g. buckling pin, rupture disk, etc.).

3.2.49**opacity**

Degree of nontransparency to rays of light.

NOTE The opacity is typically quantified by the Ringelmann number.

3.2.50**overaeration
oversteaming**

Introducing too much assist utility (whether steam or air injection) in a flare flame.

NOTE Too much assist utility reduces flare combustion performance by diluting the combustion zone.

3.2.51**pilot
pilot burner**

A small continuously operating burner that provides ignition energy to ignite the flared gases.

3.2.52**pilot flame detection system
pilot flame monitor**

System that verifies a flame is present within the pilot.

3.2.53**pressure design code**

Recognized pressure equipment standard specified or agreed by the purchaser.

NOTE Examples include ASME *BPVC* Section VIII or EN 13445 (all parts) for pressure vessels and ASME B31.3 for piping or EN 13480 (all parts).

3.2.54**purge gas**

Noncondensable flammable or inert gas added upstream of the flare stack to ensure positive flow out of the flare burner to mitigate air ingress and burnback.

NOTE 1 Purge gas is defined here for consistent usage within the context of this standard. Individual owners and vendors may use different terms to refer to purge gas and purge gas usage.

NOTE 2 Local regulations may define and use the term purge gas differently than the definition and usage in this standard.

3.2.55**radiation intensity**

Radiant heat flux from the flare flame.

NOTE 1 The heat flux rate is usually considered at grade level.

NOTE 2 The heat flux is expressed in unit of energy per unit of time and area.

3.2.56**Ringelmann number**

Visually comparative scale used to define levels of opacity, where clear is 0, black is 5, and 1 through 4 are increasing levels of gray as used in describing smoke from combustion of hydrocarbons.

NOTE The Ringelmann number is often used to describe the intensity of smoke.

3.2.57**riser**

Pipe or other conduit that conveys the relief gas, combustion air, etc. to the flare burner.

3.2.58**smokeless capacity**

Range of relief fluid flow to a flare burner that can be burned without smoke.

NOTE The term “without smoke” can be quantified using the Ringelmann number.

3.2.59**staged flare**

Group of two or more flares or burners that are controlled so that the number of flares or burners in operation is proportional to the flare gas flow.

3.2.60**stoichiometric air**

Chemically correct amount of air required for complete combustion with no unused fuel or air.

3.2.61**structural design code**

Recognized structural standard specified or agreed by the purchaser.

NOTE Examples include AISC S302, ASCE 7, and ASME STS-1.

3.2.62**turndown**

The minimum rate at which the flare burner is designed to operate normally with stable combustion, as compared to the maximum hydraulic design capacity of the flare burner.

NOTE Flares operate normally at an extreme turndown (sometimes in excess of 50,000:1), which poses operational challenges.

3.2.63**velocity seal****orifice seal**

Dry vapor cone-shaped obstruction device that minimizes the required purge gas needed to protect against air infiltration into the flare stack or riser from the burner.

3.2.64 **V_{eq}**

The volumetric flow rate of air at standard temperature that produces the same velocity pressure as the actual gas flow at the same compression and actual gas temperature.

NOTE This value is proportional to the flare gas flow rate and is independent of the pipe diameter used to evaluate velocity pressure.

3.2.65

wind fence

Structure surrounding a flare at ground level to modify the effect of crosswinds on the combustion process, to prevent unauthorized access, limit the radiation to the surroundings, and/or make the flame less visible.

3.2.66

windshield

Device used to protect the outside of an elevated flare burner from direct flame impingement.

NOTE 1 The windshield on a flare burner is so named because external flame impingement occurs on the downwind side of an elevated flare.

NOTE 2 Windshields are also integral to the design of pilots to avoid flame-outs during high winds.

3.3 Acronyms and Abbreviations

BPVC	<i>Boiler and Pressure Vessel Code</i>
DCS	distributed control system
FPSO	floating production storage and offloading
IR	infrared
LHV	lower heating value
LNG	liquefied natural gas
PLC	programmable logic controller
SI	International System of Units
TEAO	totally enclosed, air over
TEFC	totally enclosed, fan cooled
UAS	unmanned aerial system
USC	United States customary
UV	ultraviolet
VOC	volatile organic compound

4 Design

4.1 General

4.1.1 Being critical to the safety of an operating plant, a flare shall be continuously available and capable of its intended performance through all operating-plant emergency conditions, including a site-wide general power failure as defined in the flare datasheets.

4.1.2 The flare and related mechanical components shall be designed to operate and properly perform for the specified service conditions for a minimum of 5 years without the need for an outage of the operating facility, unless a shorter duration is specified by the purchaser.

NOTE Flare availability and reliability are strongly dependent on the design of the related mechanical equipment and on its installation, commissioning, maintenance, and operation.

4.1.3 A framework of processes and procedures shall be in place that:

- a) clearly document the intended capacity, performance, and operational limitations of the pressure-relieving and vapor-depressurizing systems and flare;
- b) provide operating procedures and operator training;
- c) provide planned and routine maintenance of components critical to the safety and operating goals.

4.1.4 The hydraulic design of the flare system shall be such as to properly allow flare gas discharge from the burner within the allowable pressure drop and flame combustion velocity limits.

NOTE 1 There are velocity limits for proper combustion based on the flare gas LHV.

NOTE 2 In some locations, the regulatory agencies may set exit velocity limits.

4.2 System Design

4.2.1 General

The following system design requirements shall be defined on the datasheets:

- a) design flow cases from the pressure-relieving and vapor-depressurizing system, including maximum continuous case and maximum intermittent case as defined by mass flow and heat release;
- b) flare staging requirement and method;
- c) maximum allowable flare burner exit velocity;

NOTE The gas heating value and tendency of the flare gas to produce unstable flames/flame blowoff at velocities that are too high for the particular flare burner type and design are important considerations in determining the maximum exit velocity.

- d) system hydraulics with respect to allowable pressure drop, static pressure, and diameter of the flare;
- e) environmental performance requirements related to smokeless capacity, opacity/Ringelmann number limits, ground-level concentration of pollutants, and permissible noise limits;
- f) operating performance such as peak radiation intensity at grade;
- g) functional description of the intended system operation;
- h) selection of major system components that can be integral to the flare such as a knockout drum, liquid seal, purge reduction device, etc.;
- i) site and ambient design conditions;
- j) utilities available;
- k) materials of construction;
- l) maximum available steam flow and the supply pressure where applicable for smoke control.

NOTE 1 Also see 4.3 for process functional requirements.

NOTE 2 Fundamental system design requirements are established through consideration of the requirements and guidance provided in API 521.

4.2.2 Purging

4.2.2.1 The complete flare system shall be initially purged to reduce oxygen level from the system to below the safe flammable mixture level, e.g. NFPA 69 guidelines, by utilizing a noncondensable flammable or inert gas. This applies to both elevated and ground flare systems.

NOTE 1 Oxygen level reduction within a flare is accomplished with a pre-commissioning purge and a continuous flow that is a combination of purge/normal flare gas flow through the flare system.

NOTE 2 The pre-commissioning purge is typically defined as 10 flare system volumes.

4.2.2.2 For elevated flares following the pre-commissioning purge, a continuous purge shall be provided unless the gas from the normal process vents can provide the required flow rate to limit the flare stack oxygen.

4.2.2.3 A continuous purge of the flare stack is not required provided at least one of the following measures is included in the flare system design.

- a) A liquid seal has been provided at the base of the flare stack and the design of the stack to ensure mechanical integrity in consideration of a deflagration occurring.
- b) There is an adequate amount of sweep gas through the flare gas system such that it meets the requirements of low oxygen level in the stack.

NOTE See API 521 for details on sweep gas.

- c) The flare stack/flare header is provided with a detonation arrestor designed to prevent the propagation of any deflagration/detonation upstream of the arrestor. The detonation arrestor shall be certified for all the specified service conditions.

Caution—Deflagration/detonation arrestors in flare systems are susceptible to fouling/plugging. Monitoring is important. Routine inspection/cleaning is required. In some cases, parallel devices have been used to allow for maintenance.

4.2.2.4 Purge rates higher than those provided by continuous sweeps or continuous flare burner purges shall be considered and appropriately designed into the flare system design for the following reasons:

- a) to establish an initial, very low oxygen condition during start-up;
- b) to maintain adequate positive system pressure, limiting air ingress to prevent combustible conditions while performing maintenance activities on an operating flare system;
- c) to mitigate undesirable conditions (e.g. presence of combustibles, oxygen, condensables, and corrosives) between flaring events in flare systems that are designed to operate intermittently without a continuous purge (e.g. post-purge of a staged flare downstream of the stage isolation valves).

4.2.3 Continuous Purging Requirements for Stacks without a Purge Reduction Seal

NOTE The amount of purge gas required to prevent air infiltration from the elevated flare tip can be reduced using a purge reduction seal (e.g. buoyancy seal or velocity seal).

4.2.3.1 The vendor shall provide the purge rate requirements for both the purge reduction seal design provided and without the device.

4.2.3.2 Although it is possible to calculate a negative purge rate with Equation (1) and Equation (2), if the overall K value is negative, the minimum continuous purge rate for stacks without a purge reduction seal shall not be less than zero.

NOTE 1 For lighter-than-air purge gases, Equation (1) can be used to determine the purge gas rate (Q), expressed in normal cubic meters per hour and Equation (2) expressed in standard cubic feet per hour for continuous purge requirements in open flares without the effect of buoyancy seal or velocity seal [20, 51].

In SI units:

$$Q = 190.8 D^{3.46} \frac{1}{y} \ln \left(\frac{20.9}{O_2} \right) \left(\sum_i^n C_i^{0.65} \times K_i \right) \quad (1)$$

In USC units:

$$Q = 0.07068 D^{3.46} \frac{1}{y} \ln \left(\frac{20.9}{O_2} \right) \left(\sum_i^n C_i^{0.65} \times K_i \right) \quad (2)$$

where

- D is the flare stack internal diameter, expressed in m (in.);
- Y is the column depth at which the oxygen concentration (O_2) is predicted, expressed in meters (feet);
- O_2 is the oxygen volume fraction, expressed as a percentage;
- C_i is the volume fraction of component i , a number between 0 and 1;
- K_i is a constant for component i .

The following are typical values for K_i (independent of wind except where noted):

Hydrogen: $K = +5.783$

Helium: $K = +5.078$

Methane: $K = +2.328$

Nitrogen: $K = +1.067$ (no wind)

Nitrogen: $K = +1.707$ [with a wind speed of approximately 7 m/s (23 ft/s)]

Ethane: $K = -1.067$

Propane: $K = -2.651$

CO₂: $K = -2.651$

C₄₊: $K = -6.586$

NOTE 2 Steam or other condensable gases are not suitable purge gases.

NOTE 3 The reference temperature for standard conditions [15.6 °C (60 °F)] is not the same as the reference temperature for normal conditions [0 °C (32 °F)]. The conversion between standard and normal conditions has been incorporated when reporting the results in the different unit systems. The user is cautioned that the volumetric rates reported in the different unit systems might not appear to be equivalent because of this temperature conversion.

NOTE 4 Equation (1) and Equation (2) can be simplified to Equation (3) and Equation (4) using the typical criteria of limiting the oxygen volume fraction to 6 % at a distance of 7.62 m (25 ft) down from the top of the flare stack and assuming a single component:

NOTE 5 Lower oxygen concentrations should be used for certain compounds such as hydrogen. Consideration for the use of a lower oxygen limit is based on the lower flammability limit/lower oxygen level required for flammability.

In SI units:

$$Q = 31.25D^{3.46} \times K \quad (3)$$

In USC units:

$$Q = 0.0035283D^{3.46} \times K \quad (4)$$

NOTE 6 Based on test data involving natural gas production facility flares ^[52], a significant reduction in purge rates as predicted by Equations (1), (2), (3), and (4) may be taken under certain constraints.

NOTE 7 The user is cautioned not to extrapolate outside the bounds and conditions under which the tests were conducted. If the purge gas is heavier than air, no significant positive buoyancy force exists. For this condition, the purge rate for nitrogen should be used ^[51].

NOTE 8 If the gas in the stack (e.g. hydrogen or methane) is lighter than air, the pressure in the bottom of the stack can be lower than atmospheric, even with some outflow from the top of the stack. This condition creates a situation in which any flange leaks, open drains/vents, or other openings in the flare header draw air into the flare header, resulting in potential for an internal explosion. For this reason, users are cautioned to maintain the integrity of their equipment and follow proper safety precautions when opening an active header.

4.3 Process Definition

4.3.1 In addition to the functional system design requirements as defined in 4.2, complete composition, range of temperature, and hydrocarbon characterization information of the process stream(s) shall be provided.

Caution—See A.2.6 for guidance on the compatibility with high-pressure flare burners for the specified range of relief gas composition and/or flow rate.

4.3.2 In consideration that various operating or pressure-relieving cases can individually define various aspects of the flare design, the purchaser shall provide detailed process definition for all operating or pressure-relieving cases, including situations where multiple cases operate simultaneously. The process definition shall also include the expected duration and frequency for the specified cases.

NOTE Aspects of a flare design that can define the design of the flare may include, but are not limited to, the following:

- hydraulic capacity;
- ground-level radiation;
- aeration requirement for the defined smokeless capacity;
- requirement for dilution gas;
- design metal temperature;
- thermal expansion;
- material selections;
- etc.

4.3.3 The potential for liquid introduction or the condensation of hydrocarbons, or the formation of hydrates in the flare header or flare stack, which can be carried to the combustion zone, shall be considered by both the user and the flare designer.

NOTE 1 Hydrocarbon droplets entrained in the gas stream that are carried into the flame usually burn incompletely, can produce burning liquid droplets, form soot, and decrease the smokeless capacity of the flare. The maximum liquid droplet size that can enter the combustion zone and can be handled within achievable measures for smokeless control depends on the burner design.

NOTE 2 Fundamental process definition is primarily established in API 521.

4.4 Types of Flares

Through an understanding of the process, performance, and operational requirements for the flare and with consideration of the mechanical, operability, and maintenance implications for each, the designer shall specify the most appropriate type of flare, configuration, and components to meet the safety, operability, and the functional requirements established through use of this standard. Decisions on flare type and functional requirements shall be documented in the datasheets.

NOTE 1 Refer to Figure A.1 for a general flare type selection guide. Within each general type of flare, various alternatives and proprietary design aspects can exist. An understanding of alternatives and/or proprietary design aspects can be obtained and evaluated using the datasheets in Annex F and instructions on their use in Annex E.

NOTE 2 For further guidance on the types of flares, the mechanical details, and the requirements of design for each, refer to Section 5 and Section 6 and Annex A, Annex B, and Annex C. Decisions on functional requirements shall be documented in the datasheets.

NOTE 3 For guidance on offshore flares, see Annex D.

4.5 Flare Burners

A flare burner supplied in accordance with this standard shall be designed to operate and properly perform as specified under the defined service conditions for a minimum of 5 years (unless a shorter duration is specified by the purchaser) when installed and operated in accordance with the vendor's recommendations. Although many design alternatives for flare burners exist, including those of a proprietary nature, the following are the functional requirements that shall be met.

a) For all flare burners:

- Flare burners shall incorporate flame retention devices or aerodynamic methods with proven capability to provide stable combustion and protection from flame blowoff.
- Air or steam injection, if applied, shall not disrupt the basic flame stabilization mechanisms of the flare burner or pilot operation.
- Flare burners in combination with their system of pilot(s)/ignition system(s) shall be capable of maintaining stable combustion of the main flame for the specified service conditions, including the environmental conditions as specified for pilots in this standard.
- The flare flame shall be stable over the entire defined operating range.

NOTE Stable flame being defined as either an "attached stable" or "detached stable" flame.

b) For flare burners with internal steam injection to induce air:

- Steam condensate shall be drained from the internal steam/air injection point and from any muffler surrounding these tube assemblies.
- The vendor shall define and document the range of steam flow rate necessary to achieve smokeless flare operation at required design conditions.

c) For staged flare burners:

- If flare system safety considerations include valve bypasses, then each of which shall contain a failsafe device if the flare is the final relief protection for the system, e.g. rupture disc, nonreclosing pressure-relief device, or any device that is approved by a recognized pressure-relief authority.

4.6 Mechanical Design

4.6.1 There are numerous physical arrangements and mechanical designs available from which to select the most appropriate for the application, in accordance with the local codes and regulations. Whichever selection is made, the following shall apply.

- a) The pressure design code shall be specified or agreed by the purchaser. Pressure components shall comply with the pressure design code and the supplemental requirements in this standard.
- b) The structural and mechanical design codes shall be specified or agreed by the purchaser. Structural components shall comply with the structural design code and the supplemental requirements in this standard.
- c) The purchaser and the vendor shall mutually determine the measures required to comply with any local or national regulations applicable to the equipment.
- d) The purchaser shall specify the design temperature and design pressure.

NOTE For uninsulated flare stacks, it is not necessary to consider that the maximum design temperature and wind loads apply simultaneously because of the cooling effect of the wind.

4.6.2 For the design wind case, a credible metal temperature under design wind conditions shall be established, listed on the datasheet, and used in the design.

4.6.3 For vertical thermal expansion analysis, the maximum operating temperature shall be used as the design basis.

4.6.4 For insulated or shielded flare stacks, design temperature and wind loads shall be considered to apply simultaneously.

NOTE Further guidance on metal temperature considerations is given in E.3.3, Form Elevated 4.

4.6.5 The following shall be taken into account in the mechanical design, fabrication, inspection, and testing of the mechanical components of a flare:

- a) flared stream temperature, pressure, and composition;
- b) corrosive nature and liquid content of the flared stream;
- c) ambient conditions;
- d) site conditions;

- e) wind, snow, and ice loading;
- f) seismic loading;
- g) jet loads associated with high-velocity flare burners;
- h) cyclic loading, vibration (fatigue);
- i) hydraulic forces, as are possible with blow-dry liquid seals;
- j) pressure waves, as are possible with staged flares;
- k) proximity to equipment (including other flare equipment) structures, thoroughfares, and site boundaries;
- l) maintenance and inspection criteria;
- m) contraction/expansion of stack due to ambient or process changes;
- n) pressure due to flashback, if specified by the purchaser;

NOTE The use of a properly designed, reliable purge can preclude the requirement to design for flashback pressure.

- o) bolting.

NOTE Various measures can be taken to prevent bolting from coming loose due to vibrations, etc.

EXAMPLE The use of bolts and double nuts is the preferred method. An alternative where specified, is locking or cupped spring-type washers. Where size does not allow the use of bolts, the use stud bolts with double nuts on both sides may be considered. These methods apply to any bolted connection, regardless of its size, location, or use.

4.7 Pilots

There are numerous pilot designs available from which to select the most appropriate for the application. Although design alternatives exist, the following are the functional requirements that shall be met.

- a) Pilots shall be continuously burning.
- b) Pilots shall reliably ignite the flare flame on single- and multi-burner flares.
- c) Minimum pilot heat release shall be 13.2 kW (45,000 Btu/h).
- d) Pilots shall remain burning, even if the flaring gases are not flammable.
- e) Pilots shall remain burning and capable of being re-ignited at wind speeds up to 160 km/h (100 mph) under dry conditions and 140 km/h (85 mph) when combined with at least 50 mm (2 in.) of rainfall per hour. This performance shall be verified by type testing in accordance with a documented test protocol and documented results.

NOTE The recommended functional elements for verification testing are provided in A.6.

- f) When the LHV of the flare gas is 11.82 MJ/Nm³ (300 Btu/scf) or greater, the minimum number of pilots shall be in accordance with Table 1. For low heating value and/or toxic services, additional pilots are required.

Table 1—Number of Pilots for Single-point Flares

Minimum Number of Pilots	Flare Burner Outlet Diameter (DN)	Flare Burner Outlet Diameter (NPS)
1	Up to 200	Up to 8
2	>200, up to 600	>8, up to 24
3	>600, up to 1050	>24, up to 42
4	>1050, up to 1500	>42, up to 60
To be agreed with the purchaser	>1500	>60

- g) When the LHV of the flare gas is less than 11.82 MJ/Nm³ (300 Btu/scf) and/or in toxic service, the purchaser and vendor shall agree on the number of pilots.
- h) For toxic services, there shall be a minimum of two pilots.
- i) Pilot tip and components exposed to flame shall be constructed of a heat-resistant material (e.g. type 309 SS, type 310 SS, type 310H SS, etc.).
- j) For self-aspirating pilots, the air inlet shall be located so that it has uninterrupted air access and shall be at least 1.8 m (6 ft) or 125 % of the actual burner diameter (whichever is greater) from the top of the flare.
- k) For self-aspirating pilots, a strainer shall be installed at grade for protection of the pilot regulator. A strainer or settling chamber shall also be installed just upstream of the gas orifice, unless the piping between the grade strainer and the gas orifice is stainless steel.
- l) Piping and components between the pilot tip and the air mixer shall be constructed of austenitic stainless steel.
- m) Pilots shall be designed for the specified fuel gas supply.
- n) A continuous source of clean fuel, which is regulated in pressure and has a defined range of heating value and composition (e.g. natural gas quality), shall be supplied to the pilot.
- o) Each pilot shall have at least one dedicated means of ignition and one dedicated means of pilot flame detection.

NOTE If the pilot venturi has an adjustable air door, ensure that there is a reliable locking mechanism for the air door.

- p) The pilot ignition and detection systems shall be selected with consideration of the intended maintenance intervals of the pilots.

NOTE For guidance on pilot selection, maintenance, and troubleshooting, refer to A.3.

- q) When specified by the purchaser, individual fuel supply lines shall be installed to each pilot, if required, to improve operability and reliability of the pilots.

4.8 Pilot Ignition Systems

4.8.1 There are numerous pilot ignition system designs available from which to select the most appropriate for the application. Although design alternatives exist, the following are the functional requirements that shall be met.

- a) The pilot ignition system shall be able to reliably ignite the pilot, including at wind speeds of up to 160 km/h (100 mph) under dry conditions and 140 km/h (85 mph) when combined with at least 50 mm/h (2 in./h) of rainfall. This performance shall be verifiable by type testing in accordance with a documented test protocol and documented results.

NOTE The recommended functional elements for verification testing are provided in A.6.

- b) The pilot ignition system shall be able to ignite the pilot during all defined operating and emergency relief cases, including a site-wide general power failure.
- c) It shall be possible to ignite each pilot independently of the other pilots without depending on the flare flame for ignition.
- d) Compressed-air flame front generator systems shall be designed to prevent back-flow of one utility system into another.
- e) Flame front generator systems shall be designed to ensure that the ignition lines after pilot ignition shall be free from ignitable mixture that may cause a stable flame inside the lines.

NOTE For guidance on pilot ignition equipment selection, maintenance, and troubleshooting, refer to A.4.

4.8.2 Pilot igniter controls shall be located in a safe location near the flare.

4.9 Pilot Flame Detection

There are numerous pilot flame detection system designs available from which to select the most appropriate for the application. Although design alternatives exist, the following are the functional requirements that shall be met.

- a) The pilot flame detection system shall be able to distinguish between pilot flame and flare burner flame.
- b) The pilot flame detection system shall be able to detect the pilot flame, including at wind speeds of up to 160 km/h (100 mph) under dry conditions and 140 km/h (85 mph) when combined with at least 50 mm/h (2 in./h) of rainfall. This performance shall be verifiable by testing in accordance with a documented test protocol and documented results. A typical test protocol is given in A.6.
- c) Each pilot shall have at least one dedicated means of pilot flame detection.

NOTE For guidance on pilot flame detection equipment selection, maintenance, and troubleshooting, refer to A.5.

4.10 Piping

4.10.1 Design criteria for auxiliary piping attached to the flare stack or support structure shall be in accordance with the pressure design code or the superior requirements of a user's or flare vendor's specification.

4.10.2 The material of the flare piping system shall be selected on the basis of flare gas compositions, temperature, pressure, and any potential impact of ambient conditions.

4.10.3 Flanges shall be kept to a minimum since they can be a source of leakage.

4.10.4 Piping shall be evaluated for differential thermal expansion due to the temperature gradient between the piping and the support structure/flare stack. If necessary, expansion loops shall be used in the piping on the stack and, in particular, for steam lines.

4.10.5 Expansion joints shall be avoided due to their tendency to leak and the difficulties in their maintenance.

4.10.6 Expansion joints shall not be used in lines containing flammable and/or toxic gases.

NOTE The flare system designer is responsible for specifying any required movement of the auxiliary piping interface point.

4.10.7 All piping shall be considered in the structural analysis of the wind and earthquake loads, including any insulation (whether applied before shipment or applied on site).

4.10.8 Piping shall be designed for all operating and test loads, including water-filled steam piping.

4.11 Auxiliary Components

4.11.1 There are numerous auxiliary components available from which to select those that are appropriate for the mechanical design considerations of the flare. The following are the functional requirements that shall be met.

- a) For parallel flares, at least one liquid seal or some other means of isolation shall be provided downstream of the branch between the two flares.
- b) Flares in cold service or subfreezing due to process concerns shall be equipped with means to prevent blockage that can be caused by the freezing of trapped water. Special attention shall be given to liquid seals and buoyancy seals.

NOTE The same considerations apply to the piping of the high-pressure water-assisted flare systems.

- c) Where there is the potential for solids formation, hydrates, or liquid freezing under cold climate conditions, heat-tracing system requirements shall be considered.
 - d) For an air-assisted flare where multiple blowers are used, the full operating sequence, blower staging, and system hydraulics shall be engineered in detail from start-up through their maximum flow operation.
 - e) For an air-assisted flare in which multiple blowers are used, the air-side system shall be designed with isolation dampers for any blower that is out of service.
- **4.11.2** The purchaser shall specify the type and location of a purge reduction device is required, if any.

NOTE There are two common types of purge reduction devices used to reduce the amount of continuous purge gas required to prevent air infiltration into the flare stack: a buoyancy seal and a velocity seal.

4.11.3 When a purge reduction device is used, the following functional requirements for the device shall be met:

- a) equipped with a drain that is adequately sized to prevent plugging and be sealed to prevent the entry of air;
- b) equipped with an inspection opening to allow cleaning of the drain during shutdowns;
- c) the drain line kept open and protected against freezing.

NOTE See A.7 for further guidance and design requirements for purge gas conservation seals.

4.11.4 When electric-motor drives are used for blowers on air-assisted flares, the thermal overload settings and breaker settings shall consider winter operation.

4.12 Control of Fluid Injection for Smoke Suppression

4.12.1 The instrumentation and control system used for a flare burner fluid injection smoke suppression system shall be capable of effective and efficient use of smoke suppression fluids for smokeless operation over the full range of smokeless operation specified, including turndown.

4.12.2 At low flaring rates, the control of the smoke suppression fluid shall ensure the flame is not overaerated causing an unstable flame.

NOTE Accurate control of smoke suppression fluids is more difficult at low flare flow rates. A low range flare gas flow meter is one potential method to be considered as a way to improve smoke suppression fluid control.

4.13 Sizing

4.13.1 Flare Burner Diameter

4.13.1.1 The criteria used to determine the flare burner outlet diameter/exit area is an exit velocity of no greater than Mach 0.80 in consideration of available pressure drop. The exception to this velocity limitation is for sonic flare burners.

NOTE 1 There are flare burner designs with an engineered flame stabilization device or design that can operate at Mach 1.

NOTE 2 Methods in Annex H can be used to calculate the Mach number.

NOTE 3 Burner exit velocity limitations imposed by regulatory agencies ^[40] may not apply to flares in emergency relief service.

4.13.1.2 Flare burner designs shall consider the lowest flow/lowest flare gas exit velocity scenario as part of the overall design.

NOTE 1 Flare burners with a low exit velocity can cause heat and corrosion damage to the flare burner and auxiliaries (i.e. pilots and ignitors).

NOTE 2 On flare burners with a low exit velocity, the flame is more influenced by the wind than the flame buoyancy. The low-pressure area downwind of the stack can cause the flare flame to be drawn down from the top of the stack for 3 m (10 ft) or more.

4.13.1.3 The effective exit area, i.e. total exit area minus any flame retention ring area or other exit blockage, for the burner shall be used for any flow/exit velocity calculations.

4.13.1.4 The flow area of the flame retention devices relative to the cross-sectional area of a flare burner shall be considered in sizing the flare burner.

4.13.1.5 Flow area restrictions such as flame retention devices, shall be accounted for in the flare burner and flare header sizing.

4.13.1.6 The pressure drop across the flare burner, including accessories such as seals, shall be included in the flare system hydraulic assessments to ensure backpressure limitations are not exceeded.

NOTE The pressure drop across the flare burner will vary depending upon burner type, size selection, mass flow, and fluid flow conditions and properties.

4.13.1.7 All operating cases shall be reviewed to ensure the correct definition of the flare system design case due to the effect on flare system backpressure.

NOTE The use of V_{eq} is a quick method to compare all operating cases to determine which ones may be controlling developed back pressure. See E.2 for more information on V_{eq} .

- **4.13.1.8** When specified by the purchaser, the flare burner vendor shall provide flare burner hydraulic assessments for the specified operating cases.

- **4.13.1.9** The purchase shall specify the operating cases and respective percentage of design flow required for smokeless combustion.

4.13.2 Flare Stack Diameter

4.13.2.1 The criteria used to determine the flare stack diameter shall be velocity and available pressure drop through the riser as an integral component of the flare system hydraulics.

4.13.2.2 Unless otherwise agreed between vendor and purchaser, the flare stack riser velocity shall not exceed 0.5 Mach.

NOTE 1 The flare stack riser maximum velocity limit does not apply to the flare burner.

NOTE 2 Velocities greater than 0.5 Mach may be permitted for a peak, short-term, infrequent flow for both low and high-pressure flares.

NOTE 3 The allowable velocity depends on consideration of the following:

- volume ratio of maximum conceivable flare flow to anticipated average flare flow;
- probable timing, frequency, and duration of design case flows;
- design criteria established for the project to stabilize flare burning.

NOTE 4 Sonic velocity operation can be appropriate for high-pressure flare burners, however, not within the flare stack.

4.13.3 Flare Stack Height

4.13.3.1 The primary criterion used to determine the flare stack height shall be flare flame radiant heat intensity at grade.

NOTE Several techniques are available to set the height of the flare against recommended radiation levels. See Annex H.

- **4.13.3.2** When specified by the purchaser, a dispersion analysis shall be used to aid calculating the required flare stack height in the event of a flare flame being extinguished or due to dispersion of the combustion products.

NOTE Refer to API 521 for guidance on dispersion analysis.

4.13.3.3 The flare vendor shall provide radiation isopleths for the design case controlling flare height.

4.13.3.4 For radiant heat intensity, the empirical equations in Annex H shall apply with the recommended levels of radiation intensity, K , given in Table H.3.

NOTE 1 Other references include Brzustowski and Sommer^[42] and flare vendor proprietary correlations.

NOTE 2 The quality of combustion affects the radiation characteristics. Use of the fraction of heat radiated, F , based on the United States Bureau of Mines data given in Table H.4, is considered to provide a reasonable, however conservative, stack height.

NOTE 3 Another factor to consider is the effect of wind in tilting the flame, thus varying the distance from the center of the flame, which is considered to be the origin of the total radiant heat release, with respect to the plant location under consideration. A generalized curve for approximating the effect of wind is given in Figure H.8.

5 Mechanical Details—Elevated Flares

5.1 Mechanical Design—Design Loads

The design of the support structure for both single-burner and multi-burner vertical elevated flares shall consider, as a minimum, the design loads defined below. The supplier shall advise and confirm with the purchaser before award of any exceptions that they may have or consider as not applicable to the specific application:

NOTE A general description of several methods that can be used to support a vertical flare is provided in A.1.

- a) Wind loadings—Wind loading shall take into account the flare stack and all of its appurtenances such as, but not limited to, piping (including insulation, if any), access platforms, and ladders. When appropriate, the wind loading on supporting derrick structures shall be included. Wind loads shall be based on the local regulations (e.g. ASCE 7).
- b) Earthquake-induced loads—Earthquake-induced loads shall be based on the local regulations, e.g. ICBO or ASCE 7. Structural design shall be based on wind loads and earthquake loads occurring separately.
- c) Wind-induced vibration loads—The structural design for wind-induced vibration shall be in accordance with the ISO limit-state method in API 560, Annex H or ASME STS-1.
- d) Internal pressure:
 - 1) The purchaser shall specify the internal pressure for the flare stack.

NOTE 1 Flare stacks are generally operated at near-atmospheric pressure and are not specifically designed as pressure equipment. Exceptions to this include conditions when the flare burner creates a backpressure in the flare stack that causes the pressure design code to become applicable.

NOTE 2 In some cases, the bottom portion of the stack incorporates a knockout drum or liquid seal, or both.

- 2) When specified in the datasheets, the stack portion containing the knockout drum or liquid seal shall be designed as a pressure vessel including, if specified, hydrostatic testing and code stamping. In such cases, the design of the pressure vessel portion shall be in accordance with the pressure design code and shall be based on the design pressure stated in the datasheets or at least 105 kPa (ga) (15 psig).

NOTE It is common practice that the stack be designed for structural loads and the anticipated maximum operating pressure when the base section of the stack is designed as a pressure vessel. For design purposes, the stack is deemed to start at the pressure vessel outlet.

- 3) The design of a stack base section that is a pressure vessel shall include provision for internal pressure loads and for simultaneous wind loads based on 70 % of the design wind velocity.
 - 4) The design pressure (maximum allowable working pressure) of a stack base section that is a pressure vessel shall not be increased due to any material thickness that is in excess of that thickness required to meet the design pressure.
- e) Jet loads:
 - 1) In consideration of sonic-type flares with an exit velocity greater than Mach 0.8, special considerations related to vibration and fatigue shall be considered in the mechanical design. Refer to A.2.6 for guidance.

- 2) The requirement for vibration and fatigue analysis shall be mutually agreed between purchaser and supplier.
- f) Flashback pressure—When the purchaser has specified that flashback pressure be taken into account, the pressure used in the calculations shall be specified by the purchaser.

g) Nozzle loads:

- 1) The purchaser shall specify the preliminary flare-header-imposed nozzle loads and elevation on the datasheets furnished to the vendor with the inquiry.
- 2) The purchaser shall provide final flare-header-imposed nozzle loads and elevation during the design phase. If the purchaser does not furnish nozzle load information, the flare supplier shall use the nozzle-allowable forces, moments, and elevation specified in Table 2.
- 3) The purchaser shall also define the loads and moments of the external piping nozzles (for steam, fuel-gas-to-pilot, etc.). If the purchaser does not impose them, then the designer shall select them.
- 4) The flare stack itself shall not be used as a fixed anchor point for the flare header piping.

NOTE Nozzle loads are imposed on the stack by the flare-header-to-stack connection and can have a major influence on the design of the flare stack. This influence increases as the elevation of the flare header increases.

- 5) The purchaser shall minimize the nozzle loads imposed on the stack by other service connections.

h) Thermal loads:

- 1) In consideration that the relief gas cases described in the datasheets can have a gas temperature that is different from ambient, the flare stack designer shall provide for thermal expansion and contraction that can be caused by a specified gas temperature or by temperature differences caused by wind or rain.

NOTE Thermal loads are of greatest concern on guyed stacks and derricks.

- 2) Special attention shall be given to the design of stacks where the stack wall temperature is expected to be 175 °C (350 °F) or higher.

NOTE 1 Temperature differential between a hot stack wall and varying ambient conditions, for instance, by wind rain on one side of the stack, can cause the stack to buckle or bend, inducing additional stress on the stack, guy wires, or derrick and foundations. Countermeasures include shielding or insulating of the stack.

NOTE 2 The freedom of movement of a self-supported stack reduces the thermal load considerations, providing that the thermally induced deflection does not exceed 450 mm per 30 m (18 in. per 100 ft).

- 3) The designer shall provide for thermally induced differential changes in length between the stack and the piping attached to the stack.

i) Erection and/or maintenance loads.

- 1) The flare stack designer shall be informed of the erection techniques that the purchaser plan to employ. If the stack is being erected in a single lift, the designer shall also be informed as to the degree of pre-erection attachment of piping, ladders, and platforms, etc.
- 2) Unless otherwise noted in the datasheets, lifting trunnions shall be designed for one-time use.

- 3) Wherever derrick-supported flares are designed to allow the flare riser to be lowered (either as a single section or in multiple sections), the designer shall provide for the loads imposed on the flare riser and derrick by the intended plan of demounting.
- 4) Wherever a davit, located near the top of the flare stack, is used to lower the flare burner to grade, the designer shall determine and provide for the davit-imposed loads based on the intended plan for this operation.
- 5) When specified by the purchaser, temporary platforms with relevant support for erection activities at elevation shall be considered in the structural design. Lugs, brackets, or reinforcements for erection platforms shall be properly located and designed according to the erection method and sequence.
- j) Auxiliary loads—Auxiliary loads to the flare stack shall be incorporated into the structural design, e.g. those associated with attachment of blowers, drivers, and ducting as appropriate for air-assisted flares.
- k) Special loads—The purchaser shall record on the datasheets any additional loads that will be imposed on the flare stack/support structure.

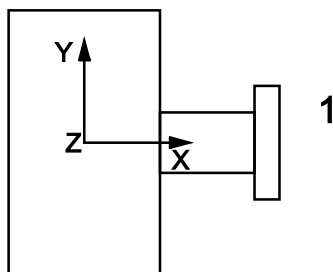
NOTE 1 Examples of special loads include the following:

- 1) loads from ice buildup;
- 2) hydrostatic testing of ancillary components;
- 3) loads imposed during transport;
- 4) dead loads including liquid in knockout drum, water seal, etc.;
- 5) hydraulic forces that are possible with blow-dry liquid seals;
- 6) pressure waves that are possible with staged flares.

NOTE 2 Hydraulic shock load is not generally considered for design.

Table 2—Allowable Forces and Moments for Flare Nozzles

Nozzle Size DN (NPS)	F_x		F_y		F_z		M_x		M_y		M_z	
	N	(lbf)	N	(lbf)	N	(lbf)	N·m	(ft·lbf)	N·m	(ft·lbf)	N·m	(ft·lbf)
50 (2)	445	100	890	200	890	200	475	350	339	250	339	250
100 (4)	890	200	1779	400	1779	400	813	600	610	450	610	450
125 (5)	1001	225	2002	450	2002	450	895	660	678	500	678	500
150 (6)	1112	250	2224	500	2224	500	990	730	746	550	746	550
200 (8)	1334	300	2669	600	2669	600	1166	860	881	650	881	650
250 (10)	1557	350	2891	650	2891	650	1261	930	949	700	949	700
300 (12)	1779	400	3114	700	3114	700	1356	1000	1017	750	1017	750
350 (14)	2003	450	3338	750	3338	750	1451	1070	1085	800	1085	800
400 (16)	2225	500	3560	800	3560	800	1546	1140	1153	850	1153	850
450 (18)	2448	550	3783	850	3783	850	1641	1210	1221	900	1221	900
500 (20)	2670	600	4005	900	4005	900	1736	1280	1289	950	1289	950
600 (24)	3115	700	4450	1000	4450	1000	1926	1420	1424	1050	1424	1050
700 (28)	3560	800	4895	1100	4895	1100	2116	1560	1560	1150	1560	1150
750 (30)	3783	850	5118	1150	5118	1150	2211	1630	1628	1200	1628	1200
800 (32)	4005	900	5340	1200	5340	1200	2306	1700	1695	1250	1695	1250
900 (36)	4450	1000	5785	1300	5785	1300	2496	1840	1831	1350	1831	1350
1000 (40)	4895	1100	6230	1400	6230	1400	2686	1980	1967	1450	1967	1450
1100 (44)	5340	1200	6675	1500	6675	1500	2875	2120	2102	1550	2120	1550
1200 (48)	5785	1300	7120	1600	7120	1600	3065	2260	2238	1650	2238	1650
1300 (52)	6230	1400	7565	1700	7565	1700	3255	2400	2374	1750	2374	1750
1400 (56)	6657	1500	8010	1800	8010	1800	3445	2540	2509	1850	2509	1850
1500 (60)	7120	1600	8455	1900	8455	1900	3635	2680	2645	1950	2645	1950

**Key**

1 Nozzle

^a Nozzle loads are applicable for the flare header to the gas riser/stack, but not applicable for auxiliary service piping (e.g. steam, pilot fuel, etc.). The location of the relief gas nozzle as a basis for design is 10 m (32.8 ft) above grade.

^b Values for nozzle sizes 50 mm (2 in.) to 300 mm (12 in.) are taken from API 560. For nozzles greater than 300 mm (12 in.), the values are extrapolated from this same source.

5.2 Design Details

The following design details shall be incorporated into the support structure design:

- a) Unless otherwise specified, stack deflection due to wind load or earthquake shall be as follows:
 - structures: 300 mm per 30 m (12 in. per 100 ft);
 - derrick-supported structures: 150 mm per 30 m (6 in. per 100 ft);
 - self-supported structures: 225 mm per 30 m (9 in. per 100 ft).
- b) Guyed stack sections in the form of a frustum of a cone shall be designed in accordance with API 2A-WSD.
- c) Field assembly of the stack sections shall be by welding, unless otherwise specified on the flare datasheets. Provisions for erection activities at elevations (e.g. lugs, brackets, or reinforcement for temporary platforms) shall be welded.

NOTE A flanged assembly may be used on multiple-section, demountable riser sections of the stack.

- d) Corrosion allowances:
 - 1) A minimum corrosion allowance of 1.6 mm ($1/16$ in.) for carbon steel components in contact with the relief gas stream shall be added to the minimum metal thickness necessary to meet the requirements of 5.1.
 - 2) No corrosion allowance is required on alloy steel portions of the stack, unless specifically noted on the datasheets.
 - 3) Nonalloy steel internal parts of the liquid seal or knockout drums that are normally in contact with the seal fluid or relief gas stream shall have the corrosion allowance applied to each side.
 - 4) No corrosion allowance is required for derrick structures and other metal objects that do not normally come into contact with the relief gas stream.
- e) The following requirements shall be incorporated when the support structure design includes the use of guy wires.
 - 1) Guy wire slope and initial tension shall take into account:
 - the elevation of the guy connections to the stack (there may be more than one connection elevation);
 - available guy wire anchor radius;
 - the range of stack temperatures, both ambient and process;
 - wind loads;
 - mass distribution.
 - 2) There are two types of cables used for guy wires: wire rope and structural bridge strand, with the following acceptable supply specifications.

— Wire rope, in accordance with:

- i) ISO 2408:2004, Quality B for 10 mm to 50 mm ($\frac{3}{8}$ in. to 2 in.) diameter, Class 6X36-IWRC with steel core;
- ii) ASTM A475-03, Class A for 16 mm ($\frac{5}{8}$ in.) diameter or less, with metallic core.

— Structural bridge strand, in accordance with:

- i) EN 12385-10 for 13 mm to 72 mm ($\frac{1}{2}$ in. to 3 in.) diameter, with zinc coating conforming to EN 10264-2:2002, Class A;
- ii) ASTM A586-04a, Class A, for diameters greater than or equal to 16 mm ($\frac{5}{8}$ in.).

NOTE Refer to ASME STS-1 for cable selection criteria.

- 3) End fittings, turnbuckles, rods, and pins shall have a load capacity suitable for the maximum guy wire tension expected. Guy wire hardware shall be strong enough to withstand a force at least equal to the minimum breaking force of the guy wire.
- 4) The initial guy wire tension shall not be less than 2 % or greater than 12.5 % of the maximum guy wire tension expected. Initial guy wire tension shall include a consideration of the ambient temperature variation and loads offset along the flare stack.
- 5) Turnbuckles or guy wire tension devices shall be located at the anchor end of the guy wire immediately above the anchorage. Locking devices shall be included with all turnbuckles and tension devices.
- 6) When guy wire deadmen (anchors) cannot be located symmetrically around the stack and at the same elevation, the analysis shall determine the load direction that provides the highest stress for all components, in addition to the design load analysis requirements in 5.1.

5.3 Flanges

- **5.3.1** When flanged flare burner connections are specified by the purchaser, flanges shall be as follows:
 - a) for DN 600 (NPS 24) and smaller burners: ASME B16.5, Class 150 RFSO or EN 1092-1:2007, PN 20 Type 01;
 - b) for sizes greater than DN 600 (NPS 24): forged flanges or fabricated plate flanges drilled to industry standard dimensions as specified in Table 3; for flange sizes greater than those shown in Table 3, follow the flare vendor's standard;
 - c) auxiliary connections such as those less than DN 600 (NPS 24) for steam and natural gas: flange ratings in accordance with ASME B16.5.

NOTE 1 See A.2.7.1 and A.2.7.2 for further guidance on flare burner and auxiliary connections.

NOTE 2 See 5.4 for flange metallurgical requirements.

- **5.3.2** When fabricated plate flanges are used for flare burner connections, the flange design calculations shall be made available by the vendor when specified by the purchaser.

5.3.3 Air ducting associated with air-assisted flares shall be assembled using the vendor's standard plate flanges including air connections at the flare burner.

- **5.3.4** When specified by the purchaser, the design calculations for the air ducting flanges shall be provided.

Table 3—Flange-bolting Dimensions for Flare Burners Larger than DN 600 (NPS 24)

Flare Burner Size at Connection ^a DN (NPS)	Bolt Circle Diameter mm (in.)	No. of Bolt Holes	Bolt Hole Diameter mm (in.)
650 (26)	758.8 (29.875)	28	22.2 (0.875)
700 (28)	809.6 (31.875)	28	22.2 (0.875)
750 (30)	866.8 (34.125)	36	22.2 (0.875)
800 (32)	917.6 (36.125)	36	22.2 (0.875)
850 (34)	974.7 (38.375)	36	25.4 (1.000)
900 (36)	1025.5 (40.375)	36	25.4 (1.000)
950 (38)	1076.3 (42.375)	36	25.4 (1.000)
1000 (40)	1127.1 (44.375)	40	25.4 (1.000)
1050 (42)	1190.6 (46.875)	40	28.6 (1.125)
1100 (44)	1241.4 (48.875)	40	28.6 (1.125)
1150 (46)	1292.2 (50.875)	40	28.6 (1.125)
1200 (48)	1343.0 (52.875)	44	28.6 (1.125)
1250 (50)	1393.8 (54.875)	44	28.6 (1.125)
1300 (52)	1454.2 (57.250)	44	31.8 (1.250)
1350 (54)	1505.0 (59.250)	44	31.8 (1.250)
1500 (60)	1657.4 (65.250)	48	31.8 (1.250)
^a Bolting dimensions are based on "Industry Standard" flanges, Class 175.			

- **5.3.5** When specified by the purchaser, measures shall be taken to prevent bolting from coming loose due to vibrations, etc.; see 4.6.5 Item o). For sonic tips (Mach >0.8), such measures are required.

5.4 Materials of Construction

5.4.1 Materials of construction shall be as specified in the flare datasheets. If a material is not specified, any portion of the flare stack that is normally exposed to the relief gases shall be of a material that is compatible with the gas composition as stated in the flare datasheets. In addition, the materials normally exposed to the relief gases shall be compatible with the most extreme maximum and minimum temperatures imposed by the relief gases, the ambient temperatures, or the design temperature(s) specified in the flare datasheets.

NOTE Portions of the flare stack or the support structure that are not normally exposed to the relief gases may be of a material suitable for their purpose.

5.4.2 The flare burner inlet flange shall meet the metallurgical requirements of the flare stack.

NOTE As an example, with a carbon steel stack, a carbon steel burner flange is acceptable.

5.4.3 Welded attachments to the portions of the stack that carry the relief gases shall be of a material that is compatible with the material of the respective gas-containing portion.

- **5.4.4** The purchaser shall specify whether the service is sour (i.e. whether sulfide stress cracking is possible) in accordance with NACE MR0103/ISO 17945 for other applications [e.g. oil refineries, liquefied natural gas (LNG) plants, and chemical plants], or in accordance with NACE MR0175/ISO 15156 (all parts) for oil and gas production facilities and natural gas industries, in which case all materials in contact with the process fluid shall meet the requirements of that standard.

5.4.5 Derrick structures shall be designed for fabrication from members that are structural shapes, pipe or plate or any combination thereof.

5.4.6 Guy wires, as set forth in 5.2 Item e), shall be all metallic, galvanized steel wire rope or structural bridge strand. Guy wire hardware shall be galvanized. Galvanizing shall be at least equivalent to the guy wires on which they are used.

5.4.7 Materials used for portions of the support structure that are designated as being designed according to the pressure design code shall be in accordance with material specification requirements of that code.

5.5 Welding

- **5.5.1** Relief-gas-containing portions of the support structure shall be fabricated in accordance with the welding requirements of the structural design code or pressure design code.

5.5.2 If the bottom portion of the stack is designed in accordance with the pressure design code, then the fabrication of that portion shall be governed by the welding qualification requirements of the pressure design code.

- **5.5.3** Non-gas-containing portions of the support structure shall be fabricated in accordance with the welding requirements of either the structural design code or the pressure design code.

5.6 Inspection

5.6.1 Relief-gas-containing portions of the support structure shall be inspected in accordance with the following requirements.

- a) The structural design code or pressure design code shall be used for nondestructive testing and inspection procedures, techniques, standards for acceptance, inspector qualification, and inspections.
- b) All welds shall be visually inspected during the welding operation and again after the work is completed to determine satisfactory penetration of weld metal fusion and satisfactory operator performance. After the welding is complete, welds shall be cleaned before the inspector performs the final weld inspection. The inspector shall pay particular attention to surface cracking, surface porosity, surface slag inclusion, undercut, overlap, gas pockets, and size of weld. Defective welding shall be corrected according to the applicable code requirements.
- c) Radiographic weld inspection shall be performed on all full-penetration structural butt welds to the extent specified in the following requirement.
 - A minimum of one radiograph per each three shop circumferential seams on the relief-gas-containing structural shell shall be carried out at the vertical weld intersection.
- d) Other types of nondestructive testing may be utilized if specified on the flare datasheets.
- e) Hydrostatic testing is not required, unless specified on the flare datasheets.

- f) If the bottom portion of the stack is to be designed and fabricated in accordance with the pressure design code, then the bottom portion shall be inspected in accordance with that code. In the case where the bottom portion is a code vessel, the upper (non-code) portion shall be inspected as set forth in Items a) through e), above. Hydrostatic testing is not required, unless specified by the flare datasheets or a code stamp is specified.

5.6.2 Non-gas-containing portions of the support structure shall be inspected visually using the procedure set forth in 5.6.1 Item b).

5.7 Surface Preparation and Protection

5.7.1 Carbon steel external surfaces of stack and piping that can be directly exposed to weather shall be cleaned in accordance with SSPC SP 6/NACE No. 3. The cleaned surfaces shall then be primed with one coat of inorganic zinc primer to a minimum dry film thickness of 75 μm (0.003 in.). Surfaces shall be painted in conditions in accordance with vendor's recommendations on temperature and relative humidity.

5.7.2 Components of derricks, ladders, platforms, etc. shall be prepared and galvanized in accordance with the applicable sections of ASTM A123/123M, ASTM A143/143M, ASTM A153/153M, ASTM A384/384M, and ASTM A385/385M. Bolts joining galvanized sections shall be galvanized in accordance with or ASTM A153/153M or zinc coated in accordance with ASTM B633.

5.7.3 Unless otherwise specified, alloy steel components do not require surface preparation or protection.

- **5.7.4** When specified by the purchaser, ladders and platforms may be painted as an alternative to galvanizing.

5.8 Attachments

5.8.1 Attachments to the support structure shall not be supported by the flare burner.

NOTE Typical attachments to the support structure include piping for steam, pilot gas and assist gas, buoyancy seal drain, muffler drains, pilot ignition, electrical conduits, and instrumentation conduits.

5.8.2 The flare structural analysis shall include piping loads and wind and earthquake loads in consideration of the attachments.

5.9 Aircraft Warning Lighting

5.9.1 Marking on the support structure shall be in accordance with the code specified by the local aviation authority.

NOTE Markings are typically the national incorporation of ICAO, Annex 14.

5.9.2 Warning lights on the structure shall be fixed or retractable. Warning lights and electrical cables shall be shielded from radiation as necessary and designed for appropriate temperature.

NOTE Depending on the type of lighting used and the height of the structure, special painting of the structure may be required.

5.10 Platforms and Ladders

- **5.10.1** The purchaser shall specify whether platforms are required. A ladder is the preferred means of access to a platform, but alternative access can be achieved via a crane basket or helicopter. The purchaser shall specify whether ladders are required.

NOTE For guidance on the provision of ladders and platforms, refer to A.1.9.

5.10.2 Ladders or platforms shall not be attached to the flare burner.

5.10.3 Platform decking shall be open grating, designed for a uniformly distributed load of 500 kg/m² (100 lb/ft²) and a point load of 450 kg (1000 lb).

5.10.4 Platforms and ladders shall be hot-dip galvanized carbon steel or shall be stainless steel.

5.10.5 Design of the ladders and platforms shall comply with local regulations.

5.10.6 Ladder safety gates in areas exposed to high flame radiation shall be galvanized or painted steel.

6 Mechanical Details—Enclosed-flame Flares

6.1 Combustion Chamber

6.1.1 The combustion chamber design shall conform to an acceptable code (e.g. ASCE 7 or EN 1993), using the site parameters for wind speed, rain, exposure factor, seismic factor, etc.

NOTE 1 Mechanically, the combustion chamber is a self-supported stack. Ladders and service platforms for access to enclosed-flame flare instruments and stack emission sampling can impact the structural design of the combustion chamber.

NOTE 2 For further guidance on the mechanical considerations for enclosed-flame flares, refer to C.2.3.

6.1.2 The stack design and material shall accommodate the thermal requirements of the enclosed flame.

6.1.3 If the exterior frame of the combustion chamber is painted and exceeds 205 °C (400 °F) during design operation, an internal refractory lining shall be provided to limit the temperature of the external shell. Where refractory lining is applicable, the refractory system design and material selections shall consider:

- a) peak operating temperature (with a safety factor);
- b) exterior shell temperature limits for materials and coating;
- c) thermal cycling with rapid increase and decrease of combustion chamber operating temperature with changes in relief gas flows to the flare;
- d) velocity of the airflow into the combustion chamber and the flue gas velocity out of the combustion chamber;
- e) environmental exposure to rain, wind, etc.;
- f) refractory weight, friability, expansion/contraction factors, durability, maintainability, and service life;
- g) refractory curing schedules and start-up plans;
- h) compatibility with waste gas composition;
- i) the need for an internal protective coating under the refractory lining.

NOTE Internally, the combustion chamber temperature is established by the flow of relief gases through the burners and how combustion and quench air are supplied to the flames. Most enclosed-flame flares are designed to operate with a maximum internal temperature of about 980 °C to 1090 °C (1800 °F to 2000 °F).

6.1.4 Personnel protection shall be provided adjacent to the combustion chamber when surface temperatures exceed 80 °C (175 °F) for areas for personnel access during operation.

6.2 Burners

6.2.1 The design of burners for enclosed-flame flares is considered proprietary to the vendor. However, inherent to all enclosed-flame flares, the burner design shall:

- a) be engineered for the relief gas flow rates and compositions and possible pressure and temperature ranges of the gases;
- b) consider the utilities that are available for burner operation;
- c) consider known likely operating conditions;
- d) operate at all airflow rates and velocities within the design range;
- e) achieve the desired level of combustion emissions with flame volumes that are contained within the combustion chamber;
- f) have a stable flame within the range of operating airflow rates and velocities in the combustion chamber design;
- g) consider cross-lighting capability when there is more than one burner, unless each burner has an individual pilot;
- h) include the required airflow rate within the design for the combustion chamber;
- i) produce a stable flame for all relief gas flow conditions and compositions within the design parameters;
- j) not induce any excessive combustion rumble that can trigger excessive noise and resonance from the combustion chamber.

NOTE Experience with a burner design operating as part of a complete design of an enclosed-flame flare is recommended.

6.2.2 The selection of the flare burner assembly connection shall take into account the composition and temperature of the relief gas and possible exposure to high thermal loads from proximity to the flames or the combustion chamber. Connection types include screwed fittings, flanged fittings, or welded.

NOTE Temperature and vibration effects can loosen some screwed and flanged connections.

6.2.3 Steam, air, or other auxiliary connections to the burner shall take into consideration their location relative to the flame and combustion chamber.

6.3 Burner Piping

6.3.1 Burner piping shall conform to the pressure design code (e.g. ASME B31.3, as a minimum).

6.3.2 The piping shall be engineered to accommodate thermal expansion of the combustion chamber.

6.3.3 Piping material selection shall be compatible with the relief gas composition and temperature.

6.3.4 The piping design shall maintain an acceptable burner position with respect to the air inlet to the combustion chamber.

6.4 Pilots

6.4.1 Each stage shall be equipped with at least one pilot.

NOTE 1 The design may have additional pilots based on process demands and flare design.

NOTE 2 For stage 1, this may include one pilot per burner.

- **6.4.2** The number of pilots per stage shall be defined by the vendor and approved by the purchaser.

NOTE 1 Depending on the burner spacing and design, a single pilot may be used to light one main burner and cross-ignite other burners.

NOTE 2 Many of the pilot and pilot ignition details covered in A.3 and A.4 are applicable to enclosed-flame flares.

NOTE 3 Refer to C.2.6 for further guidance on design and specification of pilots for enclosed-flame flares.

6.5 Wind Fence

6.5.1 The wind fence structural design shall conform to an acceptable code (e.g. ASCE 7 or EN 1993) using the site parameters for wind speed, rain, exposure factor, seismic factor, etc.

6.5.2 The wind fence design shall withstand heat, mitigate wind effects, limit access, and provide acoustical dampening.

NOTE Wind fence enclosures of steel and concrete can be utilized. Wind fence designs can also control reflected light from the combustion chamber.

6.5.3 The wind fence design shall provide for an external surface temperature acceptable for worker exposure.

6.5.4 Securable doors or manways shall be provided to limit access to the inside of the wind fence.

6.5.5 The size of the access door shall be sized for inspection, maintenance, and repairs. This can be also achieved through other methods, such as removal of wind fence panels.

6.5.6 Enclosed-flame flares shall also be equipped with at least one viewing port for observation while the flare is in service. View port(s) may be installed on the wind fence or on the combustion chamber itself if the design allows safe access to this location.

NOTE The number of doors and view ports is selected based on inspection and access requirements.

6.6 Radiation Shielding

6.6.1 All piping subject to thermal radiation, upstream of the individual burner risers, shall be adequately protected.

NOTE Such piping is typically covered with loose gravel or metallic shielding.

6.6.2 The covered piping shall be suitably protected from environmental effects and corrosion.

Annex A (informative)

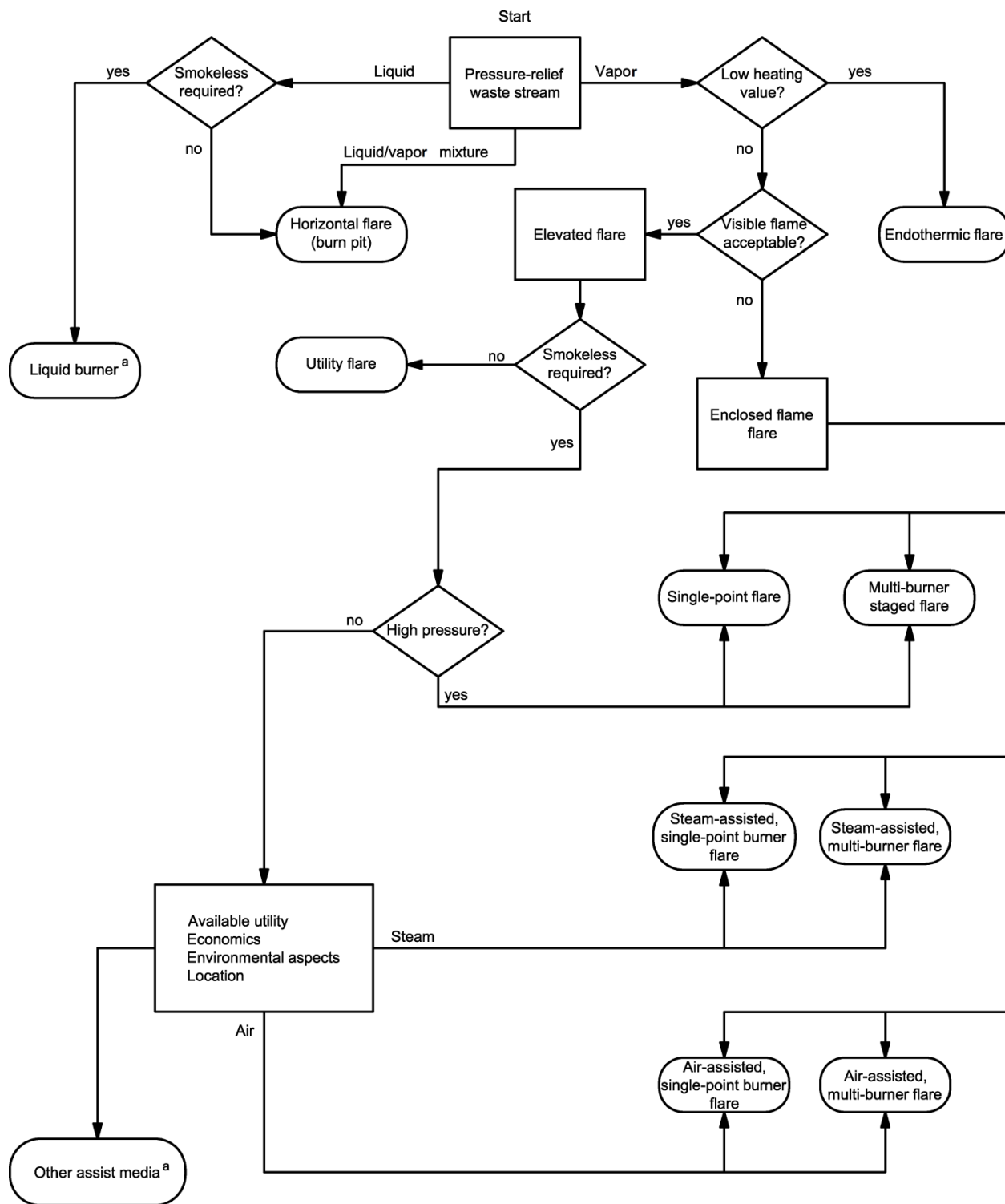
Flare Equipment Overview

A.1 Types of Flares and Components

A.1.1 General

Refer to Figure A.1 for a general flare type selection guide. Within each general type of flare, various alternatives and proprietary design aspects can exist.

Flares can be grouped into the major categories described in A.1.2 to A.1.7.



Key

^a Liquid burners and other assist media, such as high-pressure gas or water, are not typically used in refinery and petrochemical plant services, but have been used in production facilities. These technologies are outside the scope of this standard. See API 521 for considerations for liquid disposal.

Figure A.1—Flare Type Selection

A.1.2 Elevated

A.1.2.1 General

The most common type of flare in use is an elevated flare. With an elevated flare, the flare burner is mounted on top of the stack. The height of the stack is directly related to ground-level radiation and flare plume dispersion.

There are several types of support methods for elevated flares, as described in A.1.2.2 to A.1.2.4.

A.1.2.2 Self-supported

A free-standing flare stack supports the elevated flare burner without the use of guys or a derrick support. Self-supported stacks are often used where plot space is limited. Economics will typically limit the self-supported stack height to a maximum of 100 m (330 ft). See Figure A.2 for a typical self-supported structure.

A.1.2.3 Guyed

An elevated flare stack supports the flare burner using cables. Cables are attached to the flare stack at one or more elevations to limit the deflection of the structure. The cables (guy wires) are typically positioned in a triangular plan to provide strong support. Guy wire supported stacks typically require a larger land area than self-supported or derrick-supported stacks. Extreme process temperatures require special considerations when designing guy wires. This may include the use of a guy wire-supported derrick structure. The guy wire radius is typically equal to one-half the overall stack height. The guy-wired stack height is normally limited to 250 m (800 ft). See Figure A.3 for a typical guy-supported structure.

A.1.2.4 Derrick Supported

A steel trussed structure of one of the following types supports one or more flare risers/stacks. A derrick is used only on a larger stack where a self-supported design is not practical, or available land area precludes the use of a guy wire design. Some derrick designs allow the flare stack and burner to be lowered to grade on movable trolleys for inspection and maintenance. The self-lowering design is especially useful when multiple stacks are installed on the same derrick. In locations where land is not available, the multi-flare stack derrick can be used:

- a) Fixed derrick—The stack is permanently supported by the structure. The flare burner can be maintained by lowering it with a davit or crane. See Figure A.4 for a typical fixed derrick support structure.
- b) Demountable derrick (multiple-section riser)—A derrick with the riser(s) mounted to permit lowering the flare burner to grade for service. The riser is typically assembled in sections that can be raised and lowered using a track and guide system. This allows grade-level access to the flare burner. Many demountable derricks are designed to support multiple risers with their flare burners. Such a derrick can be designed so that all the flares, except the one being maintained, can be operational during the maintenance.

Figure A.5 illustrates a derrick with a multiple-section demountable riser: in the normal operation position [Figure A.5 a)], with upper sections slightly lifted at the start of the lowering operation [Figure A.5 b)], during the process of lowering the bottom section [Figure A.5 c)], and with the bottom section completely lowered [Figure A.5 d)].

- c) Demountable derrick (with single-section riser)—A derrick with a single riser utilizing a track and guide system that allows the lowering of the flare riser and burner to grade in a single piece.

Figure A.6 illustrates a derrick with a single-section demountable riser: (1) in the normal operating position, (2) during the lowering process, and (3) completely lowered to allow grade-level access to the flare burner.

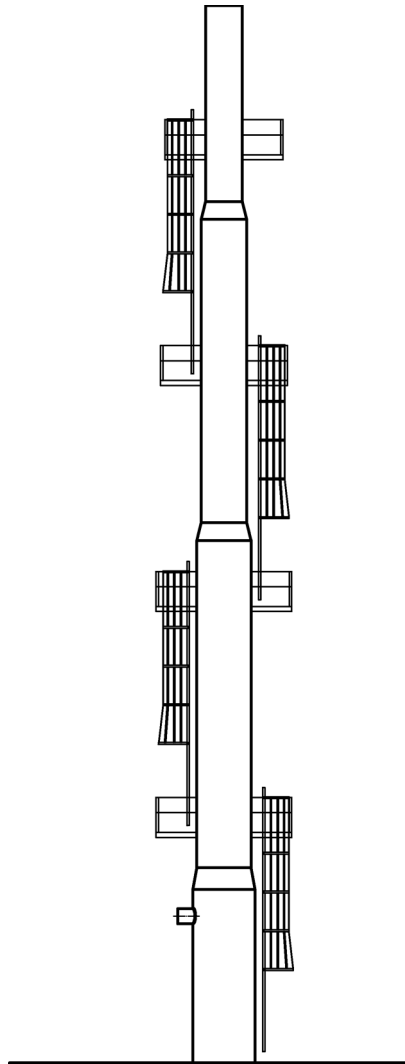


Figure A.2—Self-supported Structure

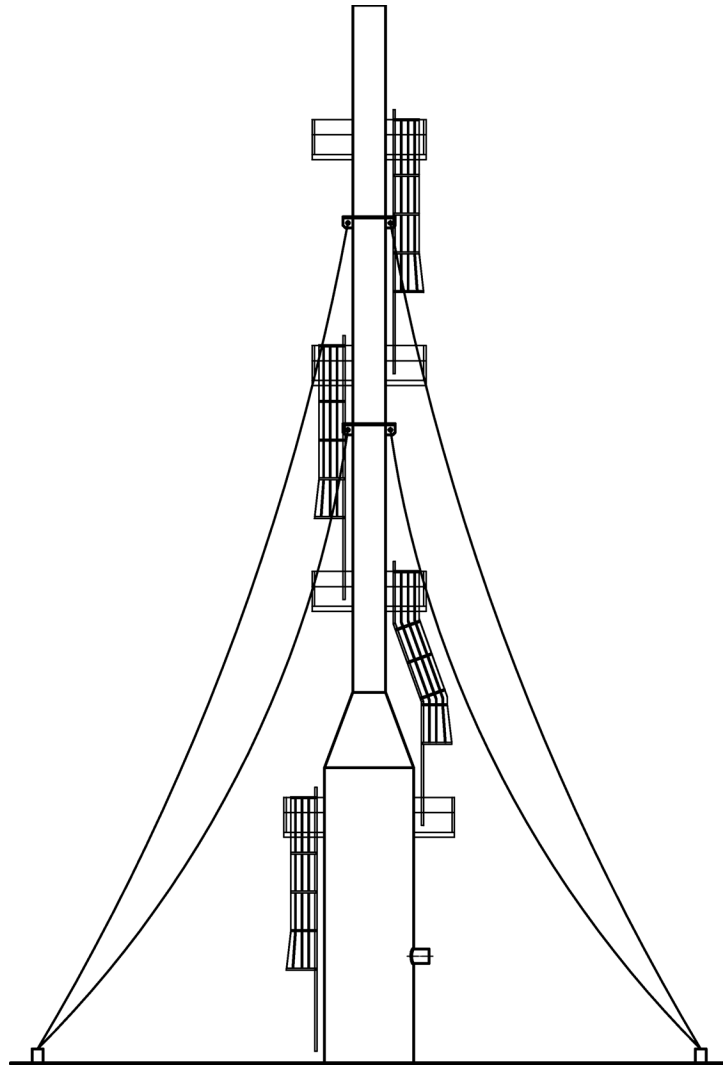


Figure A.3—Guyed-support Structure

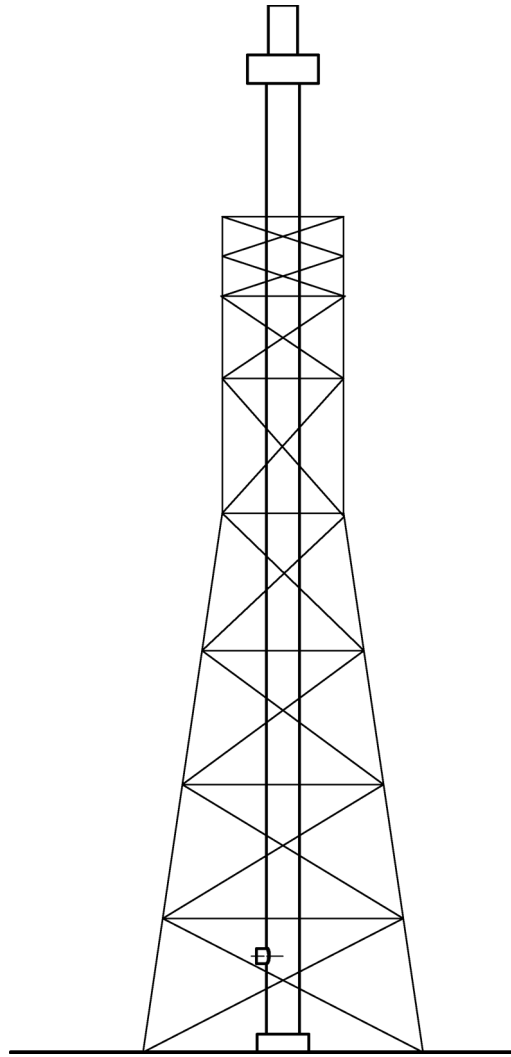
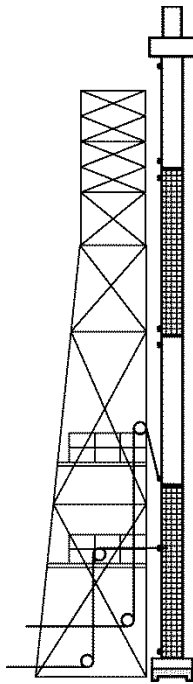
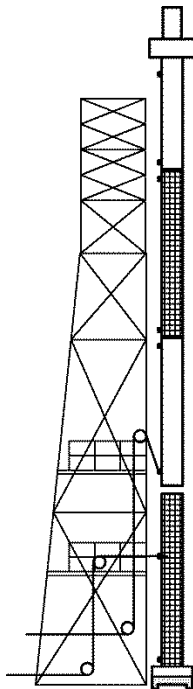


Figure A.4—Typical Fixed Derrick Support Structure

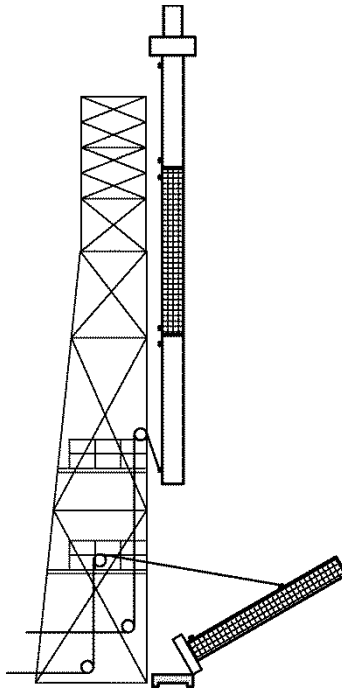


a) In the normal operating position

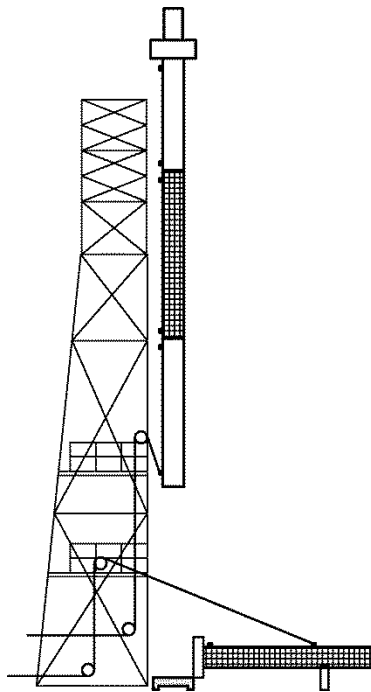


b) With upper sections slightly lifted at the start of the lowering operation

Figure A.5—Demountable Derrick with Multiple-section Riser



c) During the process of lowering the bottom section



d) With the bottom section completely lowered

Figure A.5—Demountable Derrick with Multiple-section Riser (*continued*)