INTERNATIONAL STANDARD

ISO 25457

First edition
2008-12-15

Petroleum, petrochemical and natural gas industries — Flare details for general refinery and petrochemical service

Industries du pétrole, de la pétrochimie et du gaz naturel — Détails sur les torches d'usage général dans les raffineries et dans les usines pétrochimiques

Reference number
ISO 25457:2008(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 25457 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

Introduction

Users of this International Standard should be aware that further or differing requirements may be needed for individual applications. This International 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 International Standard and provide details.

In International Standards, the SI system of units is used. Where practical in this International Standard, US Customary units are included in brackets for information.

A bullet (●) at the beginning of a clause or subclause indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on data sheets (see examples in Annex E) or stated in the enquiry or purchase order.

Petroleum, petrochemical and natural gas industries — Flare details for general refinery and petrochemical service

1 Scope

This International 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 vapour-depressurizing systems for petroleum, petrochemical and natural gas industries.

Although this International Standard is primarily intended for new flares and related equipment, it is also possible to use it to evaluate existing flare facilities.

Annexes A, B and C provide further guidance and best practices for the selection, specification and mechanical details for flares and on the design, operation and maintenance of flare combustion and related equipment.

Annex D explains how to use the data sheets provided in Annex E; it is intended that these data sheets be used to communicate and record design information.

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.

ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods*

ISO 2408:2004, *Steel wire ropes for general purposes — Minimum requirements*

ISO 8501-1:2007, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 10684, *Fasteners — Hot dip galvanized coatings*

ISO 13705:2006, *Petroleum, petrochemical and natural gas industries — Fired heaters for general refinery service*

ISO 15156 (all parts), *Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production*

ISO 23251, *Petroleum, petrochemical and natural gas industries — Pressure-relieving and depressuring systems*

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

EN 10264-2:2002[1)], *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*

API RP 2A WSD:2000[2)], *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms — Working Stress Design*

ASME B16.5-2003[3)], *Pipe Flanges and Flanged Fittings*

ASME STS-1, *Steel Stacks*

ASTM A 123/A123M[4)], *Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*

ASTM A 143/A143M, *Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement*

ASTM A 153/A153M, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*

ASTM A 384/A384M, *Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies*

ASTM A 385, *Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip)*

ASTM A 475-03, *Standard Specification for Zinc-Coated Steel Wire Strand*

ASTM A 586-04, *Standard Specification for Zinc-Coated Parallel and Helical Steel Wire Structural Strand*

ASTM B 633, *Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel*

NACE MR0103:07[5)], *Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*

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

3 Terms and definitions

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

3.1
air seal
purge reduction device
device used to minimize or eliminate the intrusion of air back into the riser from the exit

EXAMPLE Buoyancy seal, orifice seal, velocity seal.

---

1) Comité Européen de Normalisation, 36, rue de Stassart, B-1050 Brussels, Belgium.

2) American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005, USA.

3) American Society of Mechanical Engineers, 3 Park Avenue, New York, NY 10017, USA.

4) American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA.

5) NACE International, P.O. Box 218340, Houston, TX 77218-8340, USA.

6) The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, PA 15222-4643, USA.

3.2
assist gas
fuel 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.

3.3
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

3.4
blowoff
loss of a stable flame where the flame is lifted above the burner, which occurs when the fuel velocity exceeds the flame velocity

3.5
buoyancy seal
diffusion seal
dry vapour 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.

3.6
burnback
internal burning within the burner

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

3.7
burn-pit flare
open excavation, normally equipped with a horizontal flare burner that can handle liquid as well as gaseous hydrocarbons

3.8
burning velocity
flame velocity
speed at which a flame front travels into an unburned combustible mixture

3.9
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.

3.10
combustion air
air required to combust the flare gases

3.11
combustion efficiency
percentage of the combustible fluid totally oxidized in the burner

NOTE In the case of hydrocarbons, combustion efficiency is the mass percent of carbon in the original fluid that oxidizes completely to CO_2.

3.12
condensable gas
vapour that can condense at the temperature and pressure expected in a flare header during or after a flaring event

3.13
cryogenic service
systems that may be called upon to handle waste gas below –40 °C (–40 °F)

3.14
derrick support
support system for the elevated flare riser, normally used for very tall flares or when plot space is limited

NOTE Various derrick-supported arrangements are available: a fixed system has its riser permanently supported to the derrick; a demountable derrick has multiple riser sections that are designed such that they can be lowered and removed to permit lowering of the flare burner to grade; a demountable derrick with one fixed riser provides for a single-piece design that can be lowered to grade as a single component.

3.15
design flare capacity
maximum design flow to the flare

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

3.16
destruction efficiency
mass percent of the combustible vapour that is at least partially oxidized

NOTE In the case of a hydrocarbon, destruction efficiency is the mass percentage of carbon in the fluid vapour that oxidizes to CO or CO_2.

3.17
detached stable flame
flame that is not in contact with the flare burner itself but burns with a stable flame-front in the vicinity of the flare burner

3.18
direct ignition
ignition of a flare flame by a high-energy source rather than by a pilot flame

3.19
dispersion
scattering of the products of combustion over a wide area to reduce ground-level concentrations of the combustion products

3.20
enclosed flare
flare enclosure with one or more burners arranged in such a manner that the flame is not directly visible

3.21
endothermic flare
flare that utilizes outside energy, usually assist or enrichment gas, to maintain the combustion reaction

3.22
enrichment
process of adding assist gas to the relief gas

3.23
elevated flare
flare where the burner is raised high above ground level to reduce radiation intensity and to aid in dispersion

3.24
excess air
air provided to a flame in excess of stoichiometric requirements

3.25
exit velocity
velocity at which the design flare capacity exits the burner

NOTE The exit velocity is usually expressed as metres per second (feet per second) or as a fraction of the Mach number for the fluid.

3.26
flame detection system
flame monitor
system that verifies a flame is present

3.27
flame front generator
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.

3.28
flame retention device
physical device meant to prevent flame blowoff from a flare burner

3.29
flare
device or system used to safely dispose of relief fluids in an environmentally compliant manner through the use of combustion

3.30
flare burner
flare tip
part of the flare where fuel 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 measures for flame stabilization, most often of proprietary design.

3.31
flare header
piping system that collects and delivers the relief gases to the flare

3.32
flare stack
flare boom
flare tower
mechanical device upon which an elevated flare burner is mounted

3.33
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

3.34
ground flare
non-elevated flare

NOTE A ground flare is normally an enclosed flare but may also refer to a ground multi-burner flare or a burnpit.

3.35
guyed flare
elevated flare with the riser kept from overturning using cables

NOTE A typical guyed flare is shown in Figure A.2.

3.36
heat release
total heat liberated by combustion of the relief gases based on the lower heating value

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

3.37
higher heating value
HHV
gross heating value
total heat obtained from the combustion of a specified fuel at 16 °C (60 °F)

NOTE The higher heating value includes the latent heat of vaporization of water in the combustion products (including the water already present in the flare gas).

3.38
lower heating value
LHV
net heating value
higher heating value minus the latent heat of vaporization of the water (both the water formed in the combustion products and that already present in the flare gas)

3.39
knockout drum
vessel in the flare header designed to remove and store condensed and entrained liquids from the relief gases

3.40
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

3.41
Mach number
ratio of a fluid’s velocity, measured relative to some obstacle or geometric figure, divided by the speed at which sound waves propagate through the fluid

3.42
manifold
device for the collection and/or distribution of a fluid to or from multiple flow paths

3.43
multi-burner flare
group of burners designed to burn all or a portion of the design flow capacity, which are often arranged in stages to facilitate better burning

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

3.44
muffler
device that mitigates noise

3.45
multi-point flare
single flare burner with multiple separate exits

3.46
opacity
degree of non-transparency to rays of light

NOTE The opacity is quantified by the Ringelmann number.

3.47
pilot
small, continuously operating burner that provides ignition energy to ignite and/or stabilize combustion of the flared gases

3.48
pin-actuated device
non-reclosing pressure-relief device actuated by static pressure and designed to function by buckling or breaking a pin that holds a piston or plug in place; upon buckling or breaking of the pin, the piston or plug instantly moves to its full open position

3.49
pressure design code
recognized pressure equipment standard specified or agreed by the purchaser

EXAMPLES ASME VIII or EN 13445 (all parts) for pressure vessels; ISO 15649, EN 13480 (all parts) or ANSI/ASME B31.3 for piping.

3.50
purge gas
fuel gas or non-condensable inert gas added to the flare header to mitigate air ingress and burnback

3.51
radiation intensity
radiant heat transfer rate from the flare flame

NOTE The rate is usually considered at grade level.

3.52
relief gas
waste gas
flared gas
waste vapour
gas or vapour vented or relieved into a flare header for conveyance to a flare

3.53
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.

3.54
riser
pipe or other conduit that conveys the relief gas, combustion air, etc. to the flare burner of an elevated flare

3.55
smokeless capacity
range of flow to a flare burner that can be burned without smoke

NOTE The term without smoke can be quantified using the **Ringelmann number** (3.53).

3.56
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 relief-gas flow

3.57
stoichiometric air
chemically correct quantity of air, i.e., a quantity capable of perfect combustion with no unused fuel or air

3.58
structural design code
recognized structural standard specified or agreed by the purchaser

EXAMPLES AISC S302, ASCE 7, AWS D1.1/D1.1M.

3.59
supplemental gas
fuel gas burned external to a flare burner in order to facilitate the burning of low-heating-value relief gas

3.60
thermocouples
temperature-measuring devices used to detect whether the pilot is in operation

3.61
velocity seal
orifice seal
dry vapour seal that minimizes the required purge gas needed to protect against air infiltration into the flare burner exit

3.62
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 non-visible to the neighbors

See Figure A.7.

3.63
windshield
device used to protect the down-wind side of an elevated flare burner from direct flame impingement

NOTE Windshields are also integral to the design of pilots to avoid flame-outs during bad/stormy weather.

4 Design

4.1 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 vapour-depressurizing systems. Being critical to the safety of an operating plant, a flare shall be continuously available with high reliability and capable of its intended performance through all operating-plant emergency conditions, including a site-wide general power failure. The flare and related mechanical components shall be designed to operate and properly perform for the specified service conditions for a minimum of five years without the need for an outage of the operating facility.

Although flare availability and reliability are strongly dependent on the design of the related mechanical equipment, proper training, installation, commissioning, and operating and maintenance practices are critical to ensuring the safety of plant personnel, the operating facility and the general public. Management systems shall be in place which

a) clearly document the intended capacity, performance and operational limitations of the pressure-relieving and vapour-depressurizing systems and flare,

b) provide operating procedures and operator training, and

c) provide planned and routine maintenance of components critical to the safety and operating goals.

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 to exceed the maximum permissible.

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

A flare design basis is developed in consideration of the performance expectations, the functional requirements and mechanical details required to achieve the safety and operating goals established for each application. In 4.2 to 4.11, objectives are identified that establish the safety and operating goals together with the functional requirements that enable the objectives to be achieved. Clauses 5 and 6 provide functional requirements more specific to the arrangement and mechanical details of design.

The functional requirements in this International Standard are supported by the technical guidance provided in Annexes A, B and C. 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.

The finalized basis of design shall be recorded on data sheets (e.g., those provided in Annex E) in order to properly communicate requirements and preserve design information. Annex D provides instructions for completing the flare data sheets in Annex E.

4.2 System design

4.2.1 Objective

The objective is to identify fundamental requirements, specific design criteria and information consistent with the delivery of the critical safety and operating goals of the specific flare under design.

4.2.2 Functional requirements

Fundamental system design requirements are established primarily in accordance with ISO 23251, from which the following aspects shall be defined on the data sheets:

— design-flow cases from the pressure-relieving and vapour-depressurizing system, including maximum continuous case and maximum intermittent case;

— flare staging requirement and method;

— allowable flare-burner exit velocity;

— system hydraulics with respect to allowable pressure drop, static pressure and diameter of the flare;

— environmental performance requirements related to smokeless capacity, opacity limits and permissible noise limits;

— operating performance, such as peak radiation intensity at grade;

— functional description of the intended system operation;

— selection of major system components that can be integral to the flare, such as a knockout drum, liquid seal, buoyancy seal, purge-reduction device, etc.;

— site and ambient design conditions; and

— utilities available.

4.3 Process definition

4.3.1 Objective

To provide a clear process definition for the flare ensuring all capacity and process stream characterization information relevant to the system performance and mechanical design considerations are provided.

4.3.2 Functional requirements

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. In consideration that various operating or pressure-relieving cases can individually define various aspects of the design, i.e. hydraulic capacity, ground-level radiation, aeration requirement for the defined smokeless capacity, requirement for dilution gas, design metal temperature, thermal expansion, etc., multiple cases together with expected duration and frequency should be provided to permit the designer to determine which cases control the design.

The potential for liquid introduction or the condensation of hydrocarbons, or the formation of hydrates in the flare header or flare riser, which can be carried to the combustion zone, shall be considered by both the user and the flare designer. 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. ISO 23251 gives further guidance on the maximum droplet size for different types of burners.

Flare-system knockout-drum design and heat-tracing systems downstream of the knockout drum shall be designed in consideration of these potential problems.

Process definition is primarily established in ISO 23251.

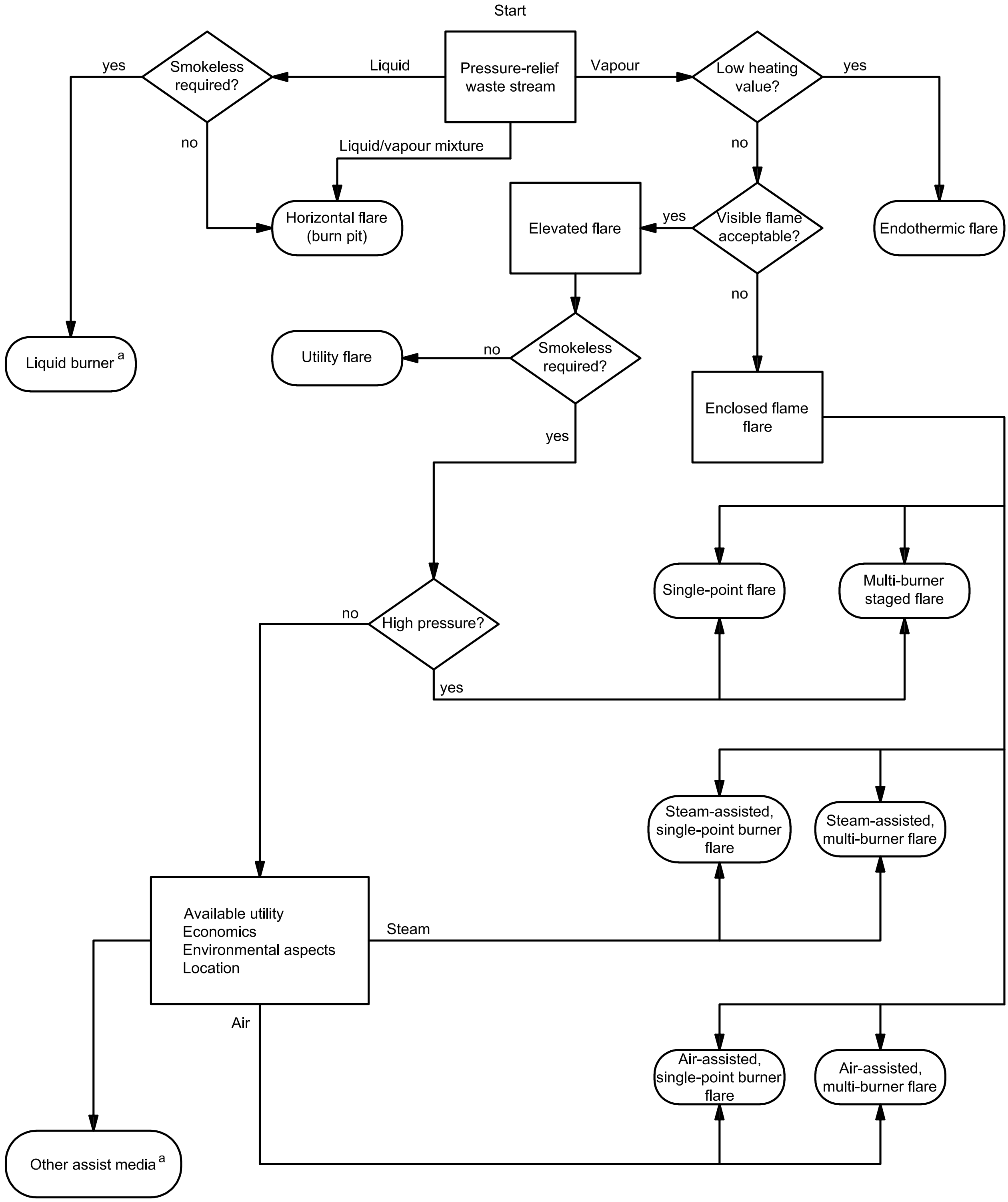
4.4 Types of flares

4.4.1 Objective

To identify and select the most appropriate type and configuration of a flare.

4.4.2 Functional requirements

Through an understanding of the process, performance and operability needs 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 International Standard. Refer to Figure 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 data sheets in Annex E and instructions on their use in Annex D.



[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 International Standard.

Figure 1 — Flare type selection

For further guidance on the types of flares, the mechanical details and the requirements of design for each, refer to Clauses 5 and 6 and Annexes A, B and C. Decisions on functional requirements shall be documented in the data sheets.

4.5 Flare burners

4.5.1 Objective

The objective is to identify the critical performance attributes for a flare burner.

4.5.2 Functional requirements

The type of flare and configuration is primarily established through consideration and application of the procedures, practices and recommendations of this International Standard. The most critical mechanical component integral to all flare types is the flare burner, with which all aspects of safe, reliable and efficient discharge and combustion of relief gases from the flare system are associated. The integrity and reliability of this component has a direct effect on the operability and run length between maintenance intervals for the facility. A flare burner supplied in accordance with this International Standard shall perform as specified under the defined service conditions for a minimum of five years when installed and operated in accordance with the manufacturer'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 blow-off.
- Air or steam injection, if applied, shall not disrupt the basic flame stabilization mechanisms of the flare burner.
- 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 International Standard.

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.

4.6 Mechanical design

4.6.1 Objective

To define the requirements for the design, fabrication, inspection and testing of the mechanical components of the flare.

4.6.2 Functional requirements

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 International 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 International 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.

If the flare mechanical design involves both pressure and structural design codes (e.g. self-supported or guyed flares), then the more severe shall govern.

● d) The purchaser shall specify the design temperature and design pressure.

For uninsulated flare risers, it is not necessary to consider that the maximum design temperature and wind loads apply simultaneously because of the cooling effect of the wind. For the design wind case, a credible metal temperature under design wind conditions shall be established, listed on the data sheet and used in the design.

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

Further guidance on metal temperature considerations is given in D.3.3, Form Elev 4.

The following shall be taken into account in the mechanical design:

— flared stream temperature, pressure and composition;

— corrosive nature and liquid content of the flared stream;

— ambient conditions;

— site conditions;

— wind, snow and ice loading;

— seismic loading;

— jet loads associated with high-velocity flare burners;

— cyclic loading, vibration (fatigue);

— hydraulic forces, as are possible with blow-dry liquid seals;

— pressure waves, as are possible with staged flares;

— proximity to equipment, structures, thoroughfares and site boundaries;

— maintenance and inspection criteria;

— contraction/expansion of stack due to ambient or process changes;

— pressure due to flashback, if specified by the purchaser.

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

4.7 Pilots

4.7.1 Objective

The objective is to reliably light the flare burner and maintain stable combustion throughout the full range of process conditions, including under severe weather conditions, without the requirement for maintenance for at least five years of operation, unless the pilot is accessible for on-stream maintenance.

NOTE It is recognized that in some extreme services, such as burn-pit flares, this five-year lifetime might be unachievable.

4.7.2 Functional requirements

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.

— Pilots shall be continuously burning.

— Pilots shall reliably light the flare flame on single- and multi-burner flares.

— Minimum pilot heat release shall be 13,2 kW (45 000 Btu/h).

— Pilots shall remain lit even if the flaring gases are not flammable.

— Pilots shall remain lit and capable of being relit 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. A typical test protocol is given in Clause A.6.

— The minimum number of pilots shall be in accordance with Table 1.

Table 1 — Number of pilots for a single-point flare

Minimum number of pilots	**Flare burner outlet diameter** (DN)	**Flare burner outlet diameter** (NPS)
1 [a]	$\leqslant 200$	$\leqslant 8$
2	$> 200, \leqslant 600$	$> 8, \leqslant 24$
3	$> 600, \leqslant 1\ 050$	$> 24, \leqslant 42$
4	$> 1\ 050, \leqslant 1\ 500$	$> 42, \leqslant 60$
[b]	$> 1\ 500$	> 60

a For toxic gas, the minimum number shall be two.

b To be agreed with the purchaser.

— Pilot tip and components exposed to flame shall be constructed of a heat-resistant material, e.g. AISI 309, 310, 310H, etc.

— 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.

— 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.

— Individual fuel-supply lines shall be installed to each pilot, if required, to improve operability and reliability of the pilots.

— Piping and components between the pilot tip and the air mixer shall be constructed of austenitic stainless steel.

— Pilots shall be designed for the specified fuel gas supply.

— 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.

— Each pilot shall have at least one dedicated means of ignition and one dedicated means of pilot-flame detection.

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

4.8 Pilot-ignition systems

4.8.1 Objective

The objective is to reliably light the pilot.

4.8.2 Functional requirements

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.

— The pilot ignition system shall be able to reliably light 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. A typical test protocol is given in Clause A.6,

— The pilot ignition system shall be able to light the pilot during all defined operating and emergency relief cases, including a site-wide general power failure.

— It shall be possible to ignite each pilot independently of the other pilots without depending on the flare flame for ignition.

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

4.9 Pilot-flame detection

4.9.1 Objective

The objective is to confirm that pilots are lit.

4.9.2 Functional requirements

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 which shall be met.

— The pilot-flame detection system shall be able to distinguish between pilot flame and flare-burner flame.

— 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 Clause A.6.

— Each pilot shall have at least one dedicated means of pilot-flame detection.

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

4.10 Piping

4.10.1 Objective

The objective is to specify the requirements for piping attached to the flare riser or support structure.

4.10.2 Functional requirements

Design criteria of the pipe shall be in accordance with the pressure design code. The material of the piping shall be selected on the basis of the fluids being transported in the piping, temperature and pressure of the fluids and potential ambient temperature impact.

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

Piping shall be evaluated for expansion due to the difference in temperature between the piping and the support structure. If necessary, expansion loops shall be used in the piping on the stack and, in particular, on steam lines. Expansion joints should be avoided due to their tendency to leak and the difficulties in their maintenance. It is recognized, however, that they are sometimes unavoidable but should be limited to steam lines only. Movement of the piping interface point should be specified by the flare system designer and accommodated in the inlet piping.

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).

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

4.11 Auxiliary components

4.11.1 Objective

The objective is to provide a clear definition for the auxiliary components included with the flare and their effect on the design of the flare.

4.11.2 Functional requirements

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.

— The flare-stack structural design shall consider the loads due to any auxiliary component directly attached to or incorporated into the design flare stack, e.g. ladders and platforms, axial blower and ducting, buoyancy seal, seal drum, etc.

— For parallel flares, at least one liquid seal or some other means of automatic isolation shall be provided downstream of the branch between the two flares.

— Flares in cryogenic service shall be equipped with means to prevent blockage that can be caused by the freezing of trapped water during a cryogenic relief. Special attention shall be given to liquid seals and buoyancy seals.

— Where there is the potential for solids formation, hydrates or liquid freezing under cold-climate conditions, heat-tracing system requirements shall be considered.

5 Mechanical details — Elevated flares

5.1 Mechanical design — Design loads

Clause 5 covers the support structure and includes both single-burner and multi-burner elevated flares.

General descriptions of several methods that can be used to support a vertical flare are given in Clause A.1.

The design of a support structure for a vertical, elevated flare shall consider, as a minimum, the design loads given below, as appropriate. The designer shall review the intended application and may ignore loads that are not applicable.

a) Wind loadings

These shall take into account the riser 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

These 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 ISO 13705:2006, Annex H, or ASME STS-1.

d) Internal pressure

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 riser that causes the pressure design code to become applicable. In some cases, the bottom portion of the stack incorporates a knockout drum or liquid seal, or both. When specified in the data sheets, the stack portion containing the knockout drum or liquid seal may 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 data sheets or at least 105 kPa (ga) [15 psig]. It is common practice that the riser section of 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 riser section is deemed to start at the pressure vessel outlet. 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. 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

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. The requirement for vibration and fatigue analysis shall be mutually agreed between purchaser and supplier.

f) Flashback pressure

If 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

These are imposed on the stack by the flare-header-to-stack connection and can have a major influence on the design and cost of the flare stack. This influence increases as the elevation of the flare-header increases. In general, the flare stack itself should not be used as a fixed anchor point for the flare-header piping. The purchaser shall specify the preliminary flare-header-imposed nozzle loads on the data sheets furnished to the vendor with the enquiry. The purchaser shall provide final flare-header-imposed nozzle loads during the design phase. The purchaser should minimize the nozzle loads imposed on the stack by other service connections. If the purchaser does not furnish nozzle-load information, the flare supplier shall use the nozzle-allowable forces and moments specified in Table 2. 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.

h) Thermal loads

Some of the relief-gas cases described in the data sheets 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. Thermal loads are of greatest concern on guyed stacks and derricks. 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. A hot stack wall, cooled on one side by wind or a combination of wind and rain, bends, inducing additional loads on the stack, guy wires or derrick and foundations. Counter-measures include shielding or insulating of the stack. 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). The designer shall also provide for thermally induced differential changes in length between the stack and the piping attached to the stack.

i) Erection and/or maintenance loads

The flare-stack designer shall be informed of the erection techniques that the purchaser will 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. Unless otherwise noted in the data sheets, lifting trunnions shall be designed for one-time use.

Some derrick-supported flares are designed to allow the flare riser to be lowered (either as a single section or in multiple sections) to allow grade-level access to the flare burner for maintenance. The designer shall provide for the loads imposed on the flare riser and derrick by the intended plan of demounting.

In some cases 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.

j) Special loads

The purchaser shall record on the data sheets any additional loads that will be imposed on the flare stack/support structure. Hydraulic shock load is not generally considered for design. Examples of special loads are

1) loads from ice build up,

2) hydrostatic testing of ancillary components,

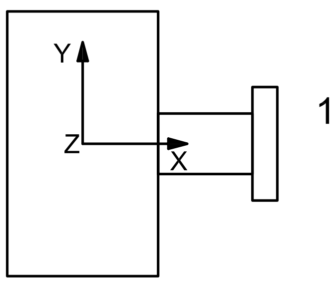
3) loads imposed during transport,

4) hydraulic forces, which are possible with blow-dry liquid seals,

5) pressure waves, which are possible with staged flares.

Table 2 — Allowable forces and moments for flare nozzles [a]

Nozzle size	F_x		F_y		F_z		M_x		M_y		M_z	
DN (NPS)	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	1 779	400	1 779	400	813	600	610	450	610	450
125 (5)	1 001	225	2 002	450	2 002	450	895	660	678	500	678	500
150 (6)	1 112	250	2 224	500	2 224	500	990	730	746	550	746	550
200 (8)	1 334	300	2 669	600	2 669	600	1 166	860	881	650	881	650
250 (10)	1 557	350	2 891	650	2 891	650	1 261	930	949	700	949	700
300 (12)	1 779	400	3 114	700	3 114	700	1 356	1 000	1 017	750	1 017	750
350 (14)	2 003	450	3 338	750	3 338	750	1 451	1 070	1 085	800	1 085	800
400 (16)	2 225	500	3 560	800	3 560	800	1 546	1 140	1 153	850	1 153	850
450 (18)	2 448	550	3 783	850	3 783	850	1 641	1 210	1 221	900	1 221	900
500 (20)	2 670	600	4 005	900	4 005	900	1 736	1 280	1 289	950	1 289	950
600 (24)	3 115	700	4 450	1 000	4 450	1 000	1 926	1 420	1 424	1 050	1 424	1 050
700 (28)	3 560	800	4 895	1 100	4 895	1 100	2 116	1 560	1 560	1 150	1 560	1 150
750 (30)	3 783	850	5 118	1 150	5 118	1 150	2 211	1 630	1 628	1 200	1 628	1 200
800 (32)	4 005	900	5 340	1 200	5 340	1 200	2 306	1 700	1 695	1 250	1 695	1 250
900 (36)	4 450	1 000	5 785	1 300	5 785	1 300	2 496	1 840	1 831	1 350	1 831	1 350
1 000 (40)	4 895	1 100	6 230	1 400	6 230	1 400	2 686	1 980	1 967	1 450	1 967	1 450
1 100 (44)	5 340	1 200	6 675	1 500	6 675	1 500	2 875	2 120	2 102	1 550	2 120	1 550
1 200 (48)	5 785	1 300	7 120	1 600	7 120	1 600	3 065	2 260	2 238	1 650	2 238	1 650
1 300 (52)	6 230	1 400	7 565	1 700	7 565	1 700	3 255	2 400	2 374	1 750	2 374	1 750
1 400 (56)	6 657	1 500	8 010	1 800	8 010	1 800	3 445	2 540	2 509	1 850	2 509	1 850
1 500 (60)	7 120	1 600	8 455	1 900	8 455	1 900	3 635	2 680	2 645	1 950	2 645	1 950



Key

1 Nozzle

[a] Nozzle loads are applicable for the flare header to the gas riser 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.

5.2 Design details

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

a) Stack deflection due to wind load or earthquake shall not exceed the following:

- 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);
- guyed structures: 300 mm per 30 m (12 in per 100 ft);

b) Stack sections in the form of a frustum of a cone shall be designed in accordance with API RP 2A WSD.

c) Field assembly of the gas riser or stack sections shall be by welding unless otherwise specified on the flare data sheets. Flanged assembly may be used on multiple-section, demountable risers.

d) 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. No corrosion allowance is required on alloy steel portions of the stack unless specifically noted on the data sheets. Non-alloy 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. 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 riser (there may be more than one connection elevation),
- available guy-wire anchor radius,
- the range of riser temperatures, both ambient and process,
- wind loads, and
- 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
  - ISO 2408:2004, Quality B for 10 mm to 50 mm (3/8 in to 2 in) diameter, class 6X36-IWRC with steel core,
  - ASTM A 475-03, Class A for 16 mm (5/8 in) diameter or less, with metallic core;
- structural bridge strand, in accordance with
  - EN 12385-10 for 13 mm to 72 mm (1/2 in to 3 in) diameter, with zinc coating conforming to EN 10264-2:2002, Class A,
  - ASTM A 586-04, Class A, for diameters greater than or equal to 16 mm (5/8 in).

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 relief gas riser.

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 Materials of construction

Materials of construction shall be as specified in the flare data sheets. 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 data sheets. 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 data sheets. Portions of the flare stack or support structure that are not normally exposed to the relief gases may be of a material suitable for their purpose. 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.

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

NOTE For the purpose of this provision ANSI/NACE MR0175 (all parts) is equivalent to ISO 15156.

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

Guy wires, as set forth in 5.2 (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.

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.

5.4 Welding

● a) 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.

b) 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.

● c) 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.

5.5 Inspection

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 non-destructive 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 requirements.

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. The developed radiographic film should show at least 150 mm (6 in) of weld seam.

d) Other types of non-destructive testing may be utilized if specified on the flare data sheets.

e) Hydrostatic testing is not required unless specified on the flare data sheets.

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 (a) through (e) above. Hydrostatic testing is not required unless specified by the flare data sheets or a code stamp is specified.

Non-gas-containing portions of the support structure shall be inspected visually using the procedure set forth under item b).

5.6 Surface preparation and protection

Carbon steel external surfaces of stack and piping that can be directly exposed to weather shall be cleaned in accordance with ISO 8501-1:2007, grade Sa 2 ½, or 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 (DFT) of 75 µm (0,003 in). Surfaces shall be painted in conditions in accordance with manufacturer's recommendations on temperature and relative humidity.

Components of derricks, ladders, platforms and the like shall be prepared for, and galvanized in accordance with, ISO 1461 or the applicable sections of ASTM A 123, ASTM A 143, ASTM A 153, ASTM A 384 and ASTM A 385. Bolts joining galvanized sections shall be galvanized in accordance with ISO 10684 or ASTM A 153, or zinc-coated in accordance with ASTM B 633.

Alloy steel components do not require surface preparation or protection.

5.7 Attachments

5.7.1 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.

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

5.7.3 The structural analysis shall include piping loads and wind and earthquake loads.

5.8 Aircraft warning lighting

● **5.8.1** Lighting on the support structure shall be in accordance with the code specified by the local aviation authority, which is typically the national incorporation of ICAO, Annex 14.

5.8.2 Warning lights on the structure shall be fixed or retractable, and shall be shielded from radiation as necessary.

5.9 Platforms and ladders

● **5.9.1** 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.

5.9.2 An elevated flare can meet its design intent as stated in 4.1 without being equipped with platforms or ladders. However, at least for elevated flares more than 15 m (50 ft) high, a 360° platform should be provided near the top. This elevation may be increased depending on site-specific capabilities and maintenance practices. This platform should be located below the flare-burner mounting flange or connecting weld and be positioned so that it can be used during inspections, maintenance and flare-burner replacement.

5.9.3 If the flare is equipped with a buoyancy-type air seal, a platform should be provided for access to the inspection and clean-out nozzles. A 120° platform is commonly used.

5.9.4 Access platform(s) should be provided for inspection and maintenance of fixed, non-retractable aircraft warning lights.

5.9.5 Additional access platforms may be located at other locations as necessary. For example, the erection plan for the flare stack can make a full 360° or partial platform desirable at each stack assembly joint.

5.9.6 The maximum distance between platforms shall be 9 m (30 ft) or in accordance with local regulations if access between platforms is via ladders.

5.9.7 If the flare system is equipped with a knockout drum and/or a liquid seal, platforms can be required for access to man-ways, level instruments, etc.

5.9.8 If the flare is of multi-stage type, a platform shall be provided for inspection and maintenance of the staging valves.

5.1.9.9 In general, the flare-burner maintenance platform should have a minimum 0,9 m (3 ft) clearance width from the flare burner and its appurtenances. In some cases, placement of the platform and the flare burner/stack connection at a somewhat lower elevation can allow the use of a smaller-diameter platform.

5.9.10 Ladders shall not be attached to the flare burner.

5.9.11 Platform decking shall be open grating, designed for a uniformly distributed load of 500 kg/m^2 (100 lb/ft^2) and a point load of 450 kg (1 000 lb).

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

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

6 Mechanical details — Enclosed-flame flare

6.1 Combustion chamber

Mechanically, the combustion chamber is a self-supported stack. The stack design should conform to an acceptable code, e.g. ASCE 7, using the site parameters for wind speed, rain, exposure factor, seismic factor, etc. The stack design and material shall accommodate the thermal requirements of the enclosed flame. 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 1 090 °C (1 800 °F to 2 000 °F). Flue-gas temperature in excess of 980 °C (1 800 °F) can produce visible emissions, not flames, due to ionization.

The combustion chamber requires an internal refractory lining. The refractory system selection and design shall consider

— peak operating temperature (with a safety factor),

— exterior shell temperature limits for materials and coating,

— thermal cycling with rapid increase and decrease of combustion chamber operating temperature with changes in relief-gas flows to the flare,

— velocity of the airflow into the combustion chamber and the flue-gas velocity out of the combustion chamber,

— environmental exposure to rain, wind, etc.,

— refractory weight, friability, expansion/contraction factors, durability, maintainability and service life,

— refractory curing schedules and start-up plans.

Refractory insulation for thermal heat loss is not a factor in the design; a large percentage of the heat of the enclosed flame flare is lost to the atmosphere.

The shape and size of the combustion chamber impacts the degree to which the flare can be pre-assembled to meet field-erection requirements. The external shell of the combustion chamber is typically fabricated of carbon steel. Internal surfaces can be lined or painted to mitigate dew-point corrosion as required by the enclosed-flame flare design and operating conditions. Any coating material shall be compatible with the design metal temperatures for the flare and its refractory lining. Special consideration shall be given to selection and application of protective coating systems since exterior metal temperatures can exceed 205 °C (400 °F).

Ladders and service platforms, for access to enclosed-flame flare instruments and for stack emissions sampling, can impact the structural design of the combustion chamber. Personnel protection is required adjacent to the combustion chamber when surface temperatures exceed 80 °C (175 °F) for areas for personnel access during operation. See 5.1 and 5.9.

6.2 Burners

There are distinct designs from several manufacturers that are available with many options. Mechanically, the burner design controls the fuel and air for combustion, its state of mixing and the ignition and completeness of combustion. Heat-affected areas are typically fabricated of heat-resistant stainless steel. Enclosed-flame flares can have the burners firing in a vertical upward direction or the burners can be horizontally fired into the combustion chamber. The choice of burner firing direction is a function of size and manufacturer’s experience.

Flare burner assemblies are typically connected to burner piping by flanged or screwed fittings, or by welding. It is necessary that the selection of the connection type 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. These temperature effects can loosen some screwed and flanged connections.

It is necessary that steam, air or other auxiliary connections to the burner, likewise, be engineered depending on their location relative to the flame and combustion chamber. These connections can be welded, flanged or screwed.

6.3 Burner piping

Burner piping should conform to the pressure design code as a minimum. The piping shall be engineered to have the flexibility to accommodate thermal expansion of the combustion chamber and the piping. It is necessary that the piping design take into consideration the requirements to maintain the engineered burner position with respect to the air inlet to the combustion chamber.

It is necessary that piping located inside the combustion chamber enclosure be engineered for high-temperature exposure since these can be subjected to flame impingement. Piping internal to the combustion chamber can be subjected to flame impingement resulting from poor air or gas distribution. Flame impingement can also result from liquid-pool fires that can form when condensation and liquid drainage into the combustion chamber occurs. It can be necessary to protect piping external to the combustion chamber, but within the wind fence, from radiant heat loads by radiation shields.

If liquid carryover and/or gas condensation can occur, the piping design should accommodate drainage. If liquid hydrocarbons are retained in the piping, they can form blockages.

Piping material selection shall be compatible with the relief-gas composition and temperature, and shall meet the requirements set by the enclosed-flame flare design.

6.4 Pilots

Each stage of an enclosed-flame flare shall be equipped with at least one pilot. The first stage can require more than one pilot; that decision should be made during the design phase. However, not every burner of every stage of an enclosed-flame flare requires a pilot. Depending on the burner design and the arrangement of the burners, a single pilot can light one main burner and cross-ignition to other burners can be achieved. The number of pilots depends on the number of burners, the design of the burners, the burner arrangement, and the operating status of the enclosed-flame flare. At higher gas-relief capacity, a substantial flame and a high temperature exist in the combustion chamber. This can ignite the relief-gas flow from the subsequent stages.

Pilot fuel and supply systems should be the cleanest, most reliable fuel source in the plant. The typical pilot is a single-firing-rate, pre-mix burner. The pilot gas orifice is generally quite small. Potential plugging of this orifice should be mitigated by good piping design and by the use of a strainer located immediately upstream of the pilot gas orifice.

Pilots for enclosed-flame flares can be engineered to facilitate inspection and maintenance while the flare remains in service. This is accomplished by locating key components external to the wind fence and/or by making the pilot assemblies easily removable from outside the wind fence.

Many of the pilot and pilot-ignition details covered in Clauses A.3 and A.4 are applicable to enclosed-flame flares. Enclosed-flame flares allow the use of flame scanners as the flames are enclosed in the combustion chamber. Pilots for burners in enclosed-flame flares are typically more protected from the weather than those of open-air elevated flares. With a properly designed enclosed-flame flare and with an effective wind fence design, the airflow across the pilot and burner is unidirectional whereas open-air elevated-flare pilots are affected by wind from varying directions.

6.5 Wind fence

Wind-fence designs follow the structural requirements as defined for the combustion chamber. The wind-fence design shall withstand heat, mitigate wind effects, limit access and provide acoustical dampening. Wind-fence enclosures of steel and concrete are typically utilized. Wind-fence designs can also control reflected light from the combustion chamber.

Wind-fence design shall limit access to the space inside the wind fence and to any hot metal surface. The wind-fence material selection shall provide for an external surface temperature acceptable for worker exposure. Doors or man-ways shall be provided to limit access to the inside of the wind fence. This access is for inspection, maintenance and repairs. Wind fences may also be equipped with viewing ports for observation while the flare is in service. The number of doors and view ports is selected based on inspection and access requirements, and on limitations to view and movement inside the wind fence.

6.6 Radiation shielding

All piping subject to thermal radiation, upstream of the individual burner risers, shall be adequately protected. Such piping is typically covered with loose gravel or metallic shielding. 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

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

A.1.2 Elevated

A.1.2.1 General

Elevated flares are generally oriented to fire vertically upward. The discharge point is at an elevated position relative to the surrounding grade and/or nearby equipment.

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 riser supports the elevated flare burner without the use of guys or a derrick support. See Figure A.1 for a typical self-supported structure.

A.1.2.3 Guyed

An elevated riser supports the flare burner through the use of cables. Cables are attached to the flare riser 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. See Figure A.2 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.

a) Fixed derrick:

   The riser is permanently supported by the structure. The flare burner can be maintained by lowering it with a davit or crane. The flare system shall be out of service when the burner is removed. See Figure A.3 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.4 illustrates a derrick with a multiple-section demountable riser: (a) in the normal operation position; (b) with upper sections slightly lifted at the start of the lowering operation; (c) during the process of lowering the bottom section; and (d) with the bottom section completely lowered.

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.5 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.

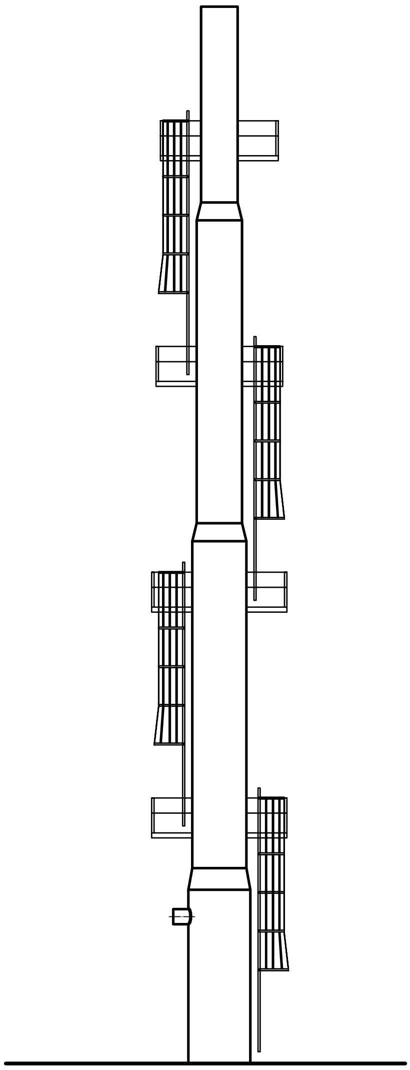


Figure A.1 — Self-supported structure

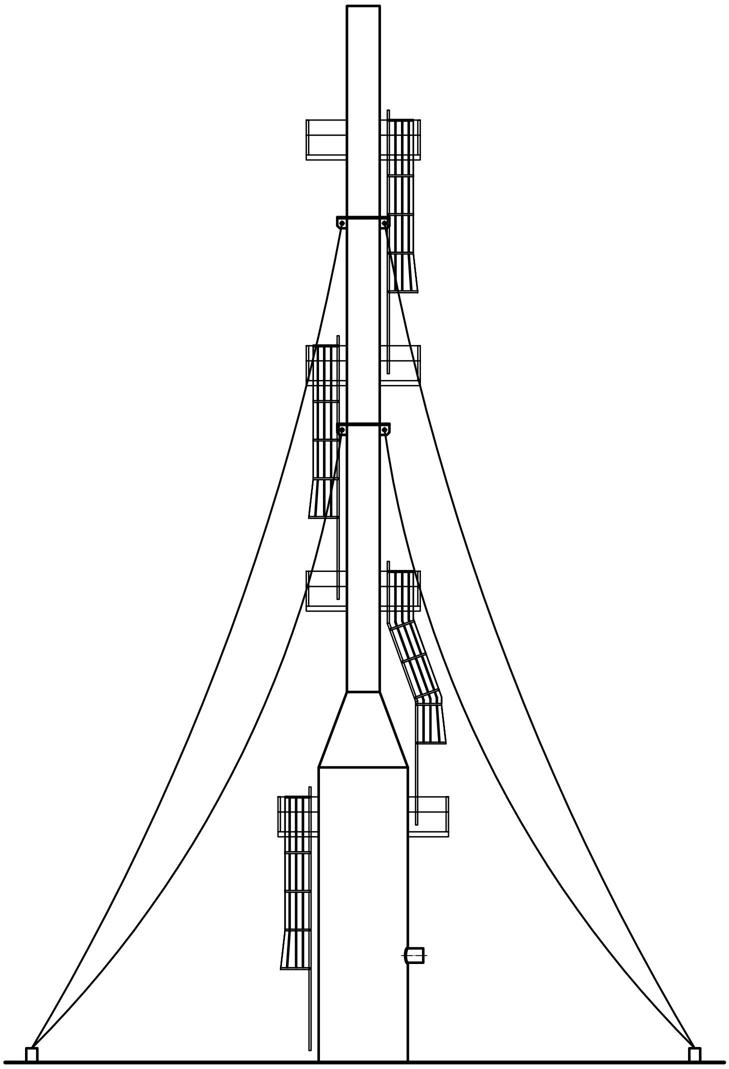


Figure A.2 — Guyed-support structure

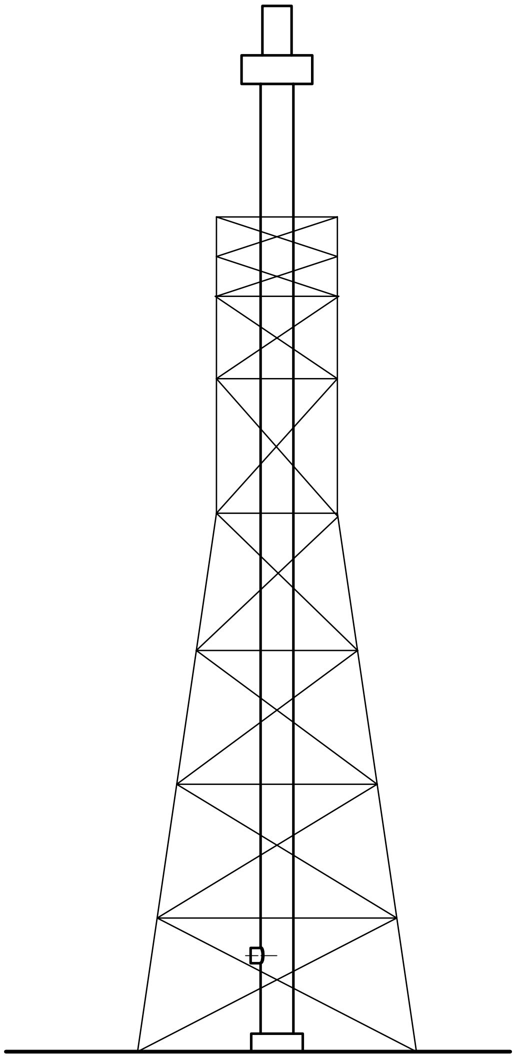
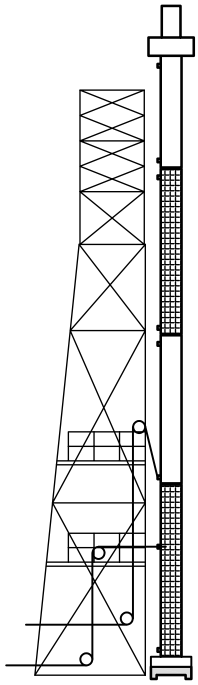
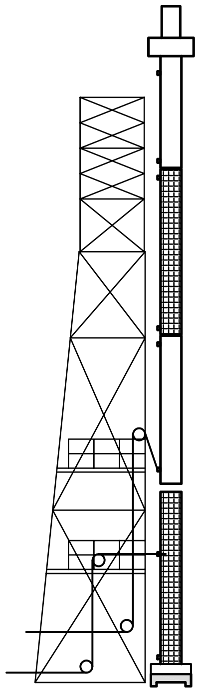


Figure A.3 — Typical fixed derrick support structure

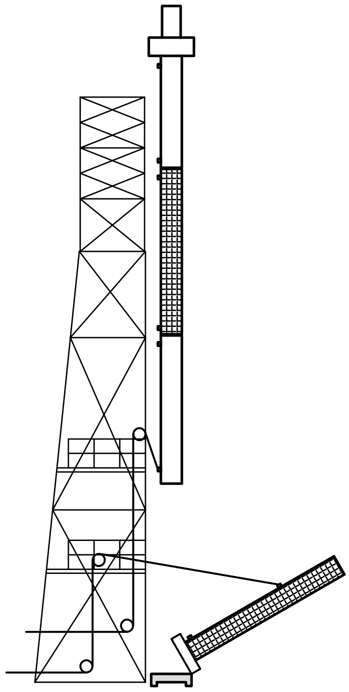


a) in the normal operating position

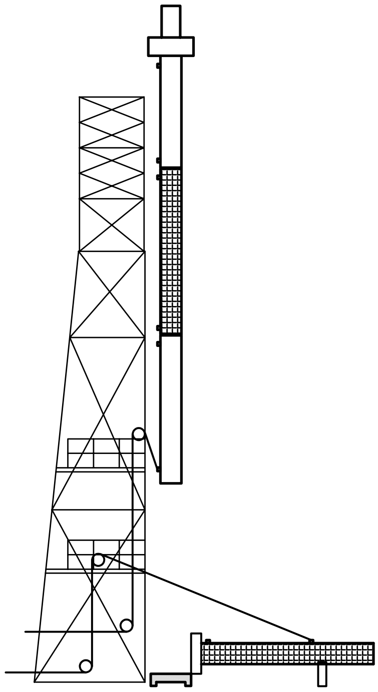


b) with upper sections slightly lifted at the start of the lowering operation

Figure A.4 — Demountable derrick with multiple-section riser (*continued*)

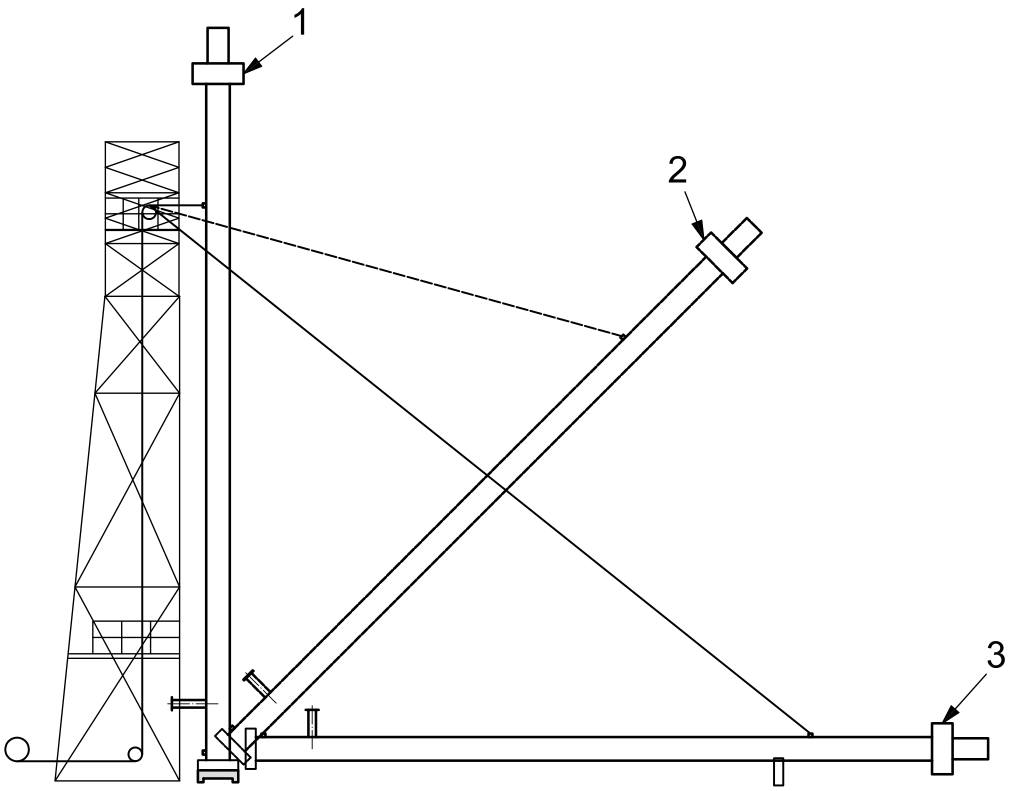


c) during the process of lowering the bottom section



d) with the bottom section completely lowered

Figure A.4 — Demountable derrick with multiple-section riser



Key

1 in the normal operating position

2 during the lowering process

3 completely lowered to allow grade level access to the flare burner

Figure A.5 — Demountable derrick with single-section riser

A.1.3 Horizontal

The flared liquids and gases are piped to a horizontal flare burner that discharges into a pit or excavation (see Figure A.6).

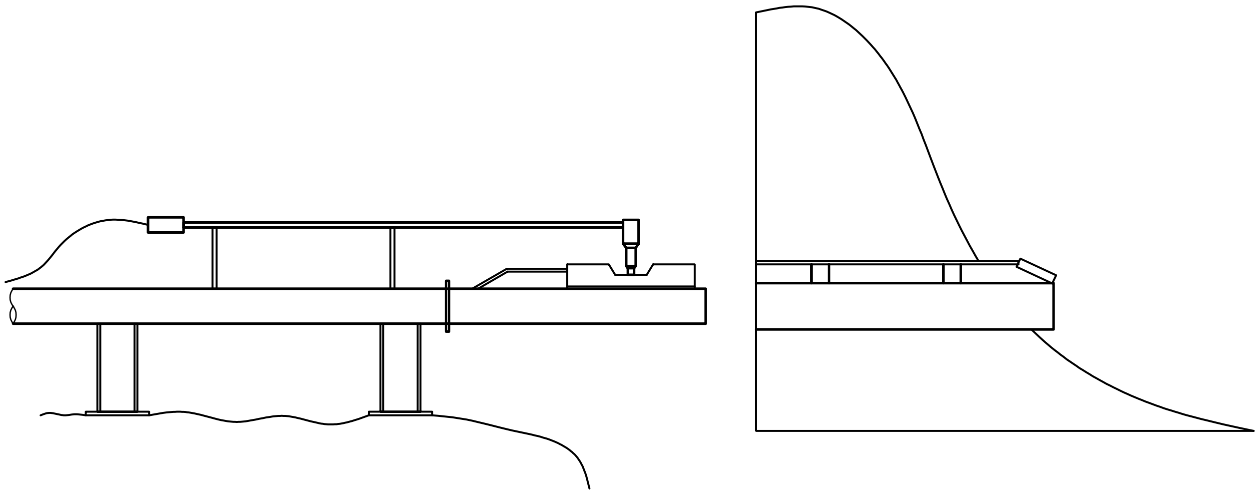
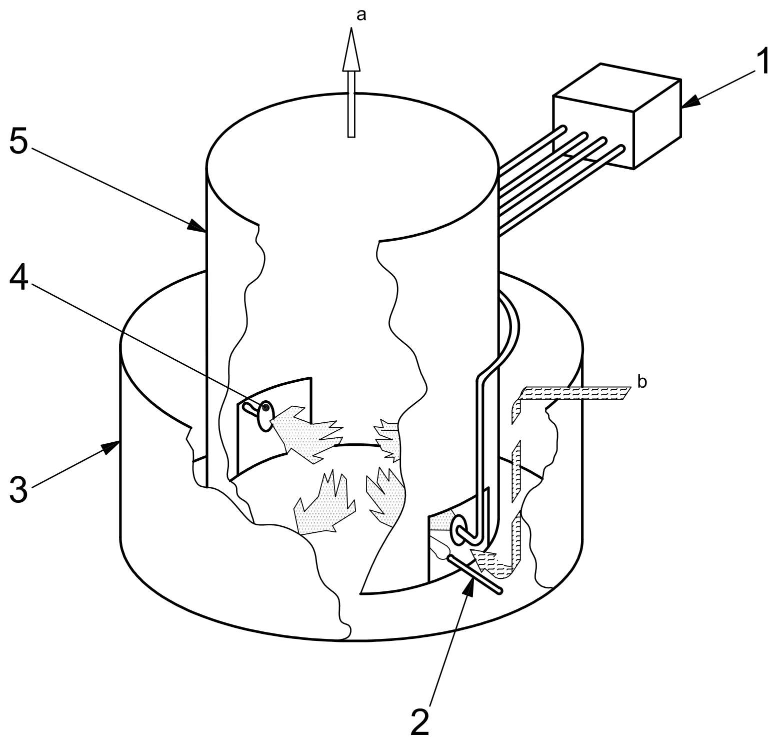


Figure A.6 — Horizontal flares

A.1.4 Enclosed-flame flares

Enclosed flares are constructed to conceal the flame from direct view. They can reduce noise and minimize radiation. Unlike an incinerator, a wide turndown is inherent with these systems. The normal flow rate allows the connected facility to start up, shut down and operate on a day-to-day basis without exposed flame flaring. Multiple stages within the enclosed flares are sometimes used. Figure A.7 illustrates a horizontally fired enclosed flare. Either horizontally or vertically fired burners can be used in enclosed-flame flares.



Key

1 staging control system
2 pilot
3 wind fence
4 burner
5 stack

[a] Flue gas.
[b] Airflow.

Figure A.7 — Enclosed flare

A.1.5 Single- and multi-burner

A.1.5.1 General

Single- and multi-burner flares may be provided with each of the flare categories in A.1.2 to A.1.4.

A.1.5.2 Single-point flares

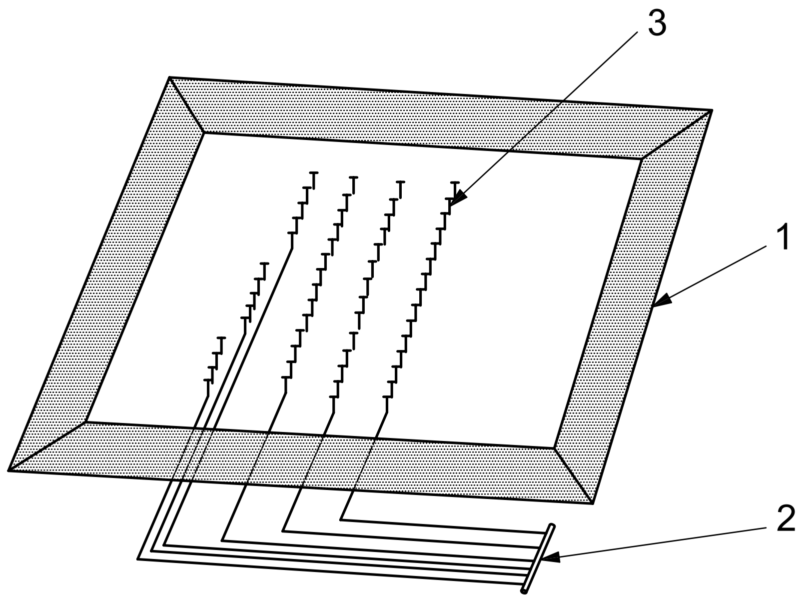
A single-point flare is an open-pipe flare with a single exit point. Single-point flares may be of the smokeless or non-smokeless design. They are generally vertical types. A single-point flare usually has a lower pressure differential than a multi-burner flare.

A.1.5.3 Multi-burner staged flares

Multi-burner flare systems utilize the available pressure energy of the gas to entrain additional air. This improves combustion as the flare gas is better mixed with the air. Multi-burner flares are usually designed to achieve smokeless combustion if adequate pressure and space are available. The multiple burning points may be arranged in arrays located near grade or at an elevated position. Figure A.8 illustrates a multi-burner staged flare located near grade.

Multiple, elevated, single-point flares in a multi-staged arrangement can be provided to accommodate very large relieving capacities, thereby reducing the size of the individual stacks and the associated burner and reducing flame-front instability and burnback at low capacities.

See also Annex B.



Key

1 berm (fence enclosure)

2 staging control system

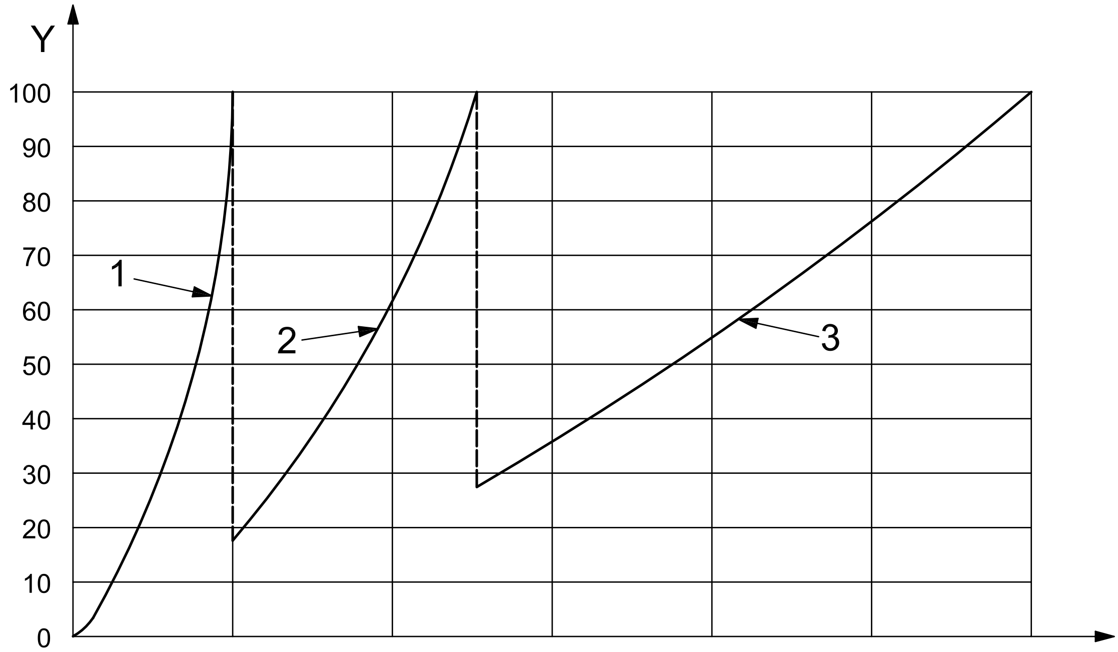
3 burner

Figure A.8 — Multi-burner staged flare

Figure A.9 illustrates the performance of a three-stage flare system. Each stage adds incremental exit area. Staging allows operation of each stage at pressures where smoking does not occur. As the flow increases in the first stage, the system pressure increases. When the system pressure reaches a maximum for the first stage, the second stage opens providing additional capacity. The additional capacity decreases the system pressure while maintaining the same flow. This process then repeats with the third stage. Decreasing flow reverses the staging process. The chart illustrates three steps of operation: step 1 equals 20 %, steps 1 and 2 equal 50 %; steps 1, 2 and 3 equal 100 %. Many variations of staging size, number of stages, pressure and sequence are possible. See also Clause A.11 and Figure A.16.

Single- and multi-burner staged flares are fed from a manifold. The manifold distributes the flow of flare gas to individual branches containing one or more flare burners. ON/OFF valves direct the flow of flare gas to each branch. The operation is described above.

Flare-system safety considerations require valve bypasses, each of which shall contain a fail-safe device, e.g., rupture disc or pin-actuated device.



Key

Y percent maximum pressure

1 first stage
2 first and second stages
3 first, second and third stages

Figure A.9 — Multi-burner flare staging curve

A.1.6 Smokeless and non-smokeless flares

A.1.6.1 Smokeless flares

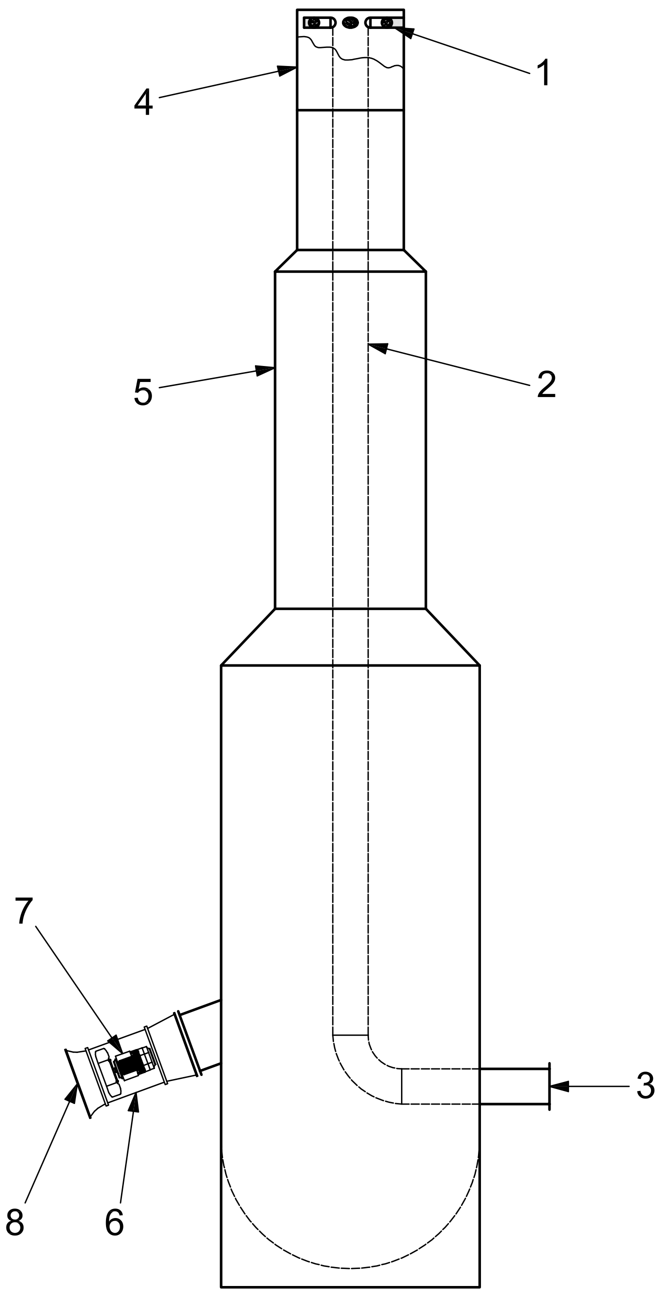
Smokeless flares eliminate any noticeable smoke over a specified range of flows. Smokeless combustion is achieved by utilizing air, steam, pressure energy, or other means to create turbulence and entrain air within the flared gas stream.

Local regulations and plant specific requirements generally define smokeless burning. Opacity is defined by the Ringelmann numbering scale (Ringelmann 1 is 20 % opacity; Ringelmann 0 is clear).

Typically, the smoking tendency is a function of the gas calorific value and of the bonding structure of the hydrocarbons. The paraffinic series of hydrocarbons has the lowest tendency to produce smoke, whereas olefinic, diolefinic and aromatic series of hydrocarbons have a much higher tendency to produce smoke.

Smokeless flares can be provided with a steam-assist or air-assist system to improve combustion. An air-assist system utilizes fans to provide mixing energy at the flare burner. See Figure A.10 for a typical arrangement of an air-assist flare.

Gas system hydraulics (i.e., the gas-pressure drop available for the flare equipment) can influence the method chosen for smoke suppression. The pressure (kinetic energy) of the flare gas can, if sufficient, be used to make the flare operate without smoke. The smoke-suppression method is dependent on the utility availability and cost of the utility.



Key

1 gas discharge ports
2 gas riser
3 flanged inlet for gases being flared
4 stainless steel flare burner
5 low-pressure air riser
6 vaneaxial low-pressure air burner
7 two-speed motor
8 inlet bell

Figure A.10 — Air-assisted flare

A.1.6.2 Non-smokeless flares

Non-smokeless flares utilize no outside methods (air, steam, etc.) to improve combustion. This sometimes results in the presence of some smoke at certain operating conditions. Non-smokeless flares are typically, but not exclusively, single-point flares. Non-smokeless flares can be used to supplement smokeless flares when the capacity on the smokeless flare is exceeded.

Non-smokeless flares are used for hydrocarbon or vapour streams that do not cause smoking (i.e., methane, hydrogen, carbon monoxide, clean-coke oven gas, ammonia, hydrogen sulfide) or when smoke is not a consideration.

A.1.7 Endothermic (fuel-gas-assisted) flares

Endothermic (fuel-gas-assisted) flares are used when flaring low-heating-value waste streams. Refer to ISO 23251 for guidance on the basis for selection of an endothermic-type flare.

There are several possible arrangements for endothermic flares including;

— simple, non-assisted flare burner with high-energy supplemental gas added to the relief-gas steam upstream of the flare;

— simple, non-assisted flare burner with a pre-mixed supplemental fuel/air mixture supplied to an annulus surrounding the relief-gas exit;

— single-point flare with an air-assisted supplemental gas burner surrounding the relief-gas exit.

A.1.8 Major components

A.1.8.1 The major and optional components for an elevated flare are the following:

— flare burner with or without smoke suppression and control (optional) capability;

— pilot(s);

— pilot igniter(s);

— pilot-flame detectors;

— buoyancy or velocity seal (optional);

— support structures;

— grounding connection;

— knockout drum (optional);

— flame/detonation arrestor (optional);

— liquid seal (optional);

— piping;

— smoke-suppression control system (optional);

— blower(s) (optional);

— flow, composition, heat content or video monitoring (optional);

— ladders (caged or with safety-climbing system) and platforms (optional);

— davit for burner removal (optional);

— aircraft warning lights and painting (optional);

— radiation heat shields (optional);

— rain shields (optional).

A.1.8.2 The major required and optional components for multi-burner flares and flare burners are similar to those for elevated flares plus the following:

— staging equipment and instrumentation (optional);

— heat shielding for gas manifolds and headers (optional);

— fence (type and purpose are site-specific) (optional).

A.1.8.3 The major required and optional components for an enclosed flare are similar to those for multi-burner flares plus the following:

— enclosure (structure, dike or fence);

— refractory (optional);

— heat shielding for gas manifolds and headers (optional).

A.2 Flare burner

A.2.1 Purpose

The flare burner is designed to provide for the safe discharge of the maximum specified relief-gas flow rates at the system-allowable pressure drop, as detailed by ISO 23251. The flare burner mixes fuel and air at velocities, turbulence and concentration required to establish and maintain proper ignition and stable combustion. The flare burner ignites and combusts vapours discharged for process relief, for plant upset and emergency conditions. This mechanical device controls the combustion process for the specified relief conditions, and produces the desired destruction/combustion efficiency. The mechanical components of typical flare burner designs are described in A.2.2 to A.2.7.

Refer to ISO 23251 for further information on steam requirements for smoke suppression and the ability of different types of flare burners to handle liquid-hydrocarbon droplets.

A.2.2 Unassisted pipe flare

An unassisted pipe flare is used where smokeless-burning assist is not required. Ignition of the flare flame is by pilots. The pilots are ignited by a pilot-ignition system.

The pipe-flare burner shall have a mechanical device or other means of establishing and maintaining a stable flame. The ignition fire from the gas discharge is initially ignited by interaction with the flames of the pilot(s). Once the pilot lights the flare-stabilizing flame, the flare is expected to maintain flame stability over the operating design range.

Some flares are subject to regulations that limit exit velocity. For example, when pipe flares are applied in the USA as control technology for volatile organic compound (VOC) emissions, the gas exit velocity can be limited by the United States Code of Federal Regulations 40 CFR PT 60.18. The allowable exit velocity designated in 40 CFR PT 60.18 is a function of flare-gas properties. It is important to note that there are many flare applications that do not involve VOC control. Such flares are not required to meet the exit velocity requirements of this regulation.

The flame produced by an unassisted pipe flare is a function of the relief-gas composition and the gas exit velocity. At higher gas velocities, the gas discharge energy pulls combustion air into the flame and produces a shorter, more erect flame that has greater resistance to wind deflections. At lower gas exit velocities, air is drawn to the flame primarily by the buoyancy of the heated products of combustion. A buoyant flame is typically softer, longer and more wind-affected than a flame associated with higher gas exit velocities.

Low gas exit velocities and buoyancy-dominated flames may be employed for successful combustion under low-heating-value relief-gas conditions. High gas exit velocities can be employed for hydrocarbon relief gases of higher heating value or for relief gases rich in hydrogen.

Flare-combustion noise is influenced by gas exit velocity. Increased relief-gas exit velocity can produce greater combustion turbulence and have higher combustion noise levels. The highest combustion noise levels are realized when a flare burner is allowed to operate at a gas exit velocity where combustion instabilities occur. Combustion instability is defined as a flame that lights, lifts off, goes out and re-ignites in a semi-cyclic mode.

The prime operating considerations with unassisted pipe flares are to safely discharge the relief gas from the flare burner within the hydraulic design for the flare system (within the allowable pressure drop and flame combustion velocity limits) and to ignite and burn the relief gas with the designed flame characteristics.

Wind action at low flaring rates can produce internal burning and/or external flames that remain attached to the flare burner. The flare burner should be designed to withstand the effects of such internal and attached external burning. On larger-sized flare burners, internal refractory linings are sometimes employed to mitigate the thermal effects of internal burning. Refractory linings reduce the high thermal gradients that produce buckling in flare burners. Buckling of the flare burner shell is the first sign of almost all flare-burner failures.

Wind shields may be employed on pipe flares to help mitigate wind-induced attachment of flames to the external flare-burner surfaces.

For plant design, the full range of relief-gas compositions and flare-burner exit velocities shall be engineered to operate successfully with the size of pipe flare selected.

A.2.3 Steam-assisted pipe flare

The basic flame stabilization for a steam-assisted smokeless pipe flare is similar to that for the basic pipe flare described in A.2.2. The steam-assist equipment should not disrupt the basic flame-stabilization mechanisms of the flare burner and can, in some cases, be made to assist in the flame stabilization.

Gas exit velocities are limited for steam-assisted flare burners in ways similar to that for basic pipe flares. Steam injection adds potential dilution to the relief gases, even when steam is operated at minimum purge rate. Steam-assisted flares typically require more combustible gas mixtures to achieve desired VOC destruction efficiencies.

As a 40 CFR PT 60.18 regulated VOC control device, a steam-assisted flare requires a relief-gas stream with a minimum calorific value of 11 175 kJ/Nm^3 (300 Btu/scf) versus 7 450 kJ/Nm^3 (200 Btu/scf) for unassisted pipe flares.

The flame produced by a steam-assisted pipe flare is a function of the relief-gas characteristics, the gas exit velocity and the steam-injection design.

Steam assist is used to control the formation of smoke that accompanies the relief of many hydrocarbon gases. In A.1.6.1 are described the considerations for smoking tendency. The steam injection functions to produce smokeless combustion by educting combustion air, thus increasing momentum and turbulence in the flare flame. The addition of combustion air, momentum and turbulence can produce flame characteristics for smokeless flaring where shorter, more intense flames are produced. These flames have greater resistance to wind deflection and can have reduced radiation fractions.

The quantity of steam required for smokeless burning is a function of the gas composition, the flare-burner size and design, the steam-injector design and operating pressure and the environmental conditions. While steam-assist enhances the combustion of relief gases that smoke, it adversely effects the combustion of relief gases with a high level of inerts. Relief gases with a high level of inerts, when flared from a steam-assisted flare, can require a greater calorific value to sustain the required flame stability and hydrocarbon-destruction efficiency.

Steam is often injected into the relief-gas discharge at the top of a flare burner. Typically, a steam ring that has a number of injection nozzles or slots is employed. The design and location of injector nozzles varies as different flare manufacturers each have their own proprietary design.

Steam consumption varies widely as a function of the particular gas being flared and the manufacturer's proprietary design of the flare burner. ISO 23251 provides guidance on typical steam rates for elevated flares.

The upper steam injection functions to inspirate air and to force the air mixture into the relief gas discharging from the flare burner. The steam-injection pattern is intended to enhance fuel-air mixing and can add to the momentum of the relief-gas discharge. The steam and air acts to dilute the hydrocarbon fuel content, which also reduces the smoking tendency. The steam vapour can also participate in the combustion kinetics, assisting in the conversion of carbon to carbon monoxide.

Compressed air or other high-pressure gases, including gaseous, light-relative-atomic-mass hydrocarbons, can be used in an upper "steam" ring, but steam has been found to be the most effective medium.

The effective addition of steam from an upper steam ring increases the turbulence of combustion. The overall noise level of the flare burner increases due to both the additional combustion noise and jet noise from the steam nozzles. Steam-assisted, smokeless flares can have significantly increased overall noise levels in comparison to flares with no steam assist.

In addition to the operating considerations mentioned previously for the pipe flare, attention shall be given to the rate of steam injection. If too little steam is added to the flare burner, a smoking, softer, more wind-deflected flame is produced. Proper steam injection proportions the steam-injection rate to the relief-gas flow rate. The lowest-cost operation for steam injection is to operate just above the incipient smoke point for the gas composition and flow rate.

Higher steam-injection rates make the flame harder, cleaner and less wind-deflected. Higher steam-injection rates also increase the noise levels. Excessive steam-injection rates produce combustion instability accompanied by excessive flare noise (low frequency, pulsating). At the extreme, over-steaming can extinguish the flame.

The addition of steam-injection equipment does not change the purge-gas requirements for a flare burner.

The upper steam ring is subjected to flame impingement due to wind action. A cooling steam flow is utilized to mitigate this. This minimum steam flow is also set to maintain a suitable temperature in the steam system to avoid condensation and water-hammer effects in the ring and steam line. The minimum steam flow is a function of the flare-burner design.

A properly designed upper steam ring can function as a windshield to reduce adverse wind effects on the flare flame. It can also be used to eliminate external flame attachment to the flare burner barrel.

Steam flows from an upper steam ring can condense and create water and ice problems for a flare burner. Excessive condensate can produce large icicles on flare structures. These icicles pose a hazard to the personnel, flare system and piping. The use of a defined minimum flow of dry or preferably, slightly superheated steam together with the proper design and layout of steam trapping facilities are critical to minimizing these problems

A centre steam injector may be used to mitigate internal burning. A properly designed centre steam injector adds steam to the low-relief-flow-rate gases. This helps to push the flame out of the flare burner and lowers the peak flame temperatures. Centre steam is also effective for smokeless burning at low relief-gas flow rates. Centre steam dilutes the fuel hydrocarbon content to avoid smoke generation.

Excessive centre steam can produce combustion instability and extremely high noise for low gas flow rates. Centre steam adds water vapour to the inside of the flare stack. The steam can condense, forming water and ice inside the flare system. The potential for such problems can be reduced by using separate steam risers and controls for the centre steam injector.

CAUTION — Care should be taken while operating centre steam systems in cold environments. The potential exists to form an ice plug that reduces the hydraulic capacity of the flare below that needed for plant safety.

The operation of steam-assisted pipe flares is described in A.2.8.

A.2.4 Pipe flares with internal steam/air eductor tubes

Smokeless flaring at higher rates and lower flare noise can be achieved by injecting steam into the relief-gas discharge from tubes located inside the flare-burner barrel. These internal tubes are designed to act as combustion air eductors that use the steam energy to pull in combustion air and to mix the air with the relief gas. The steam/air discharge out of the internal tubes can also be at a high velocity, adding to the momentum of the flare discharge and inspirating additional combustion air while stiffening and shortening the flame.

Typically, a reduced steam-to-hydrocarbon ratio is required for internal steam/air tubes. This is because the tubes increase the effective mixing of the steam and air with the gas. The internal steam/air tubes can enter the flare burner barrel at different elevations. Therefore, combustion air access is not limited to the upper perimeter of the flare burner (as it is for an upper steam ring assembly).

Greater access to combustion air increases the maximum achievable rate of smokeless burning. A flare burner that employs both internal steam/air tubes and an upper steam ring can have more than twice the maximum smokeless burning capacity of an upper steam ring flare.

With the internal steam/air tubes entering the flare barrel at elevations well below the flare-burner discharge point, the steam injector can be designed for effective air eduction with reduced steam-jet noise levels. Furthermore, at the lower tube entry location, a muffler assembly can be used to further reduce the steam-injection noise. A properly designed flare burner operating only on the internal steam/air tubes can be 10 dB to 12 dB quieter than one operating with only an upper steam ring.

There are additional flare operating considerations with internal steam tubes because of the possible condensation of steam. The use of dry steam is important to avoid condensation and possible freezing. Steam condensate shall be drained from the internal steam/air injection point and from any muffler surrounding these tube assemblies. This is especially important in areas where long periods of freezing temperatures are expected to occur.

Back-burning potential is a hazard with steam/air tubes. Care shall be taken to avoid back-flow of combustible mixtures in the internal tubes. The most common cause of back-flow in the tubes is improper flare operation. If the upper steam ring is pressurized prior to engaging the steam supply to the steam/air tubes, the upper steam can cap the top of the flare discharge and force flow backward out of the tubes.

Operation of a steam-assisted flare with internal steam/air tubes is described in A.2.8.

A.2.5 Air-assisted smokeless flares

Air-assisted flares are used where smokeless burning is required. It is used when steam is not available or where low-pressure air delivery offers a lower cost.

Air-assisted flares often employ gas distributors to promote mixing of the relief gas with a low-pressure blower-delivered forced airflow. The gas-flow distribution arrangement more closely resembles traditional burner designs than pipe flares. The gas-air distributors/mixers use the burner-type flame-stabilization mechanisms. These include flame retention devices and aerodynamic-type flame-stabilization methods.

The flame produced by a low-pressure, air-assisted flare burner is a function of the combined mixing energy of the relief-gas discharge and the forced airflow rate and velocity. Typically the low-pressure air blower delivers only a fraction of the flow rate of air required for stoichiometric smokeless combustion. This air fraction is used to promote mixing with the relief-gas discharge and to add momentum to the flare discharge to effectively entrain additional combustion air from the surrounding atmosphere.

The flame produced by an air-assisted burner can be shaped by the use of the forced-draught air. The flame can be developed in an axial airflow manner to produce an erect, vertical flame. Alternatively, the forced air can be swirled to promote a rotational airflow that can produce a wider, shorter flame.

The rate of smokeless burning and the flame characteristics are somewhat adjustable by the quantity of combustion air used and by its energy of discharge (to promote fuel-air mixing and flare-discharge momentum). The height of an air-assisted, smokeless flare should be designed for the limiting case when the flare can be required to operate without an air assist. This case can produce the greatest flare radiation. See ISO 23251 for more information regarding flare radiation.

The prime operating considerations with an air assisted flare are to safely discharge the relief gas from the flare burner within the hydraulic design for the flare system (within the allowable pressure drop and flame combustion velocity limits) and to ignite and burn the relief gas with the designed flame characteristics.

Smokeless burning is achieved with a forced-draught air supply. The quantity and velocity of the forced airflow can be proportioned to the gas flow by a blower damper, blower speed control or other means. Alternately, the forced airflow can also be controlled in discrete steps by the use of multiple-speed blowers or multiple blowers. At low relief-gas flow rates, a minimum, continuous airflow can maintain a cooling airflow and proper aerodynamic design across the burner. Airflow can be increased as the relief-gas flow rate increases. Care should be taken not to over-aerate the flame. Over-aeration can produce combustion instabilities that increase flare noise and vibration. At an extreme, excessive assist airflow can extinguish the flame.

The purge rate of the air-assisted flare should take into consideration the flare-burner design, size, and how the forced airflow interacts at turndown conditions with the wind and environmental factors. A minimum airflow rate is required to protect the spider arms or internals of the burner from overheating.

A blower system should be designed to produce the design airflow rate and velocity at the flare burner considering the air delivery system. The blower power should be selected with regard to the delivery of the densest air (coldest ambient temperature). Blowers of all types, including axial, centrifugal, etc., have been used for air-assisted smokeless flares.

A.2.6 High-pressure smokeless flares

High-pressure smokeless flares are used where smokeless burning is required and the relief gases are discharged from the flare burner at a high velocity. The pressure required is dependent on the gas composition, burner design and other factors. The pressure of the relieving gas is converted to kinetic energy to promote air entrainment and mixing, which produces smokeless burning. The advantage is that supplemental energy from a steam supply or a forced-draught blower can be eliminated or minimized.

High-pressure flare flames can be stabilized using the aerodynamic effects of the relief-gas discharge and its entrained air. Mechanical flame-holding devices are often not required when this aerodynamic effect is used in the flare burner design, e.g. coanda flare, convergent jet nozzles, etc. As high-pressure flares operate with high gas exit velocities, it is necessary that the gas compositions flared with this equipment be rich in hydrocarbon fuel and/or hydrogen. High-pressure flare technology should not be used for cases involving combustion-stability-limited relief-gases, such as those containing a high inert content. For cases when the relief-gas contains sufficient hydrocarbon fuel, high-pressure flares have been shown to produce very high hydrocarbon-destruction efficiencies, exceeding 98 %.

The flame produced by a properly designed and operated high-pressure flare burner effectively converts the gas pressure to kinetic energy that entrains and mixes combustion air with the fuel to produce a smokeless flame that is resistant to wind deflection. Proper use of the gas pressure energy requires that the gas kinetic energy have the opportunity to entrain combustion air. For some gas flow rates and composition, this requires the use of multiple nozzles or gas distributors.

If a flare burner is designed for high-pressure operation, there can be some turndown gas flow rate at which the pressure conversion to gas kinetic energy is insufficient to properly entrain and mix combustion air. At this turndown condition, the high-pressure flare can have a smoking flame that is subject to wind deflections. To improve turndown, high-pressure flares are often staged to promote smokeless burning with design flame characteristics over a wider operating range (multi-burner flare systems).

High-pressure flare technology is particularly effective for oil and gas production facilities. High-pressure flares can greatly reduce the flare flame radiation.

The prime operating considerations for high-pressure flares are to safely discharge the relief gas from the flare burner within the hydraulic design for the flare system (within the allowable pressure drop and flame combustion velocity limits) and to ignite and burn the relief gas with the designed flame characteristics. If multiple nozzles are used, these nozzles shall be located so as to ensure proper ignition for the gas discharge from each nozzle. Gas compositions and/or flow rates that are not compatible with the high-pressure flare design shall be avoided in design.

High-pressure flare operations produce both combustion noise (due to the high-intensity flame produced) and jet noise due to the high-pressure discharge of the relief gas to the atmosphere. With proper high-pressure flare design, the combined flare noise level can be managed. Overall noise levels for a properly designed high-pressure flare might not exceed the noise level of a comparably rated steam-assisted smokeless flare.

High-pressure flare operations produce flames that are dominated by the kinetic energy of the gas discharge. These flames have significant upward momentum and are not unduly affected by cross winds. High-pressure flare burners, though, should be designed to accommodate any flame impingement that can possibly occur at low relief-gas flow rates and, thus, at low-pressure operation.

NOTE Other assist media for smokeless combustion are available for flare burners, however they are not typically used in refinery or petrochemical services. Such media include high-pressure gas and water for liquid and vapour combustion. These technologies are applicable to offshore production facilities and are not included in this International Standard.

The pressure drops and high velocities associated with high-pressure flare operations can produce loading conditions usually not expected in low-pressure flares. Examples are jet forces and vibrations originated by process turbulence or operative modes that can cause acoustic-fatigue failures on mechanical details of the flare. The components typically subject to such conditions include the flare burner, the mechanical attachments to the flare burner and other components in the flare-gas line, including any purge-gas reduction seals. The process and mechanical design for high-pressure flares with exit velocity greater than 0,8 Mach should be performed in order to avoid or prevent acoustic-fatigue failures. Fabrication should follow the same approach. The pressure design code can be used by designers to support the mechanical design and manufacture of flares under vibration and cyclic conditions. An important aspect of construction is the attention to weld details. For example, welds should be the full-penetration type where butt welds are preferred.

Among the possible sources of vibrations for consideration, the most evident in high-pressure flares include combustion noise and flaring-gas pressure pulsations. The following may be used as guidance to the designer if no other information on the above sources is available.

a) Combustion noise:

The maximum combustion noise can be assumed in accordance with Table A.1 (case including smokeless steam) to be properly transformed in pressure waves loading the exposed top sections of the flare burner to the location of analysis.

Table A.1 — Combustion noise spectrum

Frequency, Hz	63	125	250	500	1 000	2 000	4 000	8 000
Loudness, dB	95	101	109	118	115	112	110	107
Total, dBA	120							

b) Gas pressure pulsation:

The gas pressure pulsation, P, is the internal pressure pulsation derived by process (flaring gas) turbulence where its most significant dynamic load can be assumed, as a first approximation, to be a sinusoidal load as given by Equation (A.1):

$$P = P_0 \times \sin(2\pi f t) \tag{A.1}$$

where

P_0 is the pressure-pulsation amplitude from top peak to bottom peak; if no data exist, it can be assumed to be between 1 % and 5 % of the local static pressure;

f is the exciting frequency range, evaluated between 0 Hz and 200 Hz;

t is the time, expressed in seconds.

In addition to the contributions of noise and pulsation from the flaring gas, other sources that can contribute to the overall vibration include

— internal discontinuities in the process gas piping, which cause vortex shedding and turbulence;

— liquid-droplet entrainment;

— fans;

— cyclic operation of the blow-down system.

Their characterization (location, amplitude and frequency) should be assessed and defined on a case-by-case basis.

A.2.7 Mechanical details of flare burners

A.2.7.1 Flare-burner dimensions and connections

Flare burners are typically dimensioned from their attachment point at the flare support structure to the gas discharge point.

Flare burners are often nominally described by their connecting pipe size, i.e. a DN 600 (NPS 24) flare burner for a DN 600 (NPS 24) pipe riser, a DN 1500 (NPS 60) flare burner for a DN 1500 (NPS 60) pipe riser. The upper diameter of a flare burner can be larger than the nominal diameter to accommodate internals such as steam/air eductors.

Elevated pipe flares with or without steam-assist nozzles are either flanged to the flare riser or can be welded. Flare burners sized DN 100 (NPS 4) or smaller may be attached by threaded connections. Steam supply connections should be forged flanges of a rating appropriate for the steam service connection. Pilot gas and flame-front generator (FFG) connections sized DN 25 (NPS 1) or less may be threaded, flanged, socket welded, or butt-welded.

Internal gas connections on air-assisted flare burners are often welded to avoid obstructing the airflow.

High-pressure flare attachments should be designed with a consideration of the thrust load produced from the gas discharge and in accordance with the principles of the design pressure code. Material thicknesses for the flare burner should be suitable for the service and should be clearly indicated on the data sheets and drawings.

A.2.7.2 Flange ratings

For gas risers to flare burner connections, flanges are normally used. Mechanical suitability shall be confirmed for the specific application. Flanges shall be as follows:

a) for DN 600 (NPS 24) and smaller burners: ASME B16.5-2003, 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 A.2; for flange sizes greater than those shown in Table A.2, follow the flare manufacturer's standard;

c) auxiliary connections greater than DN 25 (NPS 1), such as those for steam and natural gas: flange ratings in accordance with ASME B16.5.

The attaching flange should meet the metallurgical requirements of the flare support structure. For a carbon steel stack, a carbon steel burner flange is acceptable.

- The purchaser shall specify if other flange standards are to be applied, e.g. ASME B16.47 or EN 1092-1.

The attaching flange should meet the metallurgical requirements of the flare support structure. For a carbon steel stack a carbon steel burner flange is acceptable.

Flanges may be forged or fabricated from plate of an appropriate material.

Air ducting associated with air-assisted flares may be assembled using the manufacturer's standard plate flanges (including air connections at the flare burner).

Measures should be taken to prevent bolting from coming loose due to vibrations, etc. The use of bolts and double nuts is recommended, whereas the use of welded-on nuts is not. Alternatives to double nuts, if specified, include locking or cupped spring-type washers. Where size does not allow the use of bolts, use stud bolts with double nuts on both sides. This applies to any bolted connection, regardless of its size, location or use.

Table A.2 — 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)	1 025,5 (40,375)	36	25,4 (1,000)
950 (38)	1 076,3 (42,375)	36	25,4 (1,000)
1 000 (40)	1 127,1 (44,375)	40	25,4 (1,000)
1 050 (42)	1 190,6 (46,875)	40	28,6 (1,125)
1 100 (44)	1 241,4 (48,875)	40	28,6 (1,125)
1 150 (46)	1 292,2 (50,875)	40	28,6 (1,125)
1 200 (48)	1 343,0 (52,875)	44	28,6 (1,125)
1 250 (50)	1 393,8 (54,875)	44	28,6 (1,125)
1 300 (52)	1 454,2 (57,250)	44	31,8 (1,250)
1 350 (54)	1 505,0 (59,250)	44	31,8 (1,250)
1 500 (60)	1 657,4 (65,250)	48	31,8 (1,250)

[a] Bolting dimensions are based on "Industry Standard" flanges, Class 175.

A.2.7.3 Flare-burner handling and lifting lugs

Flare burners are often equipped with lifting lugs or brackets for initial attachment. These lugs or brackets should be removed prior to placing the flare burner in service. The lug or bracket, if left attached, will be subjected to the flare operating conditions, including possible internal or external flame attachment. The initial installation bracket should not be trusted for removal of a flare burner after it has been placed in service. Often such lifting lugs are made of carbon steel, designed to “burn off” in operation.

A.2.7.4 Materials

It is necessary that flare burner components have an acceptable fatigue and elevated-temperature strength. It can be necessary that they be resistant to thermal cycling, stress-corrosion cracking, high-temperature corrosion (in reducing or oxidizing atmospheres) or ambient-temperature corrosion. Flare-burner materials normally consist of austenitic stainless steel or high-nickel alloy depending on the particular service.

The upper section of the flare burner, whether or not it is steam-assisted, is typically fabricated of heat-resistant alloys. Grade 310 stainless steel is a normal standard. Alternative materials for greater heat resistance or to improve resistance to fuel and combustion product corrosion and erosion can be supplied. The lower flare-burner section material, including the attachment flange, can be fabricated of carbon steel or lower-grade 304 stainless steel where flare process conditions do not warrant alternative materials for temperature, corrosion, erosion or other factors.

The use of alternative materials entails a cost/benefit analysis. The initial cost of a more expensive material should be compared against the cost of unit outage, gas-freeing procedures, crane rental and the risks associated with having a flare out of service.

Air-assisted flare burners may use shorter lengths of 310 stainless steel and/or alternative materials as the flare burner is normally cooled by the forced airflow.

High-pressure flare-burner material is a function of the flare-burner design and flame impingement that can occur at low rates.

It should be noted that many flare-burner material failures occur at low relief-gas flow rates. At these low rates, the flare burner is most subjected to the detrimental effects of internal or external attached flames. At higher gas flow rates in a pipe flare, an air-assisted flare or a high-pressure flare burner, the flame is lifted out of and off of the flare body. In fact, at high flow rates, the convective effects of the gas flow effectively cool the flare body.

The material of the upper steam ring and ejectors shall be selected on the basis of exposure to the flame and cyclic conditions. The material selection for the flare-burner steam piping should take into account the effects of intergranular corrosion due to the wet, cyclic, high-temperature service.

A.2.7.5 Welding requirements

Flare-burner barrel and welded attachments should be welded in accordance with the applicable pressure design and/or structural design welding requirements.

A.2.7.6 Flare-burner piping

Flare-burner piping shall be in accordance with the pressure design code or the superior requirements of a user's or flare manufacturer's specification.

A.2.7.7 Hydro-testing for flare burners

Hydro-testing for flare burners is not required nor recommended.

A.2.7.8 Attachments to flare burner

Any piping load applied to the flare-burner connections should be clearly defined. Thermal load, dynamic loads and dead loads (including the mass of water in the steam lines) should be considered. Only auxiliary piping associated with the flare burner should be supported off of the flare burner. The attachment of pilots, steam-injection equipment, windshields and the like, should accommodate the differential thermal growth that can occur during service.

A.2.7.9 Windshields for flare burners

Windshields are applied to unassisted pipe flares. A properly designed steam-assisted flare, air-assisted flare or high-pressure flare burner should not require a windshield. Windshield design is somewhat proprietary to the flare-burner manufacturer. As a basic consideration, windshields for pipe flares should be considered sacrificial equipment. The windshield is likely to burn up, sacrificing itself to promote improved service life of the pipe-flare burner.

The design of a windshield located above the gas exit of the burner can require special design considerations.

A.2.7.10 Muffler for flare burners

Mufflers for flare burners should be designed to prevent damage from excessive flame conditions. Muffler design should not restrict the flow of combustion air into the flare flame. Mufflers for lower steam-/air-injection locations are effective in reducing steam-jet noise. These mufflers, if properly designed, improve airflow into the internal steam/air tubes by mitigating wind effects. Mufflers, if required for air-assisted flares, are typically applied to the forced-draught blower air intakes.

Noise from high-pressure flares is controlled by proper nozzle design factors.

A.2.7.11 Refractory for flare burners

Refractory is not always used for flare burners. However, it is sometimes used for large-diameter [greater than DN 1050 (NPS 42)] pipe flares to mitigate the effects of internal burning. External refractory has been used to protect the flare-burner barrel from external burning on the downwind side of the flare.

It is necessary that the refractory used for flare burners be temperature- and thermal-shock resistant. Flare burners experience rapid changes in temperature. Internal refractory should be well anchored and it is recommended that the refractory material include metal needles to help hold it in place. External refractory linings are similar in application.

With any refractory installation, it is necessary to consider the consequences of a refractory failure. For dense refractory material, this consideration focuses on where the failed refractory will fall. The refractory can fall inside the flare and potentially obstruct the relief-gas flow. External refractory falling to grade can limit potential access to the base of the flare structure.

If a lined burner is specified, experience has shown that no single refractory material or attachment method is suitable for all cases. In fact, vendors are continually modifying their specifications based on user experience and material improvements. Therefore when approving a lining specification, attention should be paid to the following:

a) refractory material: selection in consideration of the refractory product service temperature range, its optimum thickness, method of installation and its susceptibility to moisture;

b) attachment method: there are various methods of anchoring refractory; typically “bull horns” or hexmesh are used; consideration should be given to the installation procedure and the potential for the anchoring system to create shear planes in the lining;

c) refractory reinforcement: this is typically in the form of stainless steel needles; the needles reduce cracking and hold the refractory together;

d) refractory installation: installation is in accordance with the refractory manufacturer's recommended installation procedures by qualified personnel;

e) refractory curing and dryout: the refractory manufacturer's recommendations for proper curing and dryout of the selected refractory product are required to ensure that the published property values are achieved.

Proper steam-assisted flares can use centre steam to eliminate the requirement for internal refractory linings; air-assisted and/or high-pressure flare burners are not typically refractory-lined.

A.2.7.12 Maintenance issues

Flare burners generally should be removed when maintenance is performed. All auxiliary-piping connections should be designed to facilitate flare burner removal. When a flare burner has buckled, a temporary patch repair lasts only for the short term.

In some cases, a complete spare flare burner is kept to replace flare burners that are undergoing maintenance.

A portable crane is normally used to remove and replace the flare burner. In remote locations where cranes of sufficient height are not available, consideration should be given to providing a retractable davit on the flare structure. In normal operations, the davit is lowered below the level of the top platform or below the gas seal, to a position where the flame does not affect it. Lifting tackle should be provided to raise the davit into the lifting position.

It is necessary to give consideration to the additional wind loads resulting from the flare-mounted davit.

A.2.8 Operations

A.2.8.1 Steam control for a flare burner equipped with both an upper steam ring and centre steam is typically controlled in the following manner.

a) Set the centre steam manually to effectively mitigate internal burning and to produce the desired smokeless burning for normal, daily, minimum relief-gas flow rates. Avoid excessive centre steam quantity as it creates excessive flare noise.

b) Operate the upper steam ring to control other relief-gas flow rates, to produce smokeless burning and the desired flame characteristics. Excessive upper steam also produces excessive flare noise.

A.2.8.2 A flare burner equipped with internal steam/air tubes and upper steam ring and centre steam rings is typically controlled in the following manner.

a) Set the centre steam manually to effectively mitigate internal burning and to produce the desired smokeless burning for normal, daily, minimum relief-gas flow rates. Avoid excessive centre steam. It creates excessive flare noise.

b) Allow the internal steam/air tubes to operate before adding steam to the upper steam ring. Adjust the steam/air to produce the desired smokeless burning rate at the lowest possible noise level.

c) Start the upper steam ring, to increase the smokeless burning rate above that achievable with the internal steam/air tubes. The upper steam ring may also be used to act as a windshield to reduce wind effects on the flare flame and on the flare burner.

A.2.8.3 For pipe-flare operations, the only plant control is to maintain flare pilot ignition and maintain proper flare purge rates.

A.3 Pilots

A.3.1 Purpose

The flare pilot shall reliably ignite the flare. If the pilot fails, unburned hydrocarbons and/or toxic gases can be released to the atmosphere, potentially resulting in a vapour-cloud explosion, odour problems or adverse health effects. In most elevated-flare applications, the pilot cannot be accessed for service or replacement while the flare is in operation. The pilot system shall be reliable enough to operate for years without maintenance.

A.3.2 General description

A multitude of pilot designs exists. The majority can be described as fixed heat release, self-inspirating, pre-mix burners. The principle advantages of such pilots are

— that the pilot reliability is dependent on only one utility (i.e. fuel gas) since the air is self-inspirated;

— that the pre-mix type design affords greater stability and reliability relative to raw gas or diffusion-flame-type burners.

In some cases, compressed-air pre-mix pilots have been used instead of the inspirating type. In addition to the fuel gas supply, compressed-air pilots are dependent on the reliability of the compressed-air system. To safely utilize compressed-air pilots, an effort should be made to ensure that the installation includes one of the following functions.

a) The compressed air system has sufficient reliability. The probability of pilot failure due to air-supply failure is acceptably low.

b) The flare can be immediately taken out of service if the compressed-air system fails.

c) The pilot’s function automatically reverts to air-inspiration if the compressed-air supply fails.

d) An independent set of inspirating pilots is installed as backup.

In some cases, direct ignition of the flare or of a slipstream of the flare gas has been used in lieu of a continuous pilot. Such designs are not considered to be a suitable alternative to a continuous pilot because, without an independent fuel supply, it is impossible to ensure that a flammable mixture always exists at the location of the spark.

In order to ensure stable operation and ignition of the flare gas, the recommended minimum pilot heat release is 13,2 MW (45 000 Btu/h) (LHV) when flaring hydrocarbon gases with a lower heating value of 11 175 kJ/Nm^3 (300 Btu/scf) or greater. Pilot heat release in common practice ranges from this minimum up to 102,5 MW (350 000 Btu/h). The pilot shall remain lit and continue to ignite the flare at wind speeds up to 160 km/h (100 mph) under dry conditions and 140 km/h (85 mph) when combined with 50 mm/h (2 in/h) of rainfall. Pilot(s) shall be capable of being relit under the same environmental conditions.

The number of pilots required is a function of the flare-burner diameter. For very small flares, a single 13,2 MW (45 000 Btu/h) pilot reliably lights the flare gas. However, it should be noted that if only a single pilot is used, a single pilot failure represents a complete failure of the ignition system.

As the flare burner diameter increases, the number of pilots required to reliably light the flare, regardless of wind direction, increases. The minimum number of pilots recommended for most flare burners is given in Table A.3 as a function of burner outlet diameter (actual connection size, not hydraulic diameter) when flaring hydrocarbon gases with a lower heating value of 11 175 kJ/Nm^3 (300 Btu/scf) or greater.

While the recommended minimum number of pilots for flare burners of 200 mm (8 in) or less is only one, greater reliability can be achieved if at least two pilots are installed on every flare. Pilots in excess of those shown are often added to further reduce the risk of an unburned release.

For non-hydrocarbon gases or hydrocarbon/inert mixtures with heating values less than 11 175 kJ/Nm^3 (300 Btu/scf), additional pilots, higher heat release pilots, or some other form of fuel gas addition may be required.

NOTE Other means of direct ignition of the flare flame exist other than a continuous pilot; however, they are not typically used in refinery or petrochemical services. Such technology includes direct electrical ignition and pellet pyrotechnical ignition systems and may be used in non-continuous flare systems that include flare-gas recovery. These technologies are not included in this International Standard.

Table A.3 — Minimum number of pilots recommended for most single-point flare burners

Minimum number of pilots	**Flare burner outlet diameter** (DN)	**Flare burner outlet diameter** (NPS)
1 [a]	$\leqslant$ 200	$\leqslant$ 8
2	$>$ 200, $\leqslant$ 600	$>$ 8, $\leqslant$ 24
3	$>$ 600, $\leqslant$ 1 050	$>$ 24, $\leqslant$ 42
4	$>$ 1 050, $\leqslant$ 1 500	$>$ 42, $\leqslant$ 60
[b]	$>$ 1 500	$>$ 60

[a] For toxic gas, the minimum number shall be two.

[b] To be agreed with the purchaser.

A.3.3 Mechanical details

The continuous pilots listed above can be broken into two groups depending on the means of achieving the fuel/air pre-mix: self-inspirating and compressed air. Both self-inspirating and compressed-air pilots generally consist of the following components:

— fuel orifice that meters the fuel;

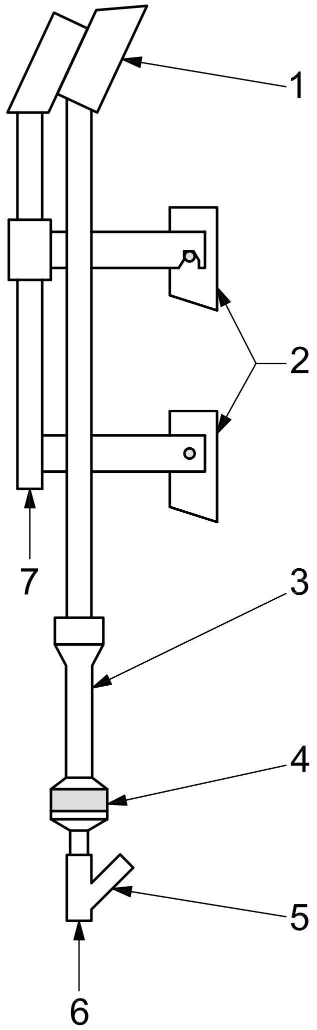
— mixer in which the air and fuel are blended;

— piping that connects the mixer and pilot tip;

— pilot tip where the flame is stabilized.

The most significant difference between self-inspirating and compressed-air pilots is the design of the mixer. In a self-inspirated pilot, the mixer is an eductor and the fuel orifice not only is used for fuel metering, but is also the means by which a fuel jet, which inspirates air into the eductor, is created. The components of a typical self-inspirating pilot are shown in Figure A.11.

In a compressed-air pilot the mixer is designed to meter and blend two pressurized gas streams. Two orifices are required in this case, one for the fuel gas and one for the air.



Key

1 pilot tip
2 pilot mounting brackets
3 pilot mixer assembly
4 pilot-gas orifice
5 strainer
6 pilot-gas inlet
7 from flame-front generator

Figure A.11 — Flare pilot assembly

The pilot should be long enough that the mixer is not exposed to the flare flame. The mixer shall never become enveloped in burned or unburned flare gas. The pilot mixer should be a distance of at least 1,8 m (6 ft) or 125 % of the actual flare burner diameter (whichever is greater) from the top of the burner. Cast iron, ductile iron and carbon steel are adequate materials for construction for the pilot mixer, pilot-gas orifice and strainer. Stainless steel is sometimes used for the mixer in order to avoid deterioration due to rust. Rust can affect the pilot reliability by blocking the mixer, thereby affecting the air-to-fuel mixture ratio of the pilot.

Pilots are available with mixers located at much greater distances from the flare burner and, in some cases, even at grade. Inspirating pilots of extended length are often made from larger piping. They have few bends in order to minimize pressure drop.

Because of the increased piping-pressure drop, less pressure drop is available at the pilot tip. Consequently, these designs often have a more restricted range of gas pressure and composition over which they can operate. Issues arising from increased pressure drop in extended-length pilots are not as problematic in compressed-air pilots. Compressed-air pilots can operate at higher pressures.

The pilot tip is continuously exposed to the pilot flame and can routinely be exposed to the flare flame. The pilot tip should be constructed of a heat-resistant material, such as 309 SS, 310 SS, CK 20 or a nickel-based alloy such as 800H. If the flare or pilot gases are expected to contain H_2S, nickel-based alloys should be avoided or some protective material should be installed to prevent high-temperature corrosion in this environment.

Weld attachments to the pilot tip should be minimized. Welds on cast pilot tips are prone to cracking, which can compromise proper operation, ignition or detection of the pilot. Threaded connections on pilot assemblies should be minimized, in particular at the pilot tip, since they often result in thermal fatigue failure.

The piping between the pilot tip and mixer can occasionally experience exposure to the flare flame. For this portion of the pilot, an austenitic stainless steel, such as 304 SS or 316 SS is adequate.

In order to minimize the chance of pilot failure due to orifice plugging, a strainer or a settling chamber should be installed just prior to the fuel orifice. The strainer should contain a screen or wire mesh with openings that are 25 % or less than the diameter of the fuel orifice.

A settling chamber should be sized to remove similarly sized particles. The strainer or settling chamber should be accessible from grade or from a platform below the flare burner. Occasionally, a pilot is designed such that it is completely retractable. In the case of a retractable pilot, not only the strainer but also the entire pilot can be serviced at grade.

With a typical-length pilot, the strainer or settling chamber, located just upstream of the fuel orifice, is very near the flare burner. It is accessible only when the flare is shut down. In some instances, this strainer has been removed since it cannot be routinely serviced. A strainer can collect many particles before it plugs, while the pilot orifice requires only one particle to plug. Strainer removal is not recommended.

In order to prevent the strainer at the pilot from plugging, an additional strainer should be mounted at grade. The strainer at grade should allow routine on-line cleaning. The strainer mounted at grade should be equipped with a screen or wire mesh that has openings the same size as or smaller than the screen installed in the strainer at the pilot.

In addition to the strainers mounted at grade, a knockout pot is recommended if there is any possibility for condensate to form in the pilot fuel line. The pilot fuel supply should also be equipped with its own regulator to prevent other intermittent gas uses to cause a significant change in pilot gas pressure. The regulator should be installed downstream of the strainer and knockout pot. A pressure gauge downstream of the regulator is necessary to properly set the regulator. A flow meter in the pilot fuel gas lines is not a requirement, but can be an extremely helpful troubleshooting tool when pilot troubles occur.

In order to accommodate pilot removals for maintenance or replacement during shutdowns, provisions should be included in the fuel supply for either a double block-and-bleed valve arrangement or the insertion of a blind flange.

If the strainers and knockout pot installed at grade function correctly, the remaining major source of debris that can plug the strainer upstream of the pilot is corrosion from the fuel-line piping. The most common pilot fuel piping is DN 15, DN 20 or DN 25 (NPS ½, NPS ¾ or NPS 1) carbon steel piping. This piping is structurally sound and inexpensive. Unfortunately, carbon steel is subject to corrosion.

In order to avoid corrosion, stainless steel piping or tubing can be used. Stainless steel piping is the best alternative, but it is expensive. Stainless steel tubing offers superior corrosion resistance, but has limited durability if not properly supported. The choice of piping material is left to the user. However, if carbon steel is used with corrosive plant fuel gas, separate fuel lines to each pilot should be considered. Fuel lines in older installations should be inspected periodically to determine the condition of the fuel lines.

A.3.4 Operation

In order to maximize pilot reliability, the most consistent and reliable fuel source should be used. Where possible, natural gas should be used. Its availability and composition are generally more consistent than that of plant gas. The likelihood of corrosion associated with impurities is much lower. If plant gas is used, due consideration shall be given to the range of fuels being handled. Some level of stability under adverse conditions is sacrificed as the range of fuel compositions being handled is increased.

Prior to operation, the pilot fuel lines should be blown clear. The pilots should not be attached to avoid blowing debris into the pilot's strainer or mixing orifice. The composition of gas within the flare system should be confirmed to be outside the explosive range prior to pilot ignition. Typically, this is achieved by purging with several system volumes of inert gas prior to pilot ignition. See ISO 23251 for more information on flare purge requirements prior to start-up.

Once the lines have been blown clear and the flare system has been confirmed to be outside the explosive range, the pilots can be ignited. Operation of the ignition equipment is covered in Clause A.4. Once ignited, the pilots should be monitored to confirm that each pilot has a flame. Flame detection is covered in Clause A.5. If the pilots are extinguished, they should be re-ignited immediately. The pilots should remain lit as long as the flare is in service.

A.3.5 Maintenance

Routine maintenance of the pilots should be performed while the flare is in service. This consists of monitoring the supply pressure and cleaning the fuel strainers, knockout pots and drains that are accessible from grade.

When the flare is taken out of service, the strainer upstream of the orifice should be cleaned and the orifice should be inspected. In addition, the pilot tip should be inspected. If the pilot tip shows signs of deterioration, it should be replaced.

A.3.6 Troubleshooting

The determination of whether a pilot flame has failed is covered in Clause A.5. If a pilot is known to have failed and will not re-ignite, the explanations in Table A.4 are possible.

Table A.4 — Troubleshooting of pilots

Problem	Possible cause	Corrective action
Ignition system failure	—	See Clause A.4 before attempting to troubleshoot the pilots themselves.
Plugged pilot tip or eductor	This can occur at start-up due to debris left behind during manufacture. Plugging causes the mixture at the pilot to be fuel-rich. If the flame does ignite, it is likely to be orange and lazy. If the plugging is severe, most of the gas can exit the mixer. Severe plugging can result in a flame exiting from the vicinity of the mixer.	Remove debris either manually or via high-pressure blowing.
Plugged pilot tip or eductor	Debris accumulation while out of service, such as a wasp nest	Remove debris either manually or via high-pressure blowing.
Plugged pilot tip or eductor	Unsaturated fuel hydrocarbons	Remove debris either manually or via high-pressure blowing. Return to design fuel gas.
Damaged pilot tip	If the pilot tip opening(s) have increased in size, the pressure drop in the pilot will have decreased. The air/fuel mixture at the pilot will become more fuel lean. The pilot might not stay lit or flashback can occur. The pilot can be difficult to light.	Replace pilot tip.
Plugged strainer, plugged nozzle or plugged orifice	This can be detected by turning the fuel gas on and then off. If the fuel line is not plugged, the fuel pressure should fall very rapidly. If the fuel pressure does not fall, or falls slowly, then the fuel line is probably plugged. The flare vendor can advise as to the time expected for the pressure to fall.	Clean strainer, nozzle or orifice as required.
Incorrect fuel	This can be determined by a fuel sample analysis. If the hydrogen concentration has increased significantly, flashbacks may be audible and flames may be visible at the mixer.	Return to design fuel gas or modify pilot to match the new fuel composition. Pilot modifications can include the following: a) replacement of the pilot orifice; b) adjustment of the air door (if any); c) replacement of the pilot entirely.

A.4 Ignition equipment

A.4.1 Purpose

Ignition equipment shall reliably ignite the pilot.

A.4.2 General description

A.4.2.1 There are four types of ignition systems that are commonly employed to light flare pilots:

— spark ignition at pilot tip;

— spark ignition of a portion of the pilot gas/air mixture prior to the pilot tip;

— compressed-air flame-front generator;

— inspirating flame-front generator.

No single ignition system is preferred in all circumstances. For improved reliability, multiple ignition systems can be installed. Spark ignition at the pilot is often preferred as the primary means of ignition because it is easily automated. A manual compressed-air flame-front generator is commonly installed as a backup system because of its ultimate reliability and serviceability. Each type of ignition system is described in A.4.2.2 to A.4.2.5

A.4.2.2 Spark ignition at pilot tip: Spark ignition of a flare pilot at the pilot tip is simple and is easy to automate. With this system, the spark generation is located somewhere near the pilot tip where it is exposed to the flammable mixture that exits the tip. In some cases, the life of the sparking device can be shortened due to continuous exposure to the pilot or flare flame once ignition is established. Unlike pilots used in boilers or process heaters, the flare pilot or sparking device cannot be replaced while the flare is in operation. Consequently, spark ignition at the pilot tip is generally not recommended as the only means of pilot ignition.

A.4.2.3 Spark ignition of a portion of the pilot gas/air mixture prior to the pilot tip: In order to limit the sparking device's flame exposure, the sparking device can be used to ignite a portion of the pilot's gas/air mixture prior to the flame exiting the tip. Downstream of the sparking device, the ignited portion of the gas/air mixture is reintroduced to the pilot tip. It is necessary that such a system be carefully designed to prevent flashback or stable burning between the ignition source and the pilot tip. As with spark ignition at the pilot tip, this type of system is relatively easy to automate. However, the sparking device is still located at the pilot and cannot be serviced while the flare is in operation. Consequently, spark ignition prior to the pilot tip is generally not recommended as the only means of pilot ignition.

A.4.2.4 Compressed-air flame-front generator: The most prevalent flare pilot ignition system is the compressed-air flame-front generator. With this system, compressed air and fuel are metered through orifices into a mixing chamber located at grade. Downstream of the mixing chamber there is a sparking device and piping which connects the mixing chamber and sparking device to the pilot tip. See Figures A.12 and A.13. During operation the flow of combustible gas is established and then ignited. This sends a flame front through the connecting piping to the pilot tip. The flame front ignites the pilot. The principal advantage of the compressed-air flame-front generator is that the flow controls and the sparking device are at grade and can be serviced while the flare is in operation. The principal disadvantage of the flame-front generator is its propensity to form moisture within the piping leading to the pilot. The moisture can cause corrosion and, if not drained prior to use, can extinguish the flame front. In cold environments, the moisture problem often results in the requirement for heat tracing and insulation in order to avoid freezing. Flushing each ignition line after use can reduce the moisture problem.

A.4.2.5 Self-inspirating flame front generator: This approach is similar to that of the compressed-air flame-front generator but, instead of compressed air, fuel pressure is used to inspirate the combustion air. The obvious advantage is that compressed air is not required. The disadvantage is that self-inspirated devices can generate only limited pressure; consequently, they can be applied only to limited distances and piping configurations.

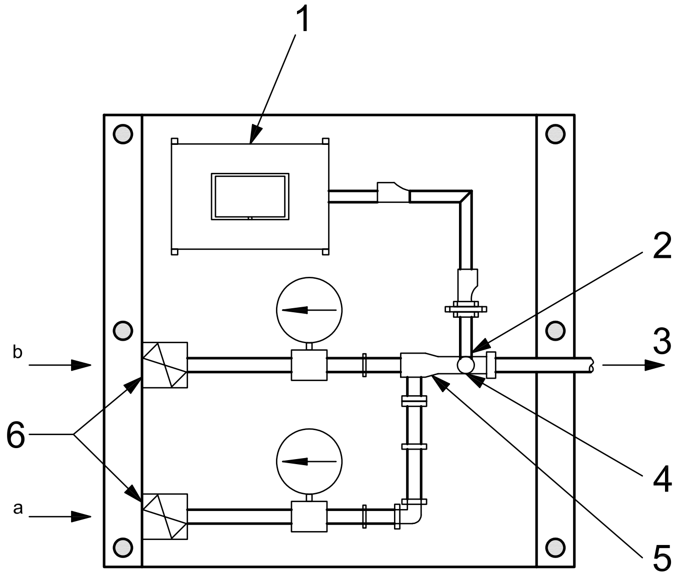
A.4.3 Mechanical details

A.4.3.1 Spark ignition at pilot tip

Generally, these systems require that an electrode capable of a capacitive high-energy or high-voltage discharge be located close to the pilot-tip discharge. The electrode may be routed down the interior of the pilot or along the outside of the pilot. It is necessary that electrode supports and/or penetrations into the pilot be constructed such that they electrically isolate the electrode from the pilot.

In some cases the electrode in this location serves the dual role of igniter and flame-ionization detector. See Clause A.5 for more on flame ionization for pilot-flame detection.

The distance between the electrode and a high-voltage power supply is often limited to approximately 7,5 m (25 ft). This limitation requires that the power supply be mounted on the flare stack. This distance is great enough that the power supply is usually not subject to damage from the flame, but small enough that the power supply cannot be accessed while the flare is in service.

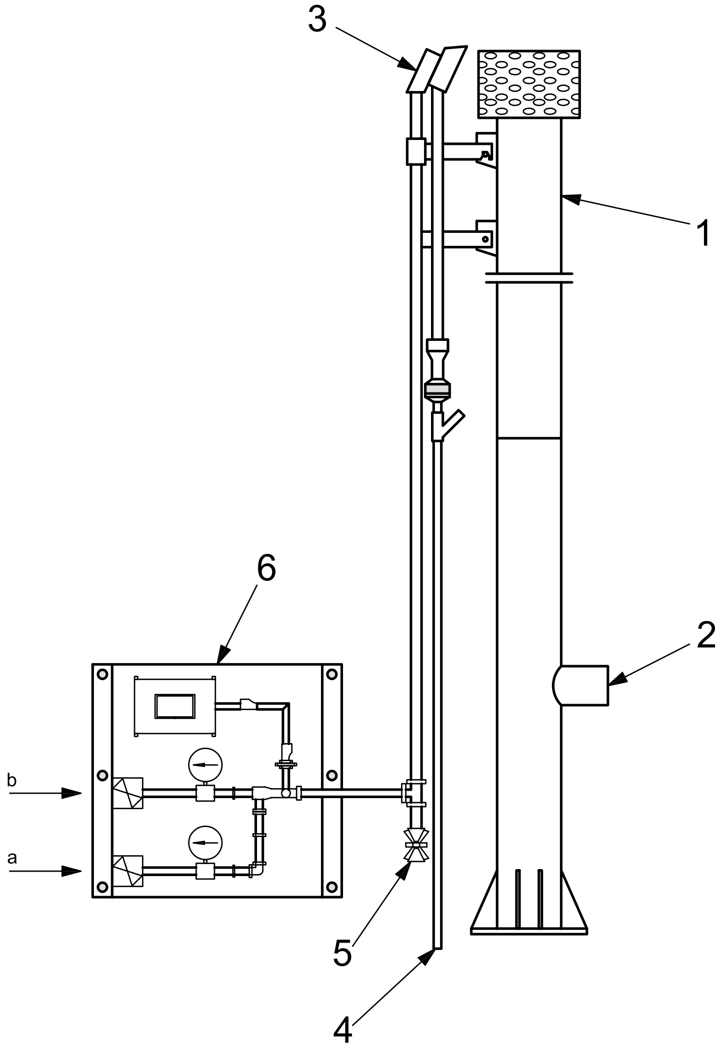


Key

1 ignition transformer with push button
2 spark plug
3 to pilot
4 sight glass
5 mixing chamber
6 flow-control valves

[a] Gas supply.
[b] Air supply.

Figure A.12 — Flame-front generator panel arrangement



Key

1 flare burner

2 relief-gas inlet

3 pilot assembly

4 pilot-gas line

5 drain

6 flame-front generator panel

[a] Gas supply.

[b] Air supply.

Figure A.13 — Flare/pilot/flame-front generator panel arrangement

Low-voltage, high-energy igniters utilize a solid-state spark plug that produces a spark, generally of 1 J or greater energy. The high energy is produced from a capacitor-discharge system. These systems use a semiconductor spark plug from the aircraft industry in place of an air-gap spark device. The semiconductor acts as an insulator that breaks down at a voltage generally less than 600 V and produces a high-energy spark. This voltage is significantly less than the several thousand volts of a standard air-gap, high-voltage spark igniter. Low-voltage, high-energy igniters can be located more than 914 m (1 000 ft) from the energy source.

These igniters offer several advantages over traditional spark igniters. The lower voltage means that the wiring between the exciter and spark device can be 600 V wiring suitable for anticipated temperature. The igniter can be located on the order of a hundred metres (feet) away from away from the electronics package. This feature allows the mounting of the electronics package for the igniter at grade, where it can be maintained and can be protected from the radiant heat of the flare. In addition, the semiconductor surface is not as likely to foul as a traditional air-gap spark system. The lower voltage is not as susceptible to grounding through insulators. The system is less affected by rain and or carbon build-up. The system is less dependent on ceramic insulators, which are prone to cracking in a flare application.

The high-energy of the igniter successfully ignites a wider range of air-fuel mixtures than a traditional spark igniter. The igniter can be located inside the pilot's air-fuel gas stream away from the normal pilot tip and its flame. The ignition of the pilot is almost instantaneous, making it well suited for automatic ignition systems. It is well suited for wet gas or harsh environments where a greater energy is required to provide ignition.

A.4.3.2 Spark ignition of a portion of the pilot gas/air mixture prior to the pilot tip

These systems generally require that an electrode capable of a high-energy capacitive discharge be located in the piping upstream of the flare burner or in a bypass line between the piping and the flare burner discharge. As with the spark ignition system described above, it is necessary that electrode supports and/or penetrations into the pilot be constructed such that they electrically isolate the electrode from the pilot.

The electrode in this system is not located in close proximity to the flame. This lack of continuous flame exposure is often claimed to extend service life. The lack of flame exposure precludes use of the electrode for flame detection.

A.4.3.3 Compressed-air flame-front generator

Compressed-air flame-front generator systems are usually built with a control panel. The control panel includes the valves and orifices as well as the mixing tee, spark generator and sight glass. The spark generator is typically either a spark plug or a piezoelectric igniter. It is generally more convenient for cleaning and parts replacement if the piping at the control panel is threaded. Either orifice unions or machined orifices may be used. The fuel- and air-pressure gauges should either be liquid filled or installed with a snubber to prevent damage to the gauge due to pressure pulses. All valves downstream of the point where the fuel and air are mixed should be full port. The sight port at the spark generator should be designed for at least the same pressure as the piping. The system shall be designed to prevent back-flow of one utility system into another.

The piping downstream of the control panel is usually constructed from welded DN 25 (NPS 1), schedule 40 carbon steel pipe. However, stainless steel pipe and/or threaded fittings can be used. Larger pipe sizes are more likely to have the flame front transition to a detonation. Smaller pipe sizes are more likely to have the flame front quenched before it reaches the pilot. Piping with equivalent lengths in excess of 1,6 km (1 mile) has been successfully employed in flame-front generator service.

In order for a flame front to propagate down the flame-front generator line, it is necessary that the line be dry. Consequently, it is essential that all the flame-front generator lines be sloped to drains that can be accessed, opened and drained prior to use. In cold environments, the flame-front lines are often heat-traced and insulated to prevent plugging due to freezing.

One flame-front generator can be used to light multiple pilots. This can be done one of two ways. The flame-front generator can be connected to a manifold of valved lines, each of which ignites a single pilot. In this case, each pilot is ignited individually. A flame-front generator can also be designed to light all pilots simultaneously with a single branching flame-front line. If this is done, care shall be taken to ensure that the flow to each line is balanced adequately to light all pilots, regardless of the wind condition. The design with a single line that branches and lights all pilots simultaneously is less expensive. However, this design has the disadvantage that the pulse from the flame-front generator can fail to light all pilots. Then, a re-ignition attempt is required to again light all pilots rather than the single failed pilot. The flame-front generator pulse during this re-ignition attempt can possibly extinguish a working pilot.

A.4.3.4 Self-inspirating flame-front generator

A self-inspirating flame-front generator has a pressure-loss limitation because the fuel/air mixture is created with an eductor. This pressure-loss limitation has a significant impact on the mechanical design. First, branching lines and valve manifolds are generally not feasible; consequently, each self-inspirating flame-front generator is dedicated to a single pilot. Second, the piping is usually limited to 90 m (300 ft) in length with very few turns. Because of the pressure-drop limitations, the eductor and spark generator are usually mounted vertically near the base of the stack. Assuming there are no horizontal sections and the eductor is open to the atmosphere, no drains are required. In cold environments, the flame-front lines are often heat-traced and insulated to prevent plugging due to freezing.

A.4.4 Operation

A.4.4.1 General

During start-up, the operator should ensure that the flare system is free of oxygen prior to igniting the pilots.

A.4.4.2 Direct spark igniter

Systems that involve spark ignition at the pilot are either controlled by a central sequencing system such as a programmable logic controller (PLC) or have a push button on a control panel located at grade. Operation of these systems is summarized as follows.

a) Turn on the fuel to the pilot that is being ignited and set it at the manufacturer’s recommended pressure. Allow adequate time for the fuel to reach the pilot tip.

b) Press and release the button to initiate the spark.

c) Monitor the flame-detection system for confirmation of pilot ignition.

If the pilot flame is not detected, repeat steps a) and b). If a pilot flame is not detected after several attempts, refer to the troubleshooting guide in A.4.6.

A.4.4.3 Compressed-air flame-front generators

These ignition systems are the most complex to operate. Operation of these systems is summarized as follows.

a) Drain condensate from fuel and compressed-air supply lines to avoid entraining condensate into the flame-front generator.

b) Confirm that the fuel inlet valve is closed. Confirm that at least one pilot ignition line is open.

c) Open the air inlet and flush the flame-front generator line(s) with air.

d) Close the air inlet.

e) Open all condensate drains in the flame-front generator line(s). Clean the drains as necessary to ensure that all liquid is removed. Close the drains.

f) If the valves connect the flame-front generator to several separate pilots, open the valve to the pilot being ignited and close all others.

g) While observing the sight glass, test the spark generator to confirm that a spark is generated. Alternatively, try to detect radio frequency (RF) interference from a spark on an open channel of a radio, but this is directionally less reliable than sight observation.

h) Turn on the fuel to the pilot that is being ignited; set it at the manufacturer's recommended pressure. Allow adequate time for the fuel to reach the pilot tip.

i) Turn on the air to the flame-front generator and set it at the manufacturer's recommended pressure.

j) Turn on the fuel to the flame-front generator and set it at the manufacturer's recommended pressure. Allow adequate time to develop a sufficient quantity of pre-mixed fuel and air in the ignition line.

k) Press and release the button to initiate the spark. Observe the sight glass and/or the pressure gauges at the time of the spark. If the mixture ignites, a flame should be visible in the sight port and a pulse should be seen in the pressure gauges. Do not hold down the button that initiates the spark. The intent is to ignite the mixture once and then to allow the flame front to travel down the pipe to the pilot. Holding the button down does not continue to generate a flame front and can stabilize a flame at the spark generator. A stabilized flame at the spark generator quickly overheats the equipment in the vicinity of the spark generator. If such a stabilized flame occurs, immediately close the fuel block valve, maintain airflow and allow equipment to cool. Restart the ignition sequence from step j).

l) If no flame is observed in the sight glass and no pulse seen in the pressure gauges when the spark is generated, refer to the operations manual or contact the manufacturer. In most cases, an incorrect fuel/air mixture is the cause and this typically requires field adjustment. See the troubleshooting guide in A.3.6.

m) Once ignition is observed at the control panel, wait for the flame front to reach the pilot. Allow an appropriate amount of time for the flame front to reach the pilot. About 1 s to 3 s for each 30 m (100 ft) of piping is typical. Consult the operations manual or manufacturer for the system specifics. Monitor the flame-detection system for confirmation of pilot ignition.

n) When awaiting a successfully detected pilot ignition, some delay can occur with thermocouple detectors. Do not quickly repeat FFG ignition attempts.

o) If the pilot flame is not detected, repeat steps k), l), m) and n). If a pilot flame is not detected after several attempts, see the troubleshooting guide in A.3.6.

p) Once the pilot is ignited, flush the line with air only to remove corrosive combustion products. After the line is flushed, close the valve leading to the ignited pilot and open the valve to the next pilot being ignited. Repeat steps j), k), l), m) and n) for all pilots being lit.

q) Once all pilots are lit, shut off the fuel to the flame-front generator, purge with air for several minutes to remove all fuel and combustion products, then shut off the air.

A.4.4.4 Self-inspirating flame-front generator

Operation of this ignition system is generally simpler than that of the compressed-air type. The differences between the former and the latter type of system are summarized below.

a) There is no compressed air. If mixture adjustment is required, it shall be accomplished through fuel orifice changes or eductor adjustments.

b) The system is not enclosed. If the flame-front line is plugged, a combustible mixture can back-flow out of the mixer. If this is the case, do not initiate the spark. Never look into the mixer during ignition.

c) These systems seldom service more than one pilot; hence, there are rarely valves downstream of the mixer.

d) These systems are usually installed vertically with very little horizontal piping. Consequently, these systems usually have no drains.

e) When the fuel supply is stopped, flashback can occur in the mixture tube. The user should decide whether special measures are required to mitigate this flashback.

A.4.4.5 Operator training

A plan for periodic training of operators in the use of pilot ignition equipment should be implemented. The training should prepare the operator to properly operate the ignition equipment under adverse or urgent conditions and can also serve as a periodic check of the functionality of the ignition system.

A.4.5 Maintenance

Routine maintenance of systems that provide a spark at the pilot is limited due to their location. Generally, these systems can be accessed only when the flare is out of service. When the flare is taken out of service, these systems should be cleaned, inspected and, if necessary, replaced.

Routine maintenance of flame-front generator systems is focused on keeping the system dry and clear as well as maintaining the valves, gauges and spark generator.

The system should be installed with drain(s) at all low spots. The drains should be left closed when not in use, but should be opened and cleaned regularly. The reason for leaving the drains closed when not in use is twofold.

a) If the drains are left open, exhaust gas from the pilot can circulate down through the flame-front generator, promoting water condensation, corrosion and accumulation of moisture.

b) If the drains are left open and accidentally not closed prior to use, a vapour-cloud explosion can be generated in the vicinity of the drain.

The pilot ignition system should be treated as an important safety-control system and should be inspected and maintained on the schedule the plant has established for such safety systems. The fuel and air orifices as well as the valves can occasionally require cleaning. The pressure gauges can occasionally require replacement or recalibration. The spark generator can also require some routine service, such as adjusting the spark gap. Periodic functional checkout should be a part of the normal maintenance procedure and can be combined with an ongoing training regimen for the operators.

A.4.6 Troubleshooting

Determination of pilot flame failure is covered in Clause A.5. If a pilot is known to have failed and will not re-ignite, it is important to understand first whether the problem is the pilot or the ignition system. Pilot problems can result from the wrong pilot fuel, no pilot fuel, improper fuel-air mixture or loss of stability. The causes of these problems are discussed in A.3.6. Ignition-system troubleshooting should be performed first because it can be done, to a large extent, without requiring a plant shutdown. See Table A.5 for ignition-system troubleshooting.

Table A.5 — Troubleshooting of ignition systems

Problem	Possible cause	Corrective action
Pilots with spark ignition at pilot tip		
No ignition	Failed electrode: This can occur due to extended flame exposure or exposure to corrosive gases.	Replace electrode.
No ignition	Liquid accumulation: Depending on location, this might or might not be possible. If the igniter is located somewhere where liquids can collect, this can isolate the spark from the gas/air mixture.	Check piping arrangement to remove low spots. Check knockout drum operation.
No ignition	Failed power supply	Replace power supply.
No ignition	Short: This can result from a failure of the cable between the electrode and the power supply or a failure of the insulation between the electrode and pilot.	Replace cable.
Pilots with spark ignition of a portion of the pilot gas/air mixture prior to the pilot tip		
No ignition	Failed electrode: See above. Liquid accumulation: See above. Failed power supply: See above. Short: See above.	See above.
No ignition	Improper pilot fuel: In this system, the spark lights a portion of the fuel-air mixture supplied to the pilot tip. Improper pilot fuel can cause flashback or stabilization of a flame upstream of the pilot tip.	Return to design fuel gas or modify pilot to match the new fuel composition. Pilot modifications can include a) replacement of the pilot orifice; b) adjustment of the air door (if any); c) replacement of the pilot entirely.
Pilots with a compressed-air flame-front generator		
Failure to spark	Failed spark generator e.g., transformer Faulty ignition lead wire Damage to spark plug Fouling or improper spark-plug gap are possible causes of spark failure.	Replace failed component.
No fuel to flame-front generator	Valves being closed or the fuel-metering orifice being plugged can cause this.	Check valve position and/or orifice cleanliness.
No air to flame-front generator	Valves being closed or the air-metering orifice being plugged can cause this.	Check valve position and/or orifice cleanliness.

Table A.5 (*continued*)

Problem	Possible Cause	Corrective Action
No flame present	Fuel composition and pressure to flame-front generator. Air pressure to flame-front generator. Improper fuel characteristics can cause no flame or a detonation. Improper fuel/air mixture: An improper mixture does not support a flame front. An improper mixture can result from incorrect fuel or air pressure setting, incorrect fuel or air orifice sizing or improper fuel composition.	Return to design fuel gas. Restore original pressure settings. Replace FFG fuel orifice to match the new fuel composition. Refer to manufacturer’s instructions.
No flame	Plugged piping to flare: Ice formation and debris are two examples. Pressurizing the air supply only while simultaneously observing the air and fuel pressure gauges can identify plugging.	High-pressure blowing to remove debris. Inject de-icing chemicals to melt ice plug.
No flame	Moisture in piping to flare. This is one of the most common problems in flame-front generators. A small amount of moisture can quench the flame front. A symptom of this problem is a seemingly strong ignition, but no evidence of a flame front reaching the pilot.	Purge flame-front generator and ignition pipe with dry air prior to attempting ignition. Drain any low points in ignition piping.
No flame	Drain open in piping to flare. In an effort to eliminate moisture in the piping, drain valves or plugs have been accidentally left open. This can result in the same symptoms observed with moisture, but is far more dangerous as combustible gas and/or a flame front can be discharged at an unexpected location.	Check drain valve position or reinstall drain plugs.
Pilots with a self-inspirating flame-front generator		
No ignition or flame.	Failed spark generator: See above. No fuel to flame-front generator: See above. Improper fuel to flame-front generator: See above. Improper fuel/air mixture: See above. Plugged piping to flare: See above. Moisture in piping to flare: See above.	See above.

A.5 Flame-detection equipment

A.5.1 Purpose

The flame-detection system confirms that the pilots are lit. This is often confused with simple confirmation that a flame exists. While these two statements are usually synonymous, there is an important difference. If the pilots are lit and a volume of inert gas is released, the flare flame is extinguished only while the inert gas is being discharged. If the pilots are not lit, but the flare is, and a volume of inert gas is released, the flare flame remains extinguished after the inert-gas release and until a pilot can be ignited. If the pilots are not lit because they have failed, the flare can remain unlit for an extended period of time. Consequently, it is important to confirm both the presence of a flame and also the presence of a pilot flame.

A.5.2 General description

A.5.2.1 General

A pilot-flame detection system utilizes the heat, ionized gas, light or sound generated by a pilot flame to verify that a pilot is burning. An example of the use of each of these energy sources for flame detection is described in A.5.2.2 to A.5.2.5 respectively.

A.5.2.2 Thermocouples

The most common flare pilot-flame detector is a thermocouple. Thermocouples have the advantage that they detect the pilot flame only and are not directly exposed to the flare flame. Relative to other types of detectors, thermocouples have the disadvantage of a relatively slow response time and an often limited service life. The limited service life is a frequent problem, since in most cases the thermocouples cannot be replaced while the flare is in operation unless a retractable type is used.

A.5.2.3 Flame ionization

A flame generates ionized gases within the flame envelope. Flame-ionization detectors function based on a change of resistance between two electrodes. Flame-ionization detectors have the advantage that they respond rapidly and that they detect the pilot flame only. The disadvantage of flame-ionization detectors is that it is necessary that they be exposed directly to the flame. Similar to a thermocouple, the flame-ionization detector is mounted on the pilot; hence, if it fails, it cannot be serviced while the flare is in operation.

A.5.2.4 Optical systems

There are two types of optical sensors: ultraviolet (UV) and infrared (IR). Both types have the advantage of being located at grade where they can be serviced while the flare is in operation. Both types can indicate false flame failures caused by obscuration due to clouds or precipitation. The most significant disadvantage concerning existing designs of these detectors is their inability to detect the pilot flame separately from the main flame. Given this disadvantage, these detectors are not recommended for use as the sole means of pilot flame detection.

Infrared imagers are being developed that can overcome this disadvantage.

A.5.2.5 Acoustic systems

A flare pilot flame generates a characteristic sound when it is burning. If the pilot flame is extinguished, the sound changes. The pilot sound is conveyed to grade where an acoustic pilot-flame detector monitors the pilot sound and signals the pilot operating condition. The acoustic detector differentiates the monitored sound from the other sounds in the neighbourhood of the pilot. An acoustic pilot-flame detector can be installed and serviced while the flare is in operation.

A.5.3 Mechanical details

A.5.3.1 Thermocouples

Typically, Type K thermocouples in 310SS or Inconel[7)] sheaths are used. The sheathing should extend throughout the zone that can experience flame impingement, typically at least 1,8 m (6 ft) or 125 % of the actual flare burner diameter. In order to improve the service life, thermocouples are sometimes located in a thermowell that is incorporated into the pilot design. In addition, some designs today are available with multiple thermocouples, such that if one fails, a second can be put into service. There are also systems that are now offered with retractable thermocouples that can be replaced while the flare is in service.

Retractable thermocouple systems usually consist of a smoothbore conduit with a limited number of bends that extends from grade to the pilot. A coiled, flexible thermocouple is inserted from grade though the conduit. These systems add expense to the flare system, but improve reliability when properly installed by allowing thermocouple replacement while the flare is in service.

A.5.3.2 Flame ionization

Two electrodes are required for a flame-ionization system. In practice, the pilot tip is usually used as the ground electrode. A conductor of much smaller area is positioned in the flame envelope and functions as the other electrode. An alternating voltage is applied across the electrodes; direct current flow is monitored as a means of flame detection.

A.5.4 Optical systems

Optical systems are mounted at grade and it is necessary that they be directed at the flare. All optical systems have some means of aiming the detector, either sighting directly through the detector optics or through a scope mounted on the detector. The detectors should be mounted on an easily accessible, vibration-free platform that is located one to three stack heights from the flare burner. Most optical systems have a maximum range of 150 m to 300 m (500 ft to 1 000 ft), which is adequate for most flares. Infrared detectors should be located such that at no time during the day does the detector face directly into sunlight. In the northern hemisphere, this means that the detector should be mounted on the south side of the stack.

The electronics associated with optical detectors are usually mounted close to the detector. Local status lights and alarm strobes are available from some manufacturers.

A.5.5 Acoustic systems

An acoustic pilot-detection system consists of a sensor unit and a signal-processing unit. Wiring interconnects the units. The pilot sound is normally conveyed to grade via the piping connecting the pilot to the flame-front generator. The sensor unit is attached to the pilot’s flame-front generator pipe near the base of the flare stack. The signal-processing unit may be placed in a location up to 365 m (1 200 ft) distant from the sensor unit.

A.5.6 Operation

A.5.6.1 Thermocouples

A temperature greater than the minimum set by the pilot manufacturer indicates the presence of a pilot flame. Some manufacturers have accelerated flame detection by monitoring the rate of temperature change as well as its magnitude.

---

7) Inconel™ is an example of a suitable product available commercially. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of this product.

A.5.6.2 Flame ionization

The presence of a flame between the electrodes creates a current flow between electrodes. The difference in electrode areas is such that the resulting current is rectified (flows preferentially in one direction). A short in the system creates current flow, but it is not rectified. Hence, the rectified current is indicative of a flame.

A.5.6.3 Optical systems

As mentioned above, both IR and UV systems are available. Because of the significant background levels of IR radiation in the atmosphere, an infrared detector shall look for more than simply the magnitude of the IR radiation within a certain waveband. Infrared detectors make use of the fact that flames emit IR radiation at relatively discrete frequencies. By observing the IR radiation in two bands, one characteristic of flame emission and one not, the ratio of the two signals is indicative of a flame.

There is substantially less background UV radiation, and flames emit UV at very discrete wavelengths. Consequently, UV systems simply monitor the magnitude of UV radiation in a particular waveband (usually that associated with emissions from OH radicals). UV is absorbed by regular glass so the optics in a UV system are generally constructed from quartz. The sun also emits UV radiation. The positioning of UV-based detectors shall avoid interference from sun-generated UV.

A.5.6.4 Acoustic systems

Pilot sound is continuously monitored by the system. A change in pilot status is detected and indicated via the local status lights and the dry contacts. Factory signal-processor settings can be field-adjusted to account for site conditions, such as the complexity of the piping from the pilot to the sensor.

A.5.7 Maintenance

A.5.7.1 Thermocouples

Unless a retractable thermocouple system is installed, there is very little maintenance that can be performed on a thermocouple, other than monitoring its performance to ensure that it has not failed. If it fails and more than one thermocouple is installed, the spare thermocouple can be put into service. If it fails and is retractable, it can be replaced.

A.5.7.2 Flame ionization

There is virtually no maintenance that can be performed on a flame-ionization system, unless the pilot is taken out of service. The only maintenance possible during operation of the flare is on the controls “at grade”.

A.5.7.3 Optical systems

The sighting of the optical systems should be checked regularly to ensure that the flare burner remains in the field of view. The optics should be cleaned periodically.

A.5.7.4 Acoustic systems

The sensor and signal-processing units are located at grade and are accessible during flare operation. The drains in the sound-conveying piping should be checked on a regular schedule.

A.5.8 Troubleshooting

See Table A.6.

Table A.6 — Troubleshooting of flame-detection systems

Problem	Possible cause	Corrective action
Pilot detector is suspected of being in error.	Pilot and its ignition system are believed to be functioning correctly, check corrective-action steps to confirm pilot ignition.	Inspect with binoculars or telescope. Inspect at night. Use the FFG to supply additional fuel to make the pilot flame more visible.
Pilot detection system is determined to be showing a false loss of flame when one is present or false confirmation of flame when it is absent.	Check electrical supply and fuses.	Perform a functional check based on the manufacturer's instructions.
	Thermocouple failure	Check for open circuit.
	Thermocouple sensing flare flame rather than pilot flame	Check wind direction and flame position relative to pilot in question.
	Flame-ionization electrode failure	Check for open circuit.
	Flame-ionization electrode shorting	The signal processor should recognize this as an unrectified signal. Check signal processor.
	Flame-ionization electrodes sensing flare flame rather than pilot flame	Check wind direction and flame position relative to pilot in question.
	Improperly aimed optical system	Check view angle.
	Optical system obscured by clouds or fog	Check line of sight.
	Optical system obscured by dirty optics	Inspect optics and clean as required.
	Optical system sensing flare flame rather than pilot flame	This is a limitation of the optical sensing devices. No corrective action is currently possible.
	The acoustic-system sound-conveying path may be blocked.	Check drains. Check for displaced or damaged piping. Confirm that the path is clear.
	Suspected false confirmation of flame by acoustic system	Check first by disconnecting the sensor unit from the sound-conveying piping and then by covering the sensor inlet. The system should then indicate the pilot is out.
Pilot detector is suspected of being in error.	Interconnecting wiring and its terminals can be compromised or faulty.	Replace or repair wiring.
	The “control” units can be faulty or be suffering from the effects of an aggressive environment.	Replace components.

A.6 Verification test

A.6.1 General

To ensure the pilots, ignitors and detectors perform under the severe weather-condition requirements of this International Standard, a production unit of each combination of pilot, ignitor and detection system should be tested to verify the ability to meet the required performance. The following is one method of such a test protocol.

A.6.2 Setup

The test should be performed at a test facility equipped with the following:

— Stack, DN 450 (NPS 18) or larger, for mounting the pilots can ensure that the effects of eddy currents around the stack are simulated.

— Air blowers that can produce the required wind speed; the volume and discharge of the air shall extend beyond the entire diameter of the stack and all of the upper portions of the pilot; this ensures that the simulated wind speed is consistent in the area of the pilot tip. If the pilot has an air inspirator, there shall also be a similar air discharge to produce wind over and around the inspirator.

— The air discharge should be equipped with water injection to produce the required amount of rain.

— Suitable, calibrated instrumentation should be used to verify the wind speed and the amount of rain.

— The stack should be equipped appropriately so that the pilot can be mounted in upwind, crosswind and downwind positions to ensure that the performance is measured under different wind directions.

A.6.3 Testing

The performance test should include testing the combination of pilot, ignitor and detector as appropriate for all three positions around the test stack. Record the data for each component at each position as follows.

a) Pilot: Record the fuel pressure, fuel composition, fuel flow rate and net heat release used for the test. Record the maximum wind speed without rain at which the pilot remains stable. The pilot flame shall be proven to be stable for at least 3 min after the airflow is established. For each position, also test and record the maximum wind speed with rain at which the pilot remains stable. Record the amount of rain for each test.

b) Ignitors: Record the maximum wind speed at which the pilot ignites three consecutive times. Provide typical details on the type of ignitor used. For FFG, include air and fuel flow rate, pressure and composition/heat release of the fuel. State the model of pilot on which the test was performed. For each position, also test as per the above with a recorded amount of rain. For electronic systems, record how long it takes to light the pilot each time.

c) Detectors: Record the maximum wind speed at which the detector can monitor the flame consistently three consecutive times. Provide typical details on the type of detector used. For thermocouples, record the temperature of the thermocouple without wind and the temperature after 3 min of stable operation with the corresponding recorded wind speed. For all types of detectors, turn the pilot fuel gas off and record the length of time required for the monitor to detect that the pilot is out. Do this with and without wind. Perform the above with rain and record the corresponding amount.

A.7 Purge-gas conservation seals

A.7.1 Purpose

All flare systems are susceptible to flashback and explosion if not properly purged to keep air (oxygen) from entering the flare stack downward through the flare burner. To prevent air from entering the system during normal operation, a continuous purge is required. A purge-conservation device may be installed in (or immediately below) the flare burner in order to reduce the purge-gas consumption.

A.7.2 General description

Purge-conservation devices are designed as stationary mechanical components. They reduce the use of purge gas while preventing some (but not all) air from entering downward into the flare stack. Several names are used to describe these seals, but some generic names are velocity seals, venturi seals, buoyancy seals and diffusion seals.

A.7.3 Mechanical details

Refer to ISO 23251 for examples and requirements for these seals.

A.7.4 Maintenance

Buoyancy or diffusion-type purge seals have several flow reversals. These act to separate the liquids from the flare gas. These liquids can accumulate in the bottom of the seal and cause several concerns, including blockage of the seal, corrosion and additional structural loads. Seals are equipped with a drain connection and separate drain line to allow removal of these liquids and elimination of these problems.

The seal shall be equipped with an inspection opening to allow cleaning of the drain during shutdowns. The drain should be designed in a manner to mitigate plugging. The drain shall be sealed to prevent the entry of air. This is often accomplished by the use of a liquid-filled loop seal sized for at least two times the sum of the calculated seal and flare-burner pressure drop at the maximum flow rate.

This seal leg should have a level indication and alarm. These drains shall be of an adequate size to prevent plugging and shall be maintained. The drain line should allow for routine back-blowing with a purge gas containing no oxygen. The drain line shall be protected against freezing. A pressure gauge should be used to ensure the line is open and free.

Velocity or venturi-type seals do not normally require maintenance except for inspection and cleanout at shutdowns. To avoid liquid accumulation, it is necessary that velocity seals incorporate drain holes at the base.

A.7.5 Troubleshooting

See Table A.7.

Table A.7 — Troubleshooting of purge-gas conservation seals — Buoyancy type

Problem	Possible cause	Corrective action
Burning through seal (hole in top or sidewall); hole in the side of the flare burner	Internal burning	Check drain loop seal. Restore liquid level if necessary. Temporary: switch to nitrogen or inert purge. Repair or replace as soon as possible. Divert to backup or rental flare.
	Corrosion from steam condensate from smokeless flare	Temporary: switch to nitrogen or inert purge. Repair or replace as soon as possible. Divert to backup or rental flare.
Excessive pressure drop	Purge-gas conservation device is plugged.	Clean drain or replace device.
	Freezing due to steam condensate from smokeless flare or rain accumulation	Blow drain (if equipped) with high-pressure hot glycol or alcohol mixture. Check that the heat tracing is operational, if installed. Divert to backup or rental flare.
	Carbon build-up due to internal burning	Blow drain (if equipped) with high-pressure gas to clear. Use pipe-cleaning service, if possible. Repair or replace as soon as possible. Divert to backup or rental flare.
	Refractory cracking and spalling causing plugging of the drain and the bottom of seal	Blow drain (if equipped) with high-pressure gas to clear. Repair or replace as soon as possible. Divert to backup or rental flare.
Excessive sway at the top of the flare	Purge-gas conservation device is plugged and full of liquid or debris.	Clean drain.
Leakage from the base of the seal	Corrosion due to plugged or fouled drain	Clean drain with high-pressure steam or gas. Temporary: switch to nitrogen or inert purge. Repair or replace as soon as possible. Divert to backup or rental flare.
Liquid carryover (burning rain)	Hydrocarbon condensate build-up and accumulation, carried out through the seal and flare burner by large gas flows; excessive liquid build-up is normally also seen as excessive pressure drop. Small amounts of HC liquid do not cause a noticeable pressure drop but are easily swept up and out of the flare by large flaring rates.	Check knockout-drum liquid level. Drain liquid if level is too high. Clean drain. Blow drain with high-pressure steam or hot nitrogen. Start blow-down procedure slowly and watch for burning rain; gradually increase blow rate. Check that heat tracing is operational, if installed. Divert to backup or rental flare.
Noise	Purge-gas conservation device is too small or is partially plugged by carbon, ice or refractory.	Clean drain or replace with a device of larger diameter. See above for recommendations regarding excessive pressure drop.

A.8 Knockout drums and liquid seals

A.8.1 Knockout drum

A.8.1.1 A flare knockout drum separates liquid from gas in a flare system and holds a specified amount of liquid that can be relieved during an emergency situation. See ISO 23251 for the amount and size of liquid droplets that can be handled smokelessly by the flare burner.

A.8.1.2 Knockout drums are typically located on the main flare line upstream of the flare stack or any liquid seal. When there are particular pieces of equipment or process units within a plant that provide major sources of liquid to the flare, it is desirable to have knockout drums inside the battery limits for these sources. This reduces the sizing requirements for the main flare knockout drum as well as facilitating product recovery.

A.8.1.3 There are three basic types of knockout-drum designs that can be incorporated into a flare system: a horizontal settling drum, a vertical settling drum and a vertical centrifugal separator.

A.8.1.4 ISO 23251 describes flare knockout-drum orientation, design criteria, instrumentation, mechanical details, operations, maintenance and troubleshooting.

A.8.2 Liquid seal

A.8.2.1 Flare liquid seals are designed to

a) prevent any flashback originating from the flare burner from propagating back through the flare system;

b) maintain a slight positive system pressure to ensure that there is no air leakage into the flare system and to permit the use of a flare-gas recovery system;

c) provide a method of flare staging between a smaller capacity smokeless flare and full-size emergency flare;

d) prevent ingress of air into the flare system during sudden temperature changes, such as that following a major release of flare gas or steaming to flare.

A.8.2.2 Liquid seals are located after the main knockout drum and before the flare itself. Elevated flares can be equipped with a separate seal drum or can incorporate the liquid seal into the base of the flare stack.

A.8.2.3 Liquid seals should preferably be vertical. An internal wave attenuator should be provided around the inlet pipe.

A.8.2.4 Liquid seal and purge system should be designed to prevent the seal from being broken as a result of the vacuum formed in the flare header following a major release of flare gas or steaming, as specified on General flare data sheet 5 in Annex E. See also the data sheet instructions for General flare data sheet 5 in Annex D.

A.8.2.5 Liquid seals may be used in services below 0 °C if the effect of the cold fluid on the seal liquid is taken into account. Water seals are not recommended where there is a risk of obstructing the flare system due to an ice plug. Alternative sealing fluids, such as stove oil or a glycol/water mixture, may be considered. If a flammable seal fluid is used, consider that liquid carryover from a liquid seal can occur during a major flaring event.

A.8.2.6 ISO 23251 provides additional information for liquid seals.

A.9 Blowers and drivers

A.9.1 Purpose

A blower (fan) is used to provide air and turbulence to the combustion process to make a flare smokeless. The circumstances when this should be considered are addressed in A.2.5. Clause A.9 describes some design and practical considerations associated with such devices.

A.9.2 General description

In general, three types of blowers have been used for this duty:

— centrifugal: commonly backward-curved bladed fans used with electric-motor drives; internal combustion engine or steam turbine drives have been used under special circumstances (see Figure A.14);

— vaneaxial axial-flow fans with fixed or adjustable pitched blades: commonly used with close-coupled electric-motor drives up to 260 kW (350 HP) (see Figure A.15);

— high-pressure blowers: commonly multi-stage, centrifugal blowers with a wide variety of impeller configurations used with discharge pressures typically up to 103 kPa (15 psig) or more.

Blowers can be used singly, in multiples allowing stand-by, or in multiples allowing added capacity (see A.9.3). The drives can be single-, double- or variable-speed, and with or without other flow control devices.

A.9.3 Mechanical details

The following mechanical details should be considered.

a) If multiple blowers are provided, attention should be paid to the potential of air from the active blower passing through the inactive (idle) blower. Back-draught dampers or “anti-sail” pawls on the blower drive should be provided to forestall problems. There are two principal effects of this air loss.

    1) The escape of air through this route lowers smokeless capacity.

    2) The passage of air causes the blades of the idle blower to rotate in the opposite direction to that of the driven condition. Thus, when it is necessary to start the blower, it is necessary that the motor stop spinning in the reverse direction. This extends the period of low-speed operation. It is common that electric-motor starters can trip on thermal overload during this extended period of low inductance. In extreme cases, it is possible to break the driveshaft under these conditions.

b) The blower selection, installation and operation are an essential part of the performance of the flare. It is recommended that the flare manufacturer be given design and supply responsibility to reduce operational problems.

c) Care should be taken when applying purchaser standards to this blower. The specifications for a blower for smokeless burning with an air-assisted flare burner might not conform to the specifications for blowers applied to process plant requirements. These purchaser fan specifications typically reflect the use of much larger fans under very different service conditions, e.g. as specified in ISO 13705. The blower on an air-assisted flare is rated for a peak duty to generate a maximum smokeless-burning capacity. This blower rarely operates at this high load condition. Normal air-assisted smokeless-flare blower operations should be at a reduced operating condition. It is not typical to rate a smoke-suppression blower with the over-rating on airflow and/or pressure that is typical for a process blower where the blower is fully loaded and critical to plant operations.

d) The driver for a blower for an air-assisted smokeless-flare operation differs from those applied to process blowers. As noted above, it is not necessary that the horsepower rating reflect the over-rating for additional airflow and/or pressure drop. The driver rating may also be engineered with regard to the typical load cycle of a smoke-suppression blower where high flow rates and pressures are atypical of daily operating conditions. It is necessary that the specifications for an electric driver reflect the flare operating-area requirements and the type of blower applied. Typically, totally enclosed motors are applied to meet electrical-area classifications.

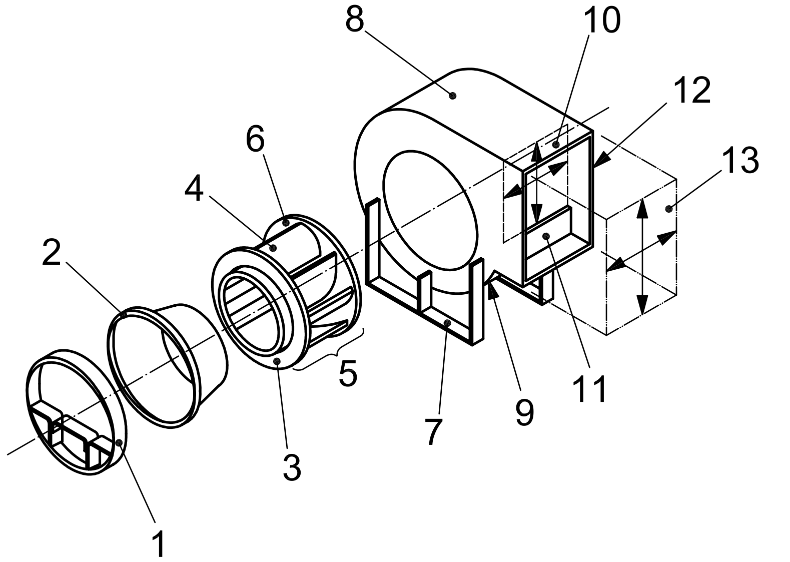
e) For centrifugal blowers, the motor is totally enclosed and fan-cooled (TEFC). For direct-drive axial blowers, a totally enclosed, air-over (TEAO) motor is typically applied. A TEAO motor is essentially a TEFC without the cooling fan. The TEAO motor uses the blower airflow for cooling and is more efficient and can have a higher power availability than does a TEFC motor. Normal electric-motor specifications can cause problems when improperly applied; e.g., most sites require all motors to be TEFC but the vaneaxial design in AMCA 801 arrangement 4 uses a TEAO motor design.

f) The blowers used for air-assisted smokeless flares can contribute to the plant noise levels. For overall noise management, mufflers and noise enclosures are sometimes used. Consideration of local noise levels at the blower should include the flare location and the worker exposure time to the blower noise. If the blower is operating at a high rate, there is significant flaring and it can be atypical for service personnel to be at the blower location and exposed to such blower noise for extended time periods. It is necessary that the impact of the application of blower mufflers and enclosures on the blower performance and power requirements be considered.

g) Winter operation will cause the motors to draw more current than summer conditions. Selection of winter thermal overload settings and breaker settings shall take into account this increase. In a TEAO configuration, the additional cooling from blowing very cold air over the motor prevents the motor from overheating.

h) Blower control options that provide enhanced flow control and substantial energy savings are available. These options include inlet-vane dampers, controllable-pitch vaneaxial fans, multiple-blower combinations and variable-speed drives.

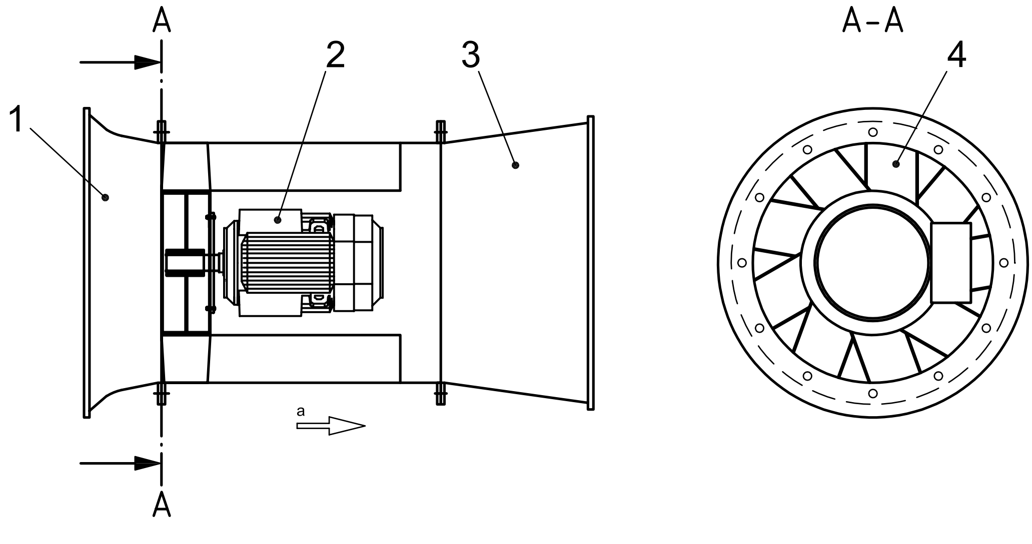
i) It is necessary that the attachment of the blower and/or its ducting to a flare stack consider the relative movement and structural loads of the attachment. For instance, if a fixed blower foundation is used, it is necessary that the ducting between the blower attachment and the flare stack take into consideration the flare-stack movement at the point of attachment. If an axial blower is directly attached to a flare stack, the flare stack structural design shall consider the loads due to the blower.



Key

1 inlet collar
2 inlet
3 rim
4 blades
5 impeller
6 backplate
7 supports
8 housing
9 scroll
10 blast area
11 cutoff
12 outlet
13 outlet area

Figure A.14 — Centrifugal fan



Key

1 inlet cone
2 motor
3 outlet cone
4 fan

[a] Airflow direction.

Figure A.15 — Vaneaxial fan

A.9.4 Operations

Operation of a blower fitted to an air-assisted flare should take into consideration the following.

a) Over-aeration can cause the following problems:

   1) flame blowout;

   2) excessive noise (low frequency);

   3) lower combustion or destruction efficiency;

   4) shorter flare burner life.

b) Most large motors have limits on the number of cold and hot starts per hour. The system shall be designed and operated to avoid excessive restarts.

c) The blower should be operating (at least at low airflow) at all times for cooling and when there is the potential of a back-flow of flare gas (especially of high relative molecular mass) within the air riser. At least one blower should be operating at all times in a multi-blower system.

A.9.5 Maintenance

Unlike many components of a flare system, blowers are generally in a position where they can be maintained. Motor and blower vendors should provide maintenance schedules for their equipment showing recommended frequency for actions such as

a) motor bearing and impeller lubrication as required;

b) free operation of back-draught dampers or anti-sail devices;

c) operation of flow-control devices, together with associated controls and actuators;

d) checking of motor-speed control devices and starters (as appropriate);

e) addressing out-of-balance or unusual vibration conditions;

f) ensuring open passage to air entry (e.g., silencers, screens);

g) replacement of any wearing parts such as rotating unions for controllable pitch fans.

Blowers are normally located at the base of the flare. It is necessary that consideration be given to the degree of radiation to which both equipment and personnel are exposed. Mitigation of such exposure can include taller flare stack and radiation shielding.

A.9.6 Troubleshooting

Possible problems with blowers that are specific to their use in a flare system are ultimately related to the production of unexpected smoke in a flare flame; such smoke is not necessarily caused by the blower system. Table A.8 provides a list of a number of potential problems and possible causes that can generally be checked without shutting down the flare system. The flare vendor and/or the blower vendor should be contacted to determine if there are any other possible problems/causes that are application-specific.

Table A.8 — Troubleshooting of blower systems

Problem	Possible cause	Corrective action
Blower not moving	Tripped overload or breaker	Check for short circuits in power wiring to blower motor. Reset overload or breaker.
	Incorrect power	Check feed voltage and current draw on each phase leg. Correct any wiring problems revealed by this check. Provide correct voltage to the blower.
Insufficient airflow	Local blockage at blower inlet	Inspect blower inlet. Remove any debris or obstructions
	Incorrect fan speed	Confirm fan speed.
	Incorrect blade pitch	Stop blower. Record actual blade settings on each fan blade. Compare average blade setting to design setting. Adjust as required to match design setting.
	Improper fan selection	Measure fan outlet pressure. Compare to fan selection basis. Adjust fan blades (if possible) to obtain proper airflow.
Incorrect airflow control	Malfunction of flow control (e.g. inlet vane damper, blade pitch or speed control)	Verify proper operation of any flow-control systems associated with the blower.
Reverse airflow	Reversed power wiring	Confirm proper wiring. Confirm correct direction of rotation of fan by shutting off power to the fan and observing rotation as the fan slows down.
	Blockage at blower outlet	Confirm position of outlet damper.
Reverse airflow when blower should be off	Back-flow from another blower	Confirm position of outlet damper.

A.10 Blower staging and control equipment

A.10.1 Purpose

In an air-assisted flare system, the objective is to achieve satisfactory performance, i.e., smokeless operation over the design range without undue noise or waste of power, possibly over a wide range of flow and gas composition. An auxiliary control system can be needed to determine what combination of blowers and operation of controls is required to achieve such performance.

A.10.2 General description

The equipment falls into three categories:

a) Detection: The condition of the flare system is continuously monitored and the system is operated in response to the parameters of this monitoring. This detection can be as simple as monitoring the flare gas pressure (by pressure switch or transmitter). However, if the temperature or gas composition can change substantially, such control can become more complex, possibly with flare and airflow measurements and/or smoke or infrared detection with added modification from such controls. See Clause A.11. Feedback control on blower output can also possibly be required.

b) Logic: It is necessary to process the signal(s) from the detection phase to give appropriate control action. This can be done by local dedicated control systems (e.g., PLCs) or the logic can be passed to a central control system (e.g., DCS).

c) Flow control: The control system from b) is arranged to provide the appropriate signals to provide control. This can be as simple as arranging for an increase in motor speed or the starting of another blower motor. However, it can be necessary for the control to be as complicated as a sophisticated logic system that uses all or some of the following techniques: stepwise speed control, continuous motor-speed control and/or additional capacity addition, continuous flow control (by damper). In all control schemes, a readily available manual override control should be fitted.

A.10.3 Mechanical details

The selection of blower and blower control equipment for an air-assisted smokeless flare is a function of

— the smokeless burning requirements,

— the flare design, and

— environmental parameters.

The quantity of forced-draught air required for smokeless burning is the most common design consideration. Often this is some fraction of the stoichiometric combustion-air requirement. The air quantity alone, though, does not determine the smokeless-burning performance. The air velocity at the mixing point with relief gas is also an important factor. This is the air energy at the flare burner. The stoichiometric air fraction used for smokeless burning can be significantly altered by the velocity employed at the flare burner and by the flare burner design.

Blower energy expended to deliver the air to the flare burner does not effectively contribute to the smokeless burning. Care is required in the design of the air-delivery piping/stack and connection of the blower(s) to the flare. Obstructions in the air-delivery system, like flanges on an internal gas riser, can significantly contribute to blower energy losses.

The blower airflow is designed for a maximum smokeless-burning rate with maximum design airflow. The flare system shall operate at reduced smokeless-burning capacities without excessive use of energy and without the generation of an unstable or noisy flame. The number of blowers and the type of airflow control employed are functions of the size, type and burning requirements of the flare system. On some systems, a single blower is sufficient. Reduced smokeless flaring, on such a system, can be achieved with the use of a multiple-speed blower motor, a variable-speed blower motor or the use of blower inlet or outlet dampers. The least operating power is realized with the use of a multiple-speed or variable-speed motor. An inlet damper also reduces operating power. Outlet dampers do not lower the operating horsepower.

In the simplest control system, a multiple-speed blower motor is advanced to high speed or returned to low-speed operation on a flow or pressure signal from the flare-relief header. It is recommended that the advancement to high speed and the return to low speed incorporate some signal hysteresis. If a single switch point is used, the blower can cycle between speeds excessively due to flow/pressure variations in the flare header. Attention should be paid to the practicality of pressure detection if there is a wide flow range (the gas pressure varies directly with the square root of the flow over the relevant range). Special care should be paid to the setting of the “deadband” to avoid frequent blower stopping and starting at a particular range of flare flow.

It is necessary that the air-assisted smokeless flare be designed to ensure that the blower-speed selections supply sufficient energy to produce smokeless burning at the maximum rate while offering sufficiently low air energy at reduced rates to burn stably at minimum flow rates.

If a variable-speed motor or inlet damper is used for proportional control of smoke-suppression airflow to relief-gas flow, then reliable instrumentation to monitor the flow of flare vapours in the header is required. It is necessary that this flow measurement consider the full operating range of the flare-system design. Air-assisted smokeless flares are often designed for large relief rates where smoke is acceptable while offering smokeless burning at much lower flow rates. For such systems, measuring low-speed, low-pressure flows in a flare header can be difficult. Refer to Clause A.11.

Continuously variable airflow control over the design range is possible by continuous motor-speed control (e.g., steam turbine, or internal combustion engine) or by a conventional damper control. To control such a system requires suitable detection devices, e.g., a pressure transmitter, a flare-gas flow-metering control or smoke control (e.g., infrared detector). Care shall be taken to ensure that the airflow response is rapid enough to avoid troublesome emissions of smoke during flow-change operations. It can be necessary to modify the control action to reduce the effects of control-loop lag.

The use of multiple blowers adds an additional consideration for the air-assisted smokeless flare design. First, the full operation of all blowers shall be engineered from their start-up sequencing through their maximum flow operation. Multiple blowers can be equipped with multiple-speed motors, variable-speed motors and/or dampers. The integration of these devices shall include a consideration as to how airflow is regulated from a minimum to a maximum. Any time an additional blower is required, it is necessary that its start-up consider the operating condition in the flare air-delivery system. A second or third blower starts up against a static pressure in the flare system. Such start-ups can cause blower surging and instability. Any blower surging and airflow instability can be amplified by the combustion at the flare burner to create an unstable, noisy flare flame. Likewise, a blower engaged on a low-speed motor might not have sufficient static-pressure capability to add airflow to an air-assisted flare that has an airflow already established by a blower operating on a high-speed motor. The lower speed fan is discharging against a “dead-head” and the fan does not contribute to the common flow until its discharge pressure is sufficiently high to cause flow. With two identical blowers, it is necessary that both operate at the same speed to cause significantly more flow than one blower alone. The control scheme shall be arranged with this in mind.

It is necessary that the entire airflow system be engineered to ensure that proper airflow to hydrocarbon-gas relief rates can be achieved over the full range of flaring conditions with any multiple-blower system. It is necessary that this engineering consider the starting and stopping of blowers as well as the airflows that they produce. Large-horsepower motors can be started only a limited number of times per hour. It is necessary that the system design address how to avoid excessive cycling of blower operations with transient flow conditions to the flare header. Most important, the multiple-blower operations should address manual operator inputs to adjust airflow for smokeless, low-noise operations.

Multiple-blower systems shall be designed with isolation dampers for any blower that is out of service. This is to prevent airflow from discharging out of the idle blower. The opening and closing of these isolation dampers shall be considered in the design of the control logic of an air-assisted smokeless-flare system with multiple blowers.

Control systems for multiple blowers can be by pressure/flow switch operation or can be by proportional control to the flare relief flow.

Variable-speed drivers can include electric, steam or internal combustion power. A hybrid system that uses a steam-driven blower motor can incorporate a steam assist for smokeless burning, using the exhaust steam from the turbine drive.

The connection of an air-assisted blower to a flare stack should consider the loads due to blower operations and the movements due to stack deflections.

A.10.4 Operations

Operation of an air-assisted smokeless-flare system should start with an initial check-out of the blower operations. Each blower should be checked for proper rotation and speed. The motor amperage should be confirmed for all operating points with multiple blowers. It should be noted that many of the axial-type blowers used for air-assisted flare applications have blade-pitch adjustments that can affect the air delivery. The blower-blade pitch should be set to the maximum allowed by the motor or as otherwise recommended by the flare-equipment manufacturer. The blower initial check-out should confirm the operation of damper, isolation or flow control. The blowers/motors should be checked for vibration limits.

Blower controls should be checked for proper blower speed and multiple-blower sequencing. Operator indication of operating blowers, blower speeds and damper positions should be provided. Maintenance items for the blowers, motors and controls should be located such that they are accessible while the flare remains in service. Some items exposed to radiant flare flame loads can require shielding.

Smokeless flaring operations should cover the range of flare relief-gas compositions and flow rates specified for the flare operation. Operator intervention into blower operations can be required at times to adjust the airflow to achieve smokeless burning and/or to reduce flare noise. Excessive airflow rates can lead to excessive flare noise.

While electrical blower motors have a limited number of starts/stops per hours, leaving a blower on after a flare smokeless relief load has subsided can create excessive noise.

Air-assisted flare operations should consider operation of the flare system if a blower power failure occurs. Lack of forced air allows the flare to smoke. Other considerations, such as migration of relief-gas flows into the air-delivery system, should be considered for flare operations and design. Likewise, the radiation from a non-assisted flame on an air-assisted smokeless flare can be significantly different from the radiation from the forced-draught air-assisted flame. The highest radiation load, blower-on or blower-off, should be used for safety.

Air-assisted flare design should mitigate any possible leakage from the pressurized air-delivery system into the flare relief-gas riser. For instance, at low relief-gas flow rates, the air pressure can exceed the gas pressure in the flare header. If an opening, such as a tear in the gas riser or a loose gas-riser flange, is encountered, forced air can flow into the gas riser. This air can travel both directions in the flare system forming a large, potentially combustible fuel-air mixture and an explosion hazard. This can create an explosion hazard in both the gas riser and the upstream flare header and equipment.

A.10.5 Maintenance

Much of the blower-staging and control equipment is located where local conditions allow maintenance, provided that access and isolation are permitted. The recommendations of the manufacturers of all equipment in the system should provide good guidance. Such advice can include such items as the following.

a) The forced-draught blower and its driver should be maintained in accordance with the manufacturer’s recommendations. This can require lubrication service.

b) Any dampers should be regularly inspected for operation and adjustment. Damper linkages can vibrate and wear and become loose. This can upset airflow and smokeless-flare operations.

c) Controls for airflow operations should be calibrated and maintained in accordance with the instrument manufacturer's recommendations.

d) Any expansion joints used to connect blowers and blower ductwork to the flare stacks should be inspected regularly for wear and leakage.

e) The air-assisted flare burner should be observed at night-time for hot spots that can occur due to internal burning.

f) Flare pilots and ignition systems should be maintained as detailed in Clauses A.3 and A.4.

g) Ensure that electrical parts are not subjected to high heat or vibration.

h) Ensure that the electrical and physical integrity of control boxes is not compromised.

A.10.6 Troubleshooting of blower staging and control systems

See Table A.9.

Table A.9 — Troubleshooting of blower staging and control systems

Problem	Possible cause	Corrective action
Smokeless burning is not being achieved	Insufficient airflow	Confirm that blowers and dampers are operating correctly.
		Confirm that blower adjustments are set to use the available power.
		Confirm that there is no significant air leakage from the flare or air delivery system.
		Confirm that relief-gas flow rates and compositions are within design specifications.
		Confirm that there is no liquid carryover in the flare relief gas.
Excessive flare noise levels	Excessive airflow	Confirm that the blower, dampers and controls are operating properly.
	Flare burner damage	Confirm that the flare flame is stable. If the flame is not stable, then evaluate airflow, gas flow and loss of flame-holding devices as potential causes.
	Incorrect waste gas composition or flow	Confirm that the relief-gas flow rates and compositions are within design specifications and that transient flow conditions between differing relief-gas scenarios are not occurring.
	Blower surging or flame instability	Reduce airflow rates to see if the excessive noise subsides. If it does, it can be possible to advance the airflow back to a higher flow rate to achieve smokeless burning. Once an unstable flame is started, it is very difficult to mitigate without reduction of either the gas flow or the airflow.

A.11 Pressure-staging equipment

A.11.1 Purpose

In some flare arrangements, the flare flow is arranged to go to a number of burning locations (stages) to achieve the specific object of the arrangement (often smokeless operation). See Clause A.2 for further information. Maintaining sufficient burner pressure during turndown conditions can be critical and often requires employing a staging system to proportionately control the number of flare burners in service relative to the amount of gas flowing. Clause A.11 addresses the auxiliary equipment necessary to operate this kind of flare.

A.11.2 General description

The equipment falls into three categories:

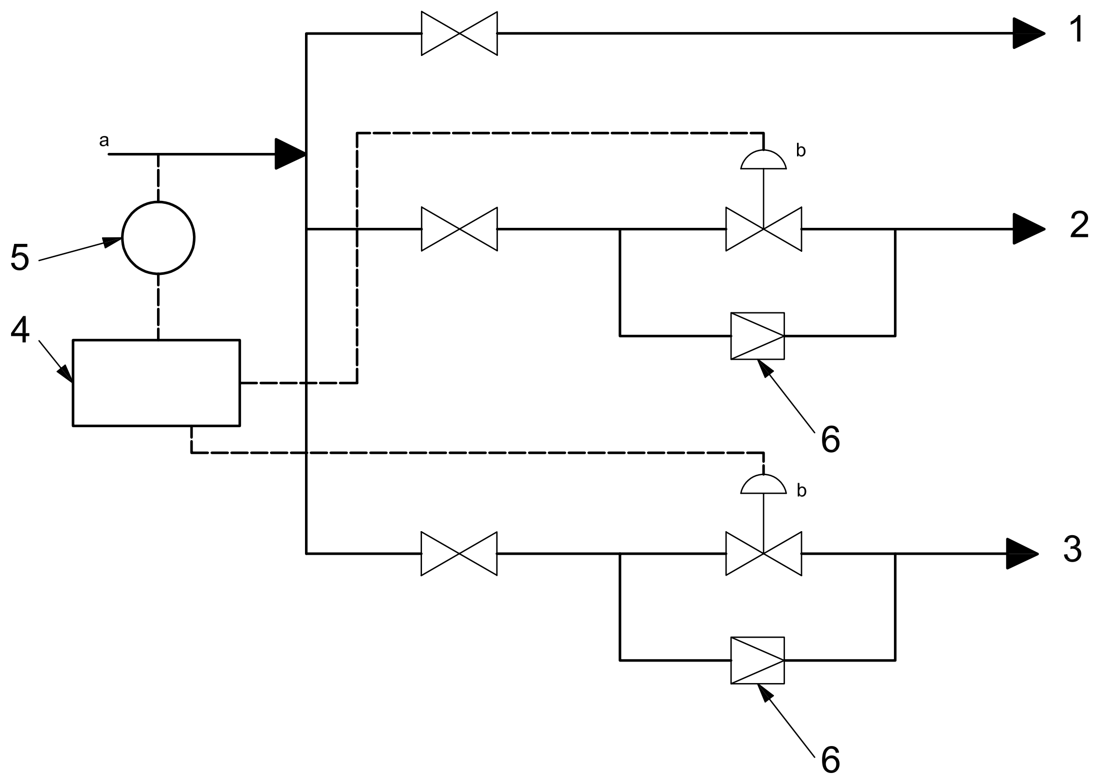
a) Detection: The condition of the flare system is continuously monitored and the system is operated in response to the parameters of this monitoring. This detection can be as simple as monitoring the flare-gas pressure (by pressure switch or transmitter), but can become more complex with the inclusion of flare and steam flow measurements with or without added modification from smoke or infrared detection (see Clause A.11 for more details).

b) Logic: It is necessary that the signal(s) from the detection phase be processed to result in an appropriate control action. This can be done by local dedicated control systems (e.g., PLCs) or the logic can be passed to a central control system (e.g., DCS). It is also common to have a local control indication of pilot and stage condition.

c) Flow control: The control system from b) is arranged to provide the appropriate signals to operate devices (usually control valves with on-off operation).

Figure A.16 shows a simplified control with a staged system containing three stages, such as the system discussed in A.1.5.3. The design and safety requirements of each application can impact the instrumentation selection and arrangement.

NOTE On some systems, the operative purpose of the above equipment can be achieved with a suitably designed liquid seal. Such a device and its operation are described in Clause A.7.



Key

1 first stage
2 second stage
3 third stage
4 staging control
5 pressure transmitter
6 rupture device

[a] Relief gas.
[b] Fail open.

Figure A.16 — Simplified control diagram for a three-stage flare system

A.11.3 Mechanical details

The actual selection and co-ordination of this type of equipment is very much an integral part of the proprietary knowledge of the system supplier. The following are only general comments that can help in acquiring such a system.

a) Reliability of the detection devices is of paramount importance; ease of maintenance is also a major consideration. Some users address these concerns by utilizing redundant control elements, such as pressure transmitters in staging systems. Some operators prefer triply redundant instrumentation for these critical control elements.

b) Particular attention should be paid to control logic, with the greatest importance being given to the safe operation of the system to act as a complete flare system.

c) The greatest concern with control valves used in this duty is that the safety of the flare system is not compromised by a valve failure. To this end, it is common to install bypasses on such valves and these bypasses are fitted with devices that are guaranteed to operate if the upstream pressure reaches an unsafe level; such devices are rupture disks or similar fail-safe devices. Care should also be taken that the access and isolation of the valve systems permit maintenance.

d) An operational note concerning rupture disks: when a valve closes to turn off a stage, there is the possibility of a flashback occurring in the pipework immediately after the valve. It is possible that a pressure wave associated with this flashback can burst rupture disks from the downstream side, thus creating serious operational problems. It is strongly urged that an after-purge with an inert material (e.g., nitrogen or carbon dioxide) be immediately introduced into the piping downstream of the valve to clear the pipe of any material that can form a burnable mixture in the pipe. It is not necessary that this purge be continuous but it is necessary that its application be at the same time, or closely following, the closing of the staging valve.

e) Opening of rupture disks can cause a pressure wave on downstream lines and on the flare. It is necessary that the designer consider this effect on the equipment mechanical rating.

A.11.4 Operations

As with many flare-system components, a staging system should be designed to operate automatically without any human intervention. After commissioning, no “operations” procedure should be required (other than maintenance and troubleshooting, see A.11.5 and A.11.6). However, any such procedure that can be required by the system supplier, or which has been developed by site engineers after due consideration, should be suitably promulgated and observed. A clear understanding of the automated sequence is necessary to enable an operator to recognize (diagnose) operational misbehaviour.

A.11.5 Maintenance

Much of the staging-system equipment is in a position where local conditions allow maintenance, provided that access and isolation are permitted. The recommendations of the manufacturers of all equipment in the system should provide good guidance. Such advice can include such items as the following.

a) ISO 23251 describes the maintenance and troubleshooting for flare knockout drums. Adequate knockout-drum capacity should be installed immediately prior to the flare for any application that deals with a gas composition that can approach its dew point. Liquid results in smoking flames and a significant growth in flame length that can produce severe damage to the surrounding equipment.

b) Stroke all staging valves fully open and then rapidly close on a routine basis. A common practice is every two to three months. This testing ensures the valves function and prevents seizure of the seating surfaces and actuators.

c) Check the bypass device or the staging valve for leakage. One method commonly used for this confirmation is to install a block valve ahead of the device and a small connection for the introduction of nitrogen. The operator confirms that pressure produced via the introduced nitrogen is maintained for a set period of time, indicating that the system is gas-tight.

d) If pin-actuated devices are installed, flex the pin moving the piston on a routine basis, sufficient to prevent seizure of the O-rings to the valve body.

e) The instruments associated with the staging and pilot systems should be treated as critical safety controls and inspected and calibrated on the schedule the plant has established for such critical control elements.

f) Refer to A.3.5, A.4.5 and A.5.7 for the maintenance of pilots, ignition systems and pilot-detection systems.

g) Ensure the scaffolding, debris, etc., does not impair the operation of any valve or similar part.

h) Ensure the electrical parts are not subjected to high heat or vibration.

i) Lubricate actuators, as appropriate.

j) Ensure that the electrical and physical integrity of control boxes is not compromised.

k) Replace burned-out indicator bulbs promptly.

A.11.6 Troubleshooting

See Table A.10.

Table A.10 — Troubleshooting of pressure-staging equipment

Problem	Possible cause	Corrective action
Smoking or flames on a stage that should be closed	Relief device has blown and the flow reduced to a low level: Smoke occurs on a stage that is now no longer under the control of the staging system, i.e., the relief device is an open pipe to the affected stage.	Restore relief device to closed condition. Arrange control scheme to indicate opening of relief device (possibly using limit switches to indicate correct operation).
Smoking or flames on a stage that should be closed	Leaking valves or bypass devices	Repair valve or bypass device.
Smoking or flames on a stage that has just closed	Normal behaviour for a short time while the residual gas downstream of a staging valve bleeds off	If the condition does not correct itself in a few minutes, check for a blown relief device (possibly using limit switches to indicate correct operation). Use a post-purge system to flush residual gas out of the affected stage more rapidly.
Smoking on a stage that should be open	Incorrect waste-gas composition	Route sources of this composition to another flare system or standby emergency flare. Replace burners with equipment designed to handle this gas composition.
Smoking Stage valve does not close at the time expected	Insufficient air pressure to valve actuator.	Check for obstructions in the instrument air line such as closed block valve, kinks in tubing, failed pressure regulator, etc. (possibly using limit switches to indicate correct operation).
Pulsing flames	Staging system can enter a mode of frequent opening and closing (“fluttering”) at certain flare loads.	Modification of the software controlling the valve action by adjusting response rates, modifying timing delays, etc.

A.12 Flow and pressure sensing equipment

A.12.1 Purpose

A flare system may be fitted with a flow and/or pressure measuring system for a number of reasons, such as

a) to act as an input element into a smoke control system or

b) to provide record-keeping for the total flow going to a flare for operational or legal reasons.

A.12.2 General description

The selection of equipment for this duty is dependent on its primary purpose. Although multiple parameters may be measured by such instrumentation, there are generally two types of systems.

a) Pressure: It is common to measure the pressure in the type of flare that uses the pressure of the gas to provide the energy necessary to give a smokeless performance. This pressure input provides the indication of flare-system condition to operate the pressure-staging system described in Clause A.11. The measuring element can be a pressure switch but pressure transducers are being used increasingly.

b) Flow: A flow meter is an alternate and more direct way to determine flow. However, the measurement of volume alone does take into account any variation in its relative molecular mass. Certain installations can require a mass flow meter to achieve the desired objectives. A system that can have flows of compositions with varying degrees of saturation can require more than just a measure of mass flow as an input for smoke control.

A.12.3 Mechanical description

The mechanical details of equipment covered by Clause A.12 are very much dictated by the requirements of the instrument supplier. There are, however, some general points that should be observed.

a) Inasmuch as the flare system, in general, should be available at all times, the application of plant-wide installation specifications might not be applicable. As an example, whereas an instrumentation specification can demand that isolating valves be fitted on all pressure-sensing devices (for service purposes), it should be recognized that a flare system can depend upon the assumption that a pressure-sensing switch or transmitter is always live to the process and it cannot be turned off except under controlled circumstances.

b) The potential flow range in a flare system is extremely wide. It is necessary to take care to ensure that equipment designed for a normal, relatively small flow rate is not damaged or upset by occasional high-flow (and -pressure) excursions. Conversely, equipment capable of measuring very high flows can have difficulty measuring low flows with sufficient accuracy for efficient day-to-day operation.

c) Flare streams are notoriously unpredictable in composition. This affects the interpretation of flow information (e.g., for smoke control, a flow meter might not be able to differentiate propane from propylene). Unpredictability can also affect the physical operational condition of a system (e.g., it is common to have gummy liquids and solids existing in flare lines that can render flow-detection elements inaccurate or inoperative).

d) Equipment reliability should be carefully assessed in reference to the importance of the function of the equipment.

A.12.4 Operations

Under normal circumstances, this equipment should operate automatically.

A.12.5 Maintenance

The manufacturer's recommendations should be used as a guide for maintenance. The opportunities for maintenance can be restricted, however, and this should be assessed at original installation [see A.12.3 a)].

A.12.6 Troubleshooting

The manufacturer's recommendations should be used as a guide for troubleshooting.

Annex B
(informative)

Components of multi-burner staged flare equipment

B.1 Burners

A multi-point flare has multiple burners to distribute flared gases across several burning points. The multiple burning points may be arranged in arrays located near grade or at an elevated position. See Figure B.1 for one example of each.

Multi-burner staged flares are fed from a manifold. The manifold distributes the flow of flare gas to individual branches containing one or more burners. Control valves direct the flow of flare gas to each branch. The control valve feeding each stage opens or closes depending upon the upstream pressure.

A burner ejects the flare gas to entrain surrounding air at sufficient velocities to induce proper mixing for ignition and stable combustion. An individual burner has multiple orifices and some means of flame stabilization. The burner can be constructed of cast or wrought materials.

Typical burner metallurgy is high-grade, austenitic stainless steel. The burners are normally welded to the flare gas risers. In some cases, they are threaded, then back-welded.

Burner riser material shall be of suitable grade to withstand operating flare and flare-gas temperatures. Flare-system operation may include situations when releases become cryogenic. Typical material for the riser is type 304 stainless steel in the upper portion [approximately 1,8 m (6 ft)]. The lower portion of the riser can be of carbon steel. It should be properly insulated and jacketed, if required.

a) Grade type

b) Elevated type

Figure B.1 — Multi-burner staged flares

Burner performance is dependent upon burner spacing and elevation and on row spacing and length. These factors influence air supply to the burners. Proper burner spacing is critical for reliable cross-lighting between burners of a given stage.

B.2 Pilots

B.2.1 Flare pilots shall reliably ignite the individual flare stages. Cross-lighting ignition from adjacent stages is not recommended. If an individual stage pilot fails to operate in correct stage sequence, unburned hydrocarbons and/or toxic gases can be released to the atmosphere, potentially resulting in a vapour-cloud explosion, odour problems or adverse health effects. Should a flare pilot fail to ignite a particular stage in proper sequence, subsequent stages can be prevented from operating. In most multi-burner flare applications, the pilot cannot be accessed for service or replaced while the flare is in operation. Consequently, the pilot system shall be reliable enough to operate for years without maintenance.

B.2.2 Pilot designs are similar to those for elevated pilots. The majority can be described as fixed heat-release, self-inspirating, pre-mix burners.

B.2.3 See Clause A.3 for additional details.

B.3 Ignition equipment

B.3.1 The purpose of the ignition equipment is to reliably ignite the pilot.

B.3.2 There are four types of ignition systems that are commonly employed to light flare pilots:

— spark ignition at pilot tip;

— spark ignition of a portion of the pilot gas/air mixture prior to the pilot tip;

— compressed-air flame-front generator;

— self-inspirating flame-front generator.

B.3.3 No single ignition system is preferred in all circumstances. For improved reliability, multiple ignition systems are often installed.

B.3.4 See Clause A.4 for additional details.

B.4 Flame-detection equipment

B.4.1 The purpose of the flame-detection system is to confirm that the pilots are lit.

B.4.2 There are several types of flame detection, such as thermocouples, flame-ionization detectors, optical systems and acoustic systems.

B.4.3 See Clause A.5 for additional details.

B.5 Buoyancy and velocity seals

Buoyancy and velocity seals are typically not applicable to multi-burner staged flares.

B.6 Manifolds

A common manifold distributes the flow of flare gas to individual manifolds that contain multiple burners. The manifold materials shall be of suitable grade to withstand operating flare and flare-gas temperatures. These individual manifolds may be externally insulated or covered by earth and stone as appropriate.

Open/close valves supply flare gas to individual manifolds. Figure A.9 shows the effect of opening additional stages as the flow increases. Should the open/close valve fail to operate as required to prevent over-pressurization, a valve-bypass piping system may be utilized.

After the closure of each stage, the piping downstream of the staging valve may be purged. An inert gas may be used to purge the line of any combustible gases.

B.7 Operations

A staging system is required to operate automatically without any human intervention. After commissioning, no “operations” procedure is required (other than that described in Clauses B.8 and B.9), but the system supplier’s advice should be followed.

B.8 Maintenance

Much of the staging-system equipment is in a position where local conditions allow maintenance, provided that access and isolation are permitted. There is nothing about the use of any such equipment that is specific to flare systems and, thus, the recommendations of the manufacturers of all equipment in the system should provide good guidance.

Maintenance items for a multi-burner staged flare system are primarily those associated with the staging system. A clear understanding of the automated sequence is necessary to enable an operator to recognize (diagnose) operational misbehaviour. Refer to A.11.5 for a list of maintenance items.

B.9 Troubleshooting

Troubleshooting of multi-burner staged flare systems most often involves troubleshooting the staging system. Refer to A.11.6 for this troubleshooting guide.

Annex C
(informative)

Enclosed-flame flares

C.1 Purpose

There are circumstances when it is desirable that all or part of a flare load be disposed of in a way that causes the minimum of disturbance to the immediate locality

a) to eliminate or reduce radiant heat to nearby equipment or work areas,

b) to reduce noise in the immediate vicinity,

c) to make the flare flame less obvious for community relations,

d) to potentially achieve improved emissions.

C.2 General description

C.2.1 Overview

Enclosed-flame flares burn the flare gas from a burner or burners placed as near the ground as is practicable to ensure good operation. The resulting flames are hidden from sight by a surrounding wall or chamber. The top of the chamber is open to the atmosphere and allowance is made in the bottom of the chamber to permit the ingress of combustion air. It is common for the chamber to be surrounded by a wind fence to modify the effect of crosswinds on the combustion process and to prevent unauthorized access.

An enclosed-flame flare system has a number of key components, including

— combustion chamber,

— burners,

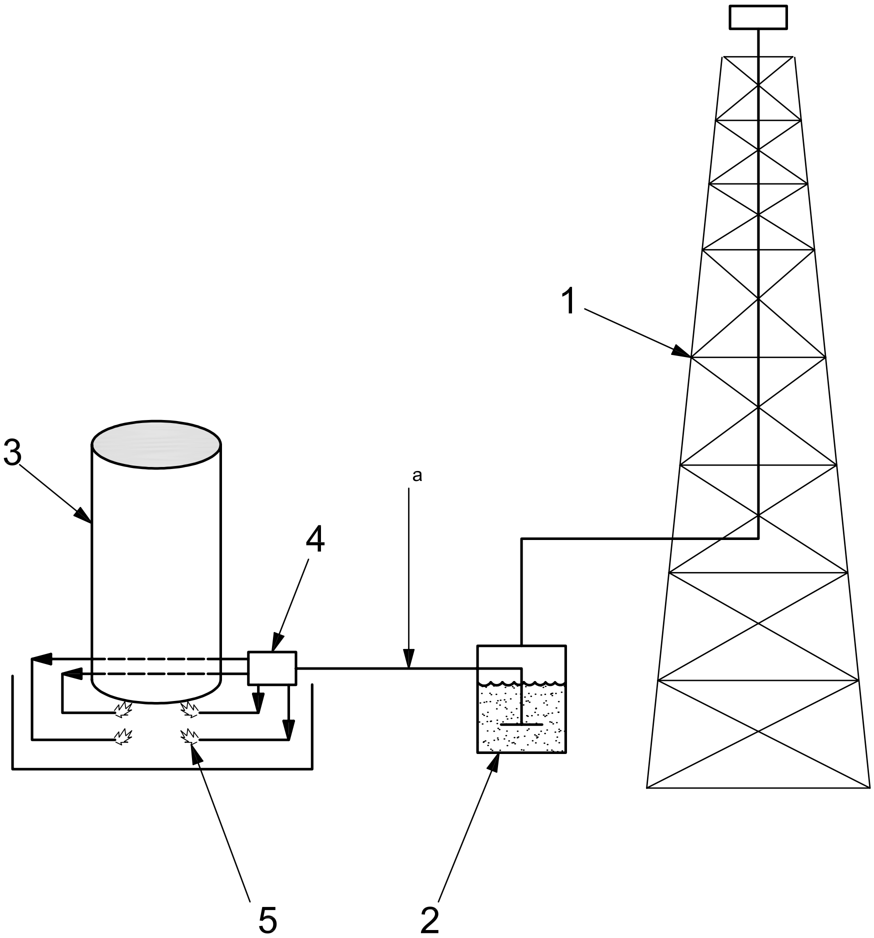
— piping systems,

— wind fence,

— operational and safety controls.

An enclosed-flame flare is more complex than simply installing a pipe flare inside a combustion chamber. This flare design requires an engineered combustion process, with considerations for airflow into the combustion chamber and flue-gas flow from the chamber. Burner designs have been specially developed to meet the combustion requirements of enclosed-flame flares.

Enclosed-flame flares are typically rated for normally occurring flare-relief conditions. There is considerable expense in providing an enclosure for larger relief capacities that rarely occur. For selected applications, an enclosed-flame flare is the first stage of a flare system that includes another flare for the combustion of larger, emergency flare-relief flows. See Figure C.1.



Key

1 elevated flare

2 liquid seal

3 enclosed flare

4 staging-control system

5 burner

a Relief gas from plant.

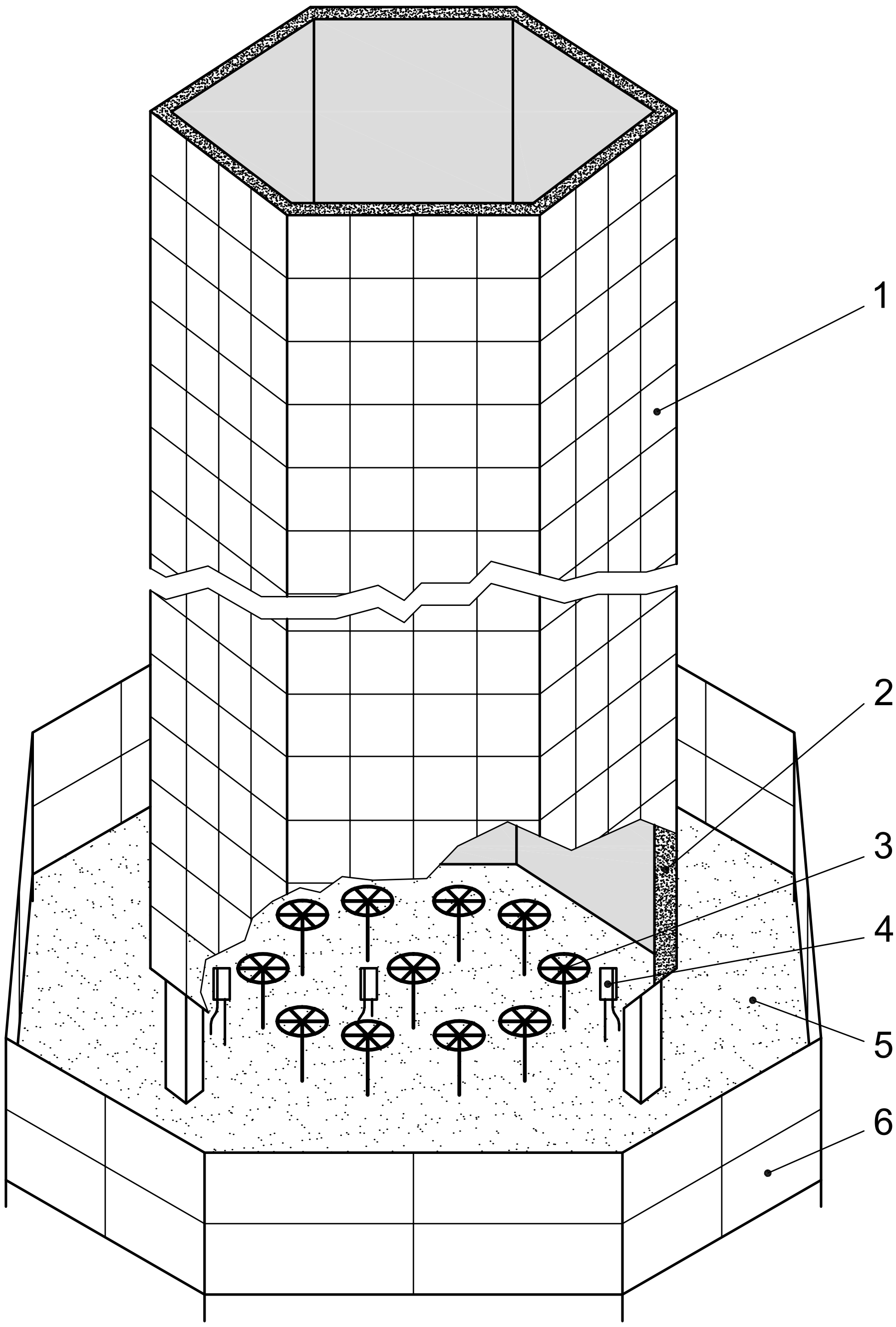
Figure C.1 — Typical enclosed flare staged to elevated flare

C.2.2 Combustion-chamber size and shape

Since the combustion chamber encloses the flare flame, It is necessary that consideration be given to the size of the flame. The flame size is a function of the burner design, the air-side pressure drop, the gas-discharge energy and the fuel and air conditions. Smaller flames can be produced with the use of higher air and gas energies.

Combustion-chamber design typically results in a volumetric heat release of about 1,12 MkJ/Nm^3 (30 000 Btu/h/ft^3). The design volumetric heat release is a function of the burner size and design, combustion-chamber geometry, relief-gas composition and other factors. The largest enclosed-flame flares now operating are rated at capacities above 90 000 kg/h (200 000 lb/h). The smallest enclosed flame flares are rated at only a few hundred pounds per hour of relief-gas flow.

The combustion chamber can be configured in several shapes, including vertical cylindrical, rectangular and multi-sided. The choice of shape includes a number of process, safety, structural and economic considerations. Site fabrication and economical factors are often paramount in the selection of the shape of an enclosed-flame flare. The top of the combustion chamber is typically open for flue-gas discharge. None of the combustion chamber shapes has an inherent advantage in the mitigation of combustion noise. See Figure C.2.



Key

1 exterior frame
2 refractory lining
3 flare-gas burners
4 pilots
5 crushed rocks/gravel
6 wind fence

Figure C.2 — Enclosed flare

C.2.3 Burners

The burners and burner-control systems for enclosed-flame flares are engineered for specified gas flow rates and compositions. Burners can be unassisted, steam-assisted, air-assisted or pressure-energized to produce smokeless burning and to assist in control of the flame volume. Burners should be fuel-gas enriched to achieve desirable combustion efficiency for low-heating-value and hard-to-combust relief gases.

All enclosed-flame flares, except the very smallest in size, use multiple burners. For larger-capacity enclosed-flame flares, the multiple burners typically operate in staged systems as is described in Clause 6.

The burners typically combust a variety of gas compositions and at a variety of flow rates. Staged and unstaged burner systems necessitate different design considerations. With a staged burner system, only the first stage turns down to purge flow rates. Furthermore, the burner staging provides control on the gas discharge energy of the burners to assure proper mixing of fuel and air and thus control of the flame volume. A large gas flow rate at a low-pressure discharge produces a softer, larger flame unless supplemented by energy from the combustion airflow. Such flames can be difficult to contain in the combustion chamber and have a propensity to produce smoke and poor combustion. If an unstaged burner system is used, then all of its burners require turndown to the minimum purge rate.

The design of burners for enclosed-flame flares is proprietary to the manufacturers.

The burner design shall

— be engineered for the relief-gas flow rates and compositions and possible pressure and temperature ranges of the gases;

— consider the utilities (or lack thereof) that are available for burner operation;

— consider known likely operating conditions;

— operate at all airflow rates and velocities within the design range;

— achieve the desired level of combustion emissions with flame volumes that are contained within the combustion chamber;

— produce a stable flame for all relief-gas flow conditions and compositions within the design parameters; and

— not induce any combustion rumble that can trigger excessive noise and resonance from the combustion chamber.

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

Airflow design into the combustion chamber establishes the distribution and velocity with which the air mixes with the fuel discharge. A pilot flame initially ignites these fuel-air mixtures. Once a main-burner flame is established, the burner should be stable and maintain continuous flame ignition on its own. It should never be necessary for the flame stability of a main burner to rely totally on the pilot flame. Burner-flame stability is produced by the flare manufacturer's proprietary means. Mechanisms include mechanical elements of the burner design in conjunction with air and gas flow dynamics.

C.2.4 Air and flue-gas flows

An enclosed-flame flare design shall provide for the airflow into the combustion chamber and for the flow of hot flue gases out of the combustion chamber. The heat produced in the combustion process is absorbed by large quantities of excess air so that the resulting flue-gas temperature is low enough to allow the use of common refractory materials. The airflow into the combustion chamber can be by natural draught or forced draught. Natural draught is most often employed on large-size enclosed-flame flares. The natural draught level produced at any flaring rate is a function of

- the gas flow rate, composition, and heat release,
- the airflow dynamics into the combustion chamber,
- frictional and combustion pressure losses as the flame propagates,
- the flow throughout the combustion chamber,
- the pressure loss of the flue gases exiting the combustion chamber, and
- the combustion chamber dimensions.

These factors can be engineered for the performance of the ground flare from minimum flow rates to maximum flow rates. The maximum operating temperature of the combustion chamber is set by such engineering. For natural-draught enclosed-flame flares, the combustion-chamber temperature at any flow rate less than maximum is lower and its operating excess air is higher. Even with cooler flue-gas exit temperatures and higher overall excess-air levels, high combustion efficiencies are achieved from the flames alone, as is the case for most open-air elevated flares.

The enclosed-flame flare can achieve higher combustion and destruction efficiencies with the flare flame contained in the combustion chamber. Dampers or other means can be used to control the natural-draught airflow into the combustion chamber. Control of the airflow can allow for control of the combustion-chamber operating temperature over variations of relief-gas flow rate and composition. Controlled combustion temperature can achieve higher hydrocarbon destruction efficiencies.

Forced-draught air movement can be used for multiple purposes in enclosed-flame flares.

a) Some air-assisted designs use forced air to supplement the flame energies to produce smokeless flames of reduced flame volume.

b) Designs for 100 % forced-draught air volumes are controllable, and thereby control the enclosed-flame flare combustion-chamber temperature.

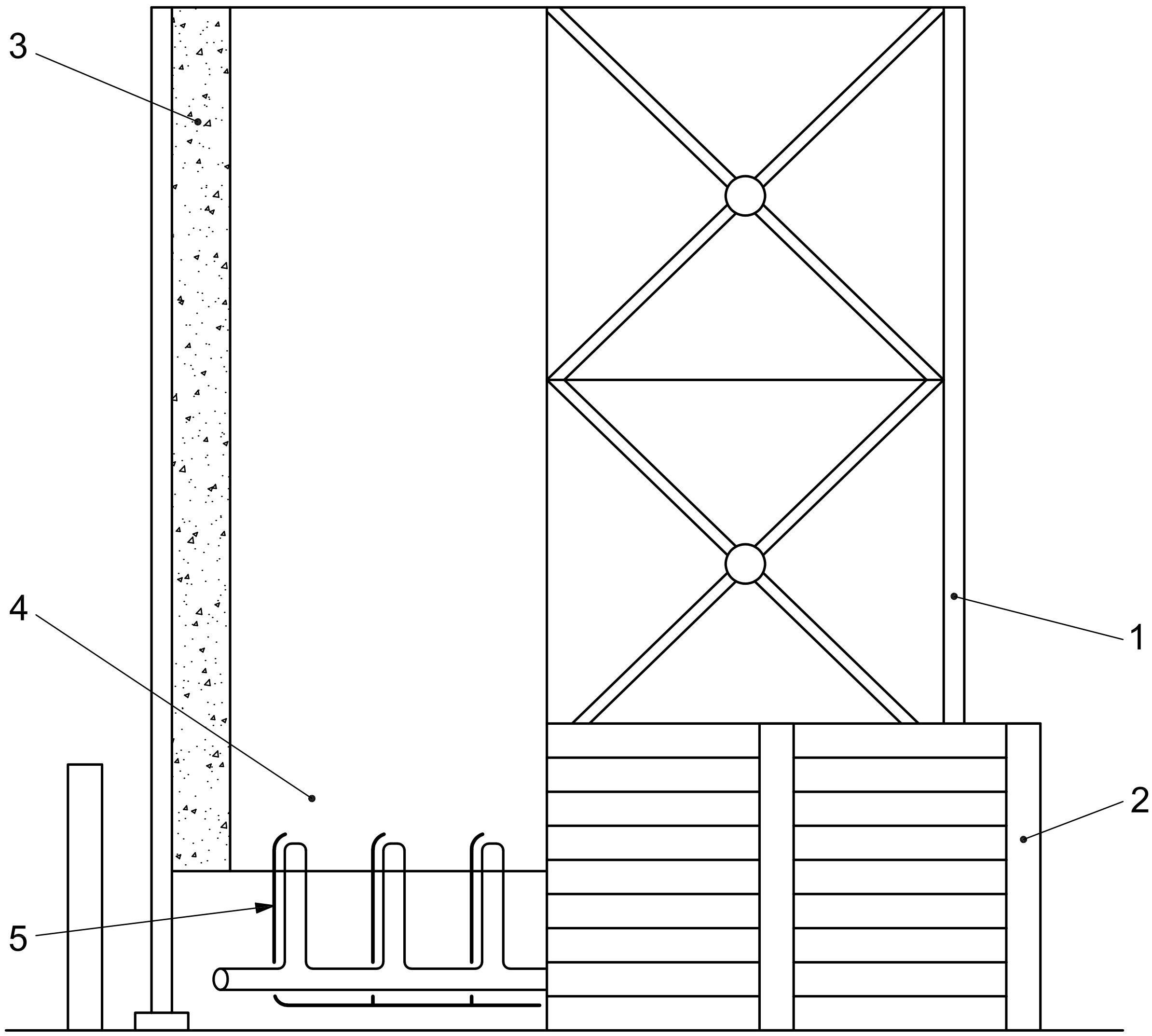
Excessive use of forced draught can contribute to enclosed-flame flare noise, resonance and vibration. The use of a forced-draught fan and its driver impacts the reliability and availability of the overall system and should be evaluated.

Flue-gas flows from the enclosed flare occur at the temperature of the combustion chamber for the given operating conditions. Typically, the temperature factor dominates for the dispersion of combustion products. If the flame volume is contained within the combustion chamber, there is very little, if any, measurable thermal radiation from the plume. However, the hot plume from the ground flare can impinge upon structures and components that are close by and above the elevation of the combustion-chamber discharge.

The flow of gas through the burner, the flow of air into the combustion chamber and the flow of flue gases out of the combustion chamber shall all be engineered for a successful enclosed-flame flare.

C.2.5 Wind fence

Enclosed-flame natural-draught flares use wind fences or other designs to mitigate the potential of the wind to upset air and flue-gas flows. Uniform airflow to all sides of all burners is important in achieving controlled combustion. Wind fences surround the burner air inlets and are designed to allow distribution of the airflow to the burners. Without a wind fence, the wind can upset the natural draught of the combustion chamber. This can result in flames exiting the base of an enclosed flare. Without a wind fence, the wind can flow in the upwind burner openings and out of the downwind ones. It is necessary that wind-fence design consider the enclosed-flame-flare operating draught levels; it shall not restrict airflow to the burner openings. See Figure C.3.



Key

1 exterior frame

2 wind fence

3 refractory lining

4 flare-gas burners

5 gas pilots

Figure C.3 — Wind fence for an enclosed flare

Wind-fence designs acoustically dampen the noise. See C.3.2.

Wind fences also offer safety protection for personnel from the radiation of the flare flames and from the external surfaces of the combustion chamber. The inside surface of the wind fence and all components of the enclosed-flame flare inside the wind fence shall be engineered for the temperatures that are experienced from the thermal radiation of the flames visible there. Personnel access inside the wind fence of an operating enclosed-flame flare is restricted.

The wind fence also isolates the air intake for the enclosed-flame flare from the adjacent ground-level environment. Elevating the air intake can mitigate the possible ignition of combustible ground-level hydrocarbon vapour clouds. This is an important factor where the enclosed-flame flare is located in close proximity to hydrocarbon storage or processing equipment.

C.2.6 Operational and safety controls

Enclosed-flame flares require a number of operational and safety controls. As for any flare, the relief gas should never be ignited without the assurance that safe operating conditions exist. The flare system can need to be purged and all flare operating systems shall be operational.

Some flare burners in a stage utilize pilots and pilot ignition systems. A flame-front generator or direct electric ignition of the pilots is often employed. Flame-detection devices monitor pilot flames. It is necessary that automatic pilot re-ignition be incorporated into the system design. Operating pilots are necessary to allow flare-burner staging.

A burner staging system, as is described for the burners above and in Annex B, is used on larger-capacity enclosed-flame flares.

The combustion chamber of an enclosed-flame flare can overheat if the gas heat release is too high and/or if the airflow is not sufficient. The gas heat release can be too high due to excessive gas flow or due to changes in gas composition. The airflow demand can exceed the design or can become restricted. A high-temperature alarm and/or shutdown should be supplied to protect the combustion chamber. The possible shutdown of an enclosed-flame flare shall not be allowed to restrict safe discharge and disposal of relief gases. The high-temperature control action can disengage a burner stage and effect a diversion of the relief gases to other systems, such as an elevated flare.

The enclosed-flame flare system can require a purge or sweep gas. As is typical for staged burner systems, only the first stage can require a purge-gas flow. Some smaller enclosed-flame flares eliminate purge gas flows by opening and closing the first-stage burners to maintain a minimum pressure in the flare header. For relief-gas compositions with a wide ratio of upper to lower flammability limit, an inert-gas post-purge of a burner stage as it turns off is recommended. The post-purge sweeps the reactive gas out of the burners and burner piping, and mitigates flashback and combustion in the flare-system piping. Gases of concern include hydrogen, ethylene, acetylene and others as defined by a high ratio of upper to lower flammability limits.

Enclosed-flame flares can be tested for combustion performance. Flue gas can be sampled in the combustion chamber or an extractive sample can be drawn out of the combustion chamber. The emission factors for an enclosed-flame flare can, thus, be measured. The ability to measure can be significantly influenced by the physical configuration of the flare.

Relief-gas compositions that are difficult to ignite and combust can be aided by the use of fuel enrichment. Flare-gas analysers combined with control systems can be implemented for fuel-gas enrichment. With temperature control in an enclosed-flame flare, less enrichment gas is required to achieve higher combustion/destruction efficiencies than are typical for an elevated flare.

For enclosed-flare flames that are located in an area where gas vapours can be present, lower explosive limit (LEL) meters with an alarm should be located adjacent to the flare. Alternate choices are to shut the flare down and/or to divert the flare gases.

C.2.7 Enclosed-flame flare applications

Enclosed-flame flare applications include

- flares for normally occurring relief rates for hydrocarbon processing and production facilities, such as start-up/shutdown flows and normal process venting;
- petroleum terminal vapour control;
- biogas disposal; the products of anaerobic digestion (e.g., from landfills, industrial digestion processes or sewage processing) are fed at a fairly steady and predictable rate;
- flare applications where combustion-chamber temperature control shall ensure a high hydrocarbon-destruction efficiency;
- flare applications where the assist fuel-gas quantity can be reduced by use of an enclosed flame;
- in refining or petrochemical applications where the flare acts as a lower stage to the complete relief system, designed to handle “day-to-day” loads (see Figure C.3);
- onboard floating-production storage and off-loading (FPSO) vessels, where the bulk of the flaring events are handled in a safe way in the confined space available.

C.3 Operating considerations for enclosed-flame flares

C.3.1 Visible flames

The purpose of the enclosed-flame flare is to hide the flame. Visible flame can be caused by the following:

- exceeding design heat-release capacity;
- undersized combustion chamber;
- burner performance or operation related to
  - control of smoke-suppression medium,
  - burner arrangement/position,
  - burner plugging or damage, and
  - liquid carryover to the burner;
- air distribution to the burners and combustion chamber;
- wind effects;
- poor temperature control for units operating with a temperature-controlled combustion chamber.

In some cases, reported flame visibility is simply reflected light from the combustion chamber on a foggy or low-cloud night. High combustion-chamber temperatures can produce a visible, ionized gas glow of the flue products exiting the combustion chamber that can appear to be visible flames.

During normal flare operation up to the maximum capacity of the units, it is necessary that the flame length be contained within the enclosure and not be directly visible from the outside. For the majority of specified operating cases, combustion is smokeless.

The flare should be designed to mechanically withstand certain overload cases for short duration. These cases cause a greater or lesser amount of flame to come out of the top of the enclosure and be visible to a remote observer. Generally, operating in an overload condition is discouraged.

C.3.2 Noise and vibration

As some heat release energy in an enclosed flame flare is converted to acoustical energy, high noise levels can be encountered. Burner design and burner stability are key elements to controlling enclosed-flame flare noise, with the following considerations.

a) Burners of moderate gas/air mixing intensity avoid creating excessive noise with typical volumetric heat release.

b) If burners of greater flame intensity are utilized, the ground flare has an increased tendency to produce excessive combustion-driven noise.

c) If burners of less intensity are used, the enclosed flare can be quieter since the combustion chamber is proportionally physically larger in size.

The combustion chamber can amplify any noise produced by unstable burners or unstable gas or airflow. Excessive low-frequency noise and vibrations can be encountered if a resonance is set up in the combustion chamber. Typically, the combustion-chamber prime resonant frequencies are sub-audible. This low-frequency noise can travel significant distances without attenuation and can induce vibrations in structures remote from the enclosed-flame flare. Resonance problems are best avoided by empirical experience. If a problem does occur, the most readily available remedy is modification of the burners and burner operating systems and/or a reduction in operating capacity.

Noise levels from an operating enclosed-flame flare are a function of heat release and equipment design. Noise levels are affected by the design factors listed above, including the number of stages that are operating. Wind fence designs can serve to acoustically isolate the combustion-chamber noise. Some flares can achieve an 85 dBA noise level or less at a distance of 0,9 m (3 ft) from the wind fence.

C.3.3 Refractory failure

Refractory failures can result in hot spots on the shell of the combustion chamber. How the refractory fails, the nature and extent of its failure and its consequences and repair are a function of the type of lining used.

For ceramic-fibre linings, shell hot spots often develop initially at the seam of the blanket lining where high-temperature contraction has opened a gap. This is avoided by proper design of the refractory lining that considers such shrinkage. Ceramic-fibre shrinkage rates can increase when subject to cyclic service and proximity to flames in enclosed-flame flares. Ceramic-fibre lining can also fail due to over-temperature and/or excessive-velocity operations. For high-velocity failures, particles of the high-temperature lining can be discharged from the top of the combustion chamber. High-temperature, high-velocity failures are avoided by proper material selection, proper anchoring design, good installation, and by good operating and maintenance practices. When using rigidizers to improve the velocity rating of ceramic-fibre linings, consider the cyclic temperature operation of enclosed-flame flares and thermal expansion difference of the rigidized material and the base material. Ceramic-fibre linings should be avoided on horizontal surfaces where liquid hydrocarbons can collect. If a pool fire develops on a flat horizontal surface, the fibre material's insulating capabilities can be significantly reduced.

For castable or other hard material linings, hot spots on the combustor shell typically occur first at expansion-joint or seam locations. These are avoided or mitigated by eliminating expansion joints where practical and/or by proper expansion-joint design and maintenance. Castable-type refractory materials are also subject to failure by reason of improper initial curing. Castable refractory should be cured in accordance with the manufacturer's recommendations. Cosmetic cracks produced during curing/initial operation can be expected and generally do not affect long-term performance. Larger cracks that are 3 mm (1/8 in) or greater in width and penetrate more than 50 % of the castable thickness shall be repaired. See ISO 13705 regarding repair techniques. Some phosphate-based castable refractories do not require a high-temperature bake-out. Castable-refractory strength and durability can be enhanced by the addition of metal needles. Polypropylene fibres have been successfully used to enhance the thermal cycling and cure-out for castable-refractories.

It is necessary to include a proper anchoring means in any hard refractory system. Repairs to hard refractory systems should be made in accordance with the manufacturer’s recommendations.

The use of high-temperature alarms and shutdowns can mitigate some refractory failures.

C.3.4 Pre-commissioning

Pipework associated with the flare should be tested prior to the installation of the flare burners and pilots, with consideration of the following.

a) All flare lines shall be free from debris and obstruction. All lines should be blown down prior to installing the flare burners, pilots and steam nozzles (if fitted). All lines should be blown down with a velocity greater than that which is encountered during normal operation. Typically, such velocity exceeds 90 m/s (300 ft/s).

b) Ensure that the pilot orifices are not blocked.

C.3.5 Commissioning

C.3.5.1 Initial commissioning

When initially commissioning the flare header or following any shutdown where the flare header is gas-free and positively isolated, the following procedure is applicable.

a) It is necessary that all scaffolding, supports, tools, etc. be removed from within the perimeter of the wind fence or other barrier that indicates restricted access.

b) The flare line downstream of the main header blind should be purged with inert gas to reduce the oxygen levels to safe proportions. The header should be purged with at least 10 times the free volume of the header with a non-condensable, inert gas. As a result of this purge, a maximum oxygen concentration of less that 6 % volume fraction is recommended unless process conditions indicate a more conservative level should be reached. The use of inert gas as the purge medium prior to pilot ignition precludes the possibility of a gas/air mixture forming within the flare enclosure that can ignite explosively when the pilots are lit. After the pilots are lit, a hydrocarbon gas purge can be used.

c) In consideration of the inert-gas purge, normal safety precautions should be taken within the flare area.

C.3.5.2 Bringing the system on-line

When bringing the system on-line, the following procedure is applicable.

a) Remove blinds from the steam line, if appropriate. Slowly admit steam to distribution pipework in a manner that avoids excessive condensation and water hammer. Check functioning of steam traps and any flexible hoses.

b) Prior to pilot ignition, ensure that the oxygen content of the flare header has been maintained at less than 6 % volume fraction.

c) Ignite pilots in accordance with manufacturer’s instructions.

d) Verify pilot ignition.

e) Remove blinds from the main headers.

The system can now be considered on-line.

C.3.6 Normal operations

C.3.6.1 Multiple-flare operations

For large plant applications, an enclosed-flame flare is typically designed for flow rates at normally occurring plant operations. In some plants, multiple enclosed-flame flares are utilized upstream of the emergency flare. Emergency flaring still requires a larger-capacity open-air flare. How the multiple flares operate, e.g., in series or in parallel, is dependent on meeting the requirements of the engineered equipment and controls of the plant. Further, the staging of flares can maximize the use of the capacity of the enclosed-flame flare. Finally, if an emergency flare relief occurs, all flare-gas flow can be directed to the emergency flare.

Safe multiple-flare operations requires the provision of a means to prevent very low relief-gas flows from going unimpeded to multiple flare locations. If low relief-gas flows have more than one possible exit point, it is quite likely that all of the gas can flow to one flare and the air ingress through the other flare(s). Such flare cross-flows are prevented by the use of flare-staging devices, including liquid-seal and valve-operated staging systems and flare purge systems.

One advantage of having a primary enclosed-flame flare is that it mitigates the internal burning and external flame impingement on a large flare sized for emergency flaring loads when lower-level flaring occurs. The service life of the emergency flare is greatly extended. If the primary enclosed-flame flare requires maintenance, this can be accomplished by diverting all flows to the emergency flare. The primary flare, thus, does not require a plant shutdown for maintenance. By reducing the potential damage to the emergency flare during lower-level flaring conditions, the likelihood of requiring an expensive crane for its maintenance is reduced.

Effective operations on an enclosed-flame flare greatly reduce the visibility of flaring occurrence, thereby improving plant-community relations.

C.3.6.2 Hydrocarbon purge

The hydrocarbon purge gas flowing from the burners is normally ignited from the pilots. If, at any time, the flame is visible or is excessively long, then the purge rate should be checked and adjusted.

Combustible purges can produce internal burning, which is indicated by smoke exiting the burners. This problem shall be corrected by adjusting the purge rate. This problem can also be caused by a failure of a staging device.

C.3.6.3 Inert-gas purge

Using inert gas for the purge medium is highly preferable for start-up and is optional for normal operations. It has the advantages of causing no detrimental effect to the burners and of not affecting pilot operation.

C.3.6.4 Normal flare operation

Any flare gas that passes to the enclosed-flame flare is distributed to flare burners, often through a valving system that responds to demand.

During normal flare operation up to the maximum capacity of the units, the flame length should be contained within the enclosure and not be directly visible from the outside. For the majority of specified operating cases, combustion is smokeless.

The flare may be designed to mechanically withstand certain types of overload for short duration. These cases cause a greater or lesser amount of flame to come out of the top of the enclosure, making the flame visible to a remote observer.

C.3.6.5 Normal shutdown procedure

The normal shutdown operation is as follows.

a) Allow flare-gas flow to decline to zero.

b) Shut off pilot gas.

c) Shut off purge gas.

d) Install line blinds as appropriate before commencing maintenance.

C.4 Maintenance

Depending on the design of the flare and its ancillaries, some maintenance work can be possible during the operation of the flare. Any valve-staging equipment, as well as instruments and devices mounted on the outside shell of the flare enclosure, is likely to be accessible. Normal inspection and maintenance procedures as specified by the manufacturer or that are normal good practice should be followed.

General inspections of all aspects of the flare should be undertaken at every convenient shutdown. In particular, the following conditions should be assessed:

a) general burner condition:

   1) distortion/damage,

   2) condition of feeder piping;

b) carbon deposits: remove any excessive deposits;

c) port blockage: blow clear, as appropriate;

d) pilot burners:

   1) nozzles should be cleaned,

   2) orifices should be cleaned;

e) refractory lining:

   1) the internal lining should be examined visually and an assessment made on the level of damage at every suitable opportunity when the flare is shut down; see C.3.3 regarding expansion-joint condition and cracking considerations,

   2) temporary patching should be considered to avoid further damage,

   3) visually inspect for hot-spot distortion during an outage,

   4) inspect for hot spots while operating, either visually or by using infrared means;

f) structure and manifolding: flare structures and burner manifolding should be examined using normal maintenance procedures and action taken as appropriate,

g) staging and block valves: valves should be regularly stroked to ensure continued operation; actual valve position should be compared versus the intended position from control signal; valves should be maintained in accordance with the manufacturer’s instructions.

C.5 Troubleshooting

See Table C.1.

Table C.1 — Troubleshooting of enclosed-flame flare systems

Problem	Possible cause	Corrective action
Pilot failure	Several	See A.4.6 for general guidance.
High-frequency noise	Most likely associated with steam injection	Check steam quantity and properties.
Combustion roar (low frequency)	Intense combustion	a) Check flare gas pressure. b) Check steam quantity.
Backfire	Flashback in stage manifold	Check after purge system is operative.
Smoke	1. Air starvation	a) Check for windfence blockage. b) Is the wind condition unusual?
	2. Low gas pressure	a) Check bypass relief devices (e.g. rupture disks). b) Check staging valve and system operation.
	3. Steam/support-air shortage	a) Check steam supply and/or blowers.
Visible flame	Excessive flow	Check diverting water seal or valve.

Annex D
(informative)

Instructions for flare data sheets

D.1 Introduction

This annex includes instructions for completing ISO 25457 flare data sheets (see Annex E).

These data sheets are designed to provide a concise but thorough definition of the flare system and its performance. The data sheets should evolve throughout the course of a project. The level of detail reflected in the data sheets should be consistent with the current stage of the project. Early in a project, the sheets may contain less detail than later revisions. Some of the fields on these sheets may remain blank if the information is not known or not relevant to the particular application. Users of these data sheets are encouraged to apply reasonable judgement in determining which fields apply.

It is intended that these data sheets become the controlling document in specifying flare equipment. Accordingly, all parties involved with the flare, including vendors, engineering contractors, purchasers and end users, shall share a clear understanding of the meaning of each field. While many of the fields are self-explanatory, some require clarification beyond the wording of the field labels. These instructions describe in more detail fields whose labels can be inadequate to fully define their purpose. In addition, to support the goal of defining the flare system, it is often appropriate to append a process control diagram to the data sheets at the start of a flare project.

Data sheets are divided into groups to facilitate use. Data sheets designated as Form Gen 1 to Form Gen 7 [Clause E.1 a) for SI units and Clause E.2 a) for USC units] set forth the general information regarding a project and may be used for any type of flare, elevated, enclosed, etc. Information specific to an elevated flare can be recorded on the data sheets that are designated as Form Elev 1 to Form Elev 5 [Clause E.1 b) for SI units and Clause E.2 b) for USC units]. Enclosed-flare data belongs on sheets designated as Form Enc 1 to Form Enc 5 [Clause E.1 c) for SI units and Clause E.2 c) for USC units]. Thus a combination of “Gen” and “Elev” forms can be used to specify an elevated-flare system.

These data sheets cover both mechanical and process aspects of flare design. Those using the data sheets are referred to ISO 23251 for process information. The combination of ISO 23251 and this International Standard provides a broad source of information for those interested in flares.

All forms have a line in the header at the top that contains Page ____ of ____. This page numbering system is an integral part of the “General notes” system. The preparer of this form is strongly encouraged to include both page numbers and total pages on all forms. In the event that subsequent revisions result in additional pages (such as additional gas stream or notes pages), it is recommended to modify the page numbers by using 3A, 3B, etc. for gas stream pages, as an example. This avoids having to renumber all pages and note references on Form(s) Gen 7 and prevents the confusion that can result from renumbering errors. Changes to the total page count at the top of each page are necessary whenever pages are added to the package.

All forms have a column labelled “Note”, which is intended to refer to additional notes on one or more copies of Form Gen 7: General notes. Numbering of the notes should start with one (1) on each new page. The liberal use of explanatory notes is strongly encouraged to ensure a clear communication of all job requirements.

EXAMPLE A system using a Form Gen 3 to define the flow conditions can be more clearly described by placing a numeral “1” in the N column on line 1 or 2 even though previous pages already contain notes. On a copy of Form Gen 7, the user would place a note referring, perhaps, to Page 3, Note 1. The note can define normal flow rates, frequency and duration for various streams on that Form Gen 3, as opposed to maximum hydraulic flow or smokeless capacity required. Such a note helps both the designer and the operator to understand how the equipment will actually be used.

It is to be expected that revisions will occur to the data sheets during the course of a project. All forms include one or more columns labelled “REV” where a revision can be marked. In addition, the heading section of each form contains a “revision number” field. When a set of changes is made to a set of data sheets, this set of changes is referred to as a revision and is assigned the next revision number. The original issue should be noted as revision zero (0). All changes made in a revision are marked with the same revision number. As a matter of reference, a copy of Form Gen 7 containing the revision history should be included. Each revision note should contain, as a minimum, the revision number, the revision date and some description of the revision, such as “Revised per vendor quote” or “Revised for purchase.” Additional information, such as a list of affected forms/lines, can be useful for tracking purposes. Each revision should be issued as a complete set of pages, not as individual pages. This ensures that all recipients have a complete, current set of data sheets.

D.2 General information forms — Instructions

D.2.1 Form Gen 1

Form Gen 1		
Line 9	Jobsite climate	Indicate type of climate, such as dusty desert, arctic tundra or tropical jungle. Can indicate a requirement for dust filters, freeze protection, special radiation considerations, instrument packaging, etc.
Line 16	Local codes	State or local codes can affect electrical equipment, mechanical design, process performance, shipping or other aspects of a major construction project such as a flare system. Any such regulations that can affect the design, fabrication, delivery, construction or operation of the system should be identified as early in the project as possible.
Line 19	Ambient conditions (design/normal)	Each of the conditions listed has design values and normal values. Design values can be necessary for proper selection of metallurgy or piping growth. Normal values can provide a better idea of conditions that will normally prevail and can allow for certain operational efficiencies most of the time. Provide minimum and maximum temperatures as they influence items such as blower design, structural materials, thermal growth/shrinkage.
Line 22	Relative humidity	Some radiation models allow a credit for atmospheric attenuation at large distances. Atmospheric humidity can affect smokeless performance, electrical circuit design, etc.
Line 24	Predominant wind direction	If the jobsite has a very predominant wind direction, it is sometimes possible to design the system to take this into consideration. A wind rose can be provided if it is available. Suitable orientation of pilots, for example, can allow longer equipment life by avoiding the predominant flame pull-down area.
Lines 25, 26	Solar radiation	Refer to ISO 23251 for a discussion of solar radiation allowances.
Line 27	Jobsite elevation	Altitude of jobsite affects local atmospheric pressure, which affects pressure drop calculations, fan sizing, etc.

D.2.2 Form Gen 2

Form Gen 2		
Line 1	Minimum flare height	Nearby structures, electrical classification issues, independent dispersion calculations or company standards can impose a minimum flare height requirement.
Line 2	Anticipated flare-header diameter	Fields in lines 2, 3 and 4 allow the designer to estimate the flare-header volume, surface area, pressure drop, etc. These factors can affect purge system design, peak waste-gas flow rate or actual gas temperature arriving at the flare, and other important design issues. It is sometimes possible to anticipate transient behaviours in the flare system that can affect overall performance. Flare-header volume includes all piping and drums that can be pressurized by a flare event regardless of whether the relief actually passes through that section of the flare-header system.
Line 3	Approx. flare-header length	
Line 4	Flare-header network volume	
Line 5	Plot space available	This can affect selection of the support method, size of component parts, guy-wire radius, etc.

Line 11	Special erection requirements	Plans to construct a system using gin poles in lieu of a crane, single-point lifting requirements, limited lay-down areas for construction or preference for bolted construction are examples of special requirements that it is necessary to define early in a flare project.
Lines 13 to 16	Nozzle location and loads	The position of the relief-gas nozzle connection to the gas riser is of primary importance to the structural and foundation design of the flare. The minimum elevation is typically imposed by the presence of a liquid seal and/or knockout drum. The nozzle location, unless otherwise specified, shall be 10 m (32,8 ft). Refer to Table 2 for allowable nozzle forces and moments.
Line 24	Utilities available (design/normal)	Each of the conditions listed has design values and normal values. Design values can be necessary for proper selection of metallurgy or piping growth, for example. Normal values can provide a better idea of conditions that will normally prevail and can allow for certain operational efficiencies most of the time.
Line 27	Location of steam conditions	Steam temperature and pressure vary from one point in the steam system to another due to heat losses and pressure drops. It is necessary that the designer know whether the indicated pressure is available at the flare burner, at the base of the stack, at a point outside a sterile radius or at a boiler somewhere. It is necessary that the designer also know whether the pressure and temperature are downstream or upstream of the control valve.
Lines 28, 29	Electrical power	It is important to know whether the local power supply is 50 Hz or 60 Hz, as this has a profound effect on blower-motor performance. It is necessary that the voltage be known before vendors can select appropriate control equipment.
Line 34	Fuel gas	One of the compositions that should be defined on a copy of Form Gen 3 is that of the fuel gas to be used for pilots, flame-front generator, enrichment gas, etc. As a minimum, it is necessary that the designer know the MW and LHV of the fuel gas. If the fuel gas contains more than 10 % volume fraction hydrogen, unsaturated hydrocarbons, hydrogen sulfide or inerts, then it is necessary that the composition be identified.
Line 35	Purge gas	Purge-gas composition should be defined on a copy of Form Gen 3.
Line 38	Nearby structures (distance, height)	Flares are usually sized to meet a specified radiation criterion at grade. Radiation on nearby structures, especially heat-sensitive structures such as cooling towers, can be accounted for only if such structures are identified and located.
Lines 39 to 42	Other active flares	If there are other flares in the vicinity of the specified flare that are expected to be flaring simultaneously with the specified flare, these should be accounted for in the design of the specified flare. In order to account for such flares properly, some clear definition of the other flare's radiation information is necessary. Heat release and radiant fraction as a minimum enable only a rough accounting. Direct information, e.g., isopleths from the other flare's vendor, is preferred. It should be included by reference with a note and any attachments that can be useful. Consideration can be given to doing maintenance work on one flare while any nearby flare is operating.

D.2.3 Form Gen 3

Form Gen 3		
Line 2	Smokeless capacity, opacity	Smokeless capacity is defined on the data sheets in kg/h (lb/h), rather than some percentage of design flow. The smokeless-capacity requirement should be established by a thoughtful review of actual relief scenarios. Conditions that are expected to occur often enough to require smokeless operation, either by regulation or company standards, should set the smokeless requirement. Indicate the opacity or Ringleman number that is allowable at the flow rate for smokeless operation.
Line 4	Static pressure	Static pressure, in this context, is the pressure exerted by the gas on the walls of the flare header. This pressure determines the gas density. A conventional pressure gauge mounted on the side of a pipe measures static pressure. An additional component of pressure at the flare inlet is the velocity pressure. The sum of these two components is called total pressure, also known as stagnation pressure. The total pressure is a good measure of the energy available in the flowing fluid. A properly positioned pitot tube measures the total pressure on the port facing the flow stream. Due to the tendency for plugging, pitot tubes are not often used for common pressure measurements. Velocity pressure can be calculated for a given flow stream if the static pressure and pipe diameters are known. This approach allows the use of conventional pressure gauges to check performance. This is the reason for requiring declaration of both static pressure and diameter at the flare inlet. If the purchaser does not define the flare inlet diameter, then the specified pressure should be indicated as total pressure. Pressure is based on relieving conditions as identified by different operations specified on these data sheets.

Line 6	V_{eq}	V_{eq} is the volumetric flow rate of air at standard temperature that produces the same velocity pressure as the specified flow stream at local atmospheric pressure and the defined stream temperature. It is proportional to the waste-gas flow rate and is independent of the pipe diameter used to evaluate velocity pressure. The volumetric flow rate, V_{eq}, is given by Equations (D.1) to (D.4): $$V_{eq} = 259 \times q_m \times \sqrt{\frac{T_{gas}}{M_{gas}}} \quad \text{(D.1)}$$ $$V_{eq} = \delta_{normal} \times \sqrt{\frac{M_{gas}}{29} \times \frac{T_{gas}}{288}} \quad \text{(D.2)}$$ where q_m is the mass flow rate of gas, expressed in kilograms per hour; T_{gas} is the absolute temperature of the gas, expressed in kelvins; M_{gas} is the relative molecular mass of the gas; δ_{normal} is the volumetric flow rate, expressed in normal cubic metres per hour at 0 °C. $$V_{eq} = 3{,}091 \times q_m \times \sqrt{\frac{T_{gas}}{M_{gas}}} \quad \text{(D.3)}$$ $$V_{eq} = \delta_{SCFH} \times \sqrt{\frac{M_{gas}}{29} \times \frac{T_{gas}}{520}} \quad \text{(D.4)}$$ where q_m is the mass flow rate of gas, expressed in pounds per hour; T_{gas} is the absolute temperature of the gas, expressed in degrees Rankine; M_{gas} is the relative molecular mass of the gas; δ_{SCFH} is the volumetric flow rate, expressed in standard cubic feet per hour at 60 °F. It should be noted that V_{eq} is intended as a means to compare hydraulic performance or requirements among flowing conditions at a fixed jobsite. If comparisons to other jobsites at other altitudes are required, then a correction shall be made for atmospheric-pressure variations.
Line 8	Duration at max. rate	Duration of the relief can affect allowable radiation levels, noise levels, smokeless requirements and other aspects of the design.
Line 9	Relief source	Some indication of the relief source and its cause is useful to the designer. A label such as “Power failure” or “Demethanizer overheads” can help both for communication about cases and for understanding the character of the relief.
Line 10	Controlling case for …	Indicate whether this relief case is the controlling case for pressure drop (DP), radiation (RAD), noise (NOI), smokeless performance (SMK), etc.

Line 11	Gas composition	It is necessary that the designer know whether the specified composition is on a mass or a molar basis to properly evaluate stream properties. Either circle one of the options (if that option applies to all streams) or define the basis explicitly for each stream.
Lines 12 to 40	Compounds	Several blank lines have been left at the end of the list to allow for inclusion of compounds not found on the pre-printed list. If necessary, one or more of the unused compounds in the pre-printed list can be struck through and replaced with additional unlisted compounds.
Line 41	Total	Ideally, gas composition should total 100 %. Compositions are sometimes provided in the form of flow rates of each component, in which case the total of flow rates should match the design flow condition.
Lines 42 to 48	Hydrocarbon characterization information	This information is used for combustion, smoking tendency and hydraulic considerations.

D.2.4 Form Gen 4

Form Gen 4		
Line 8	Flame monitors	Indicate the number of flame monitors required and whether this count is per pilot or per flare.
Line 9	Flame monitor type	Indicate type K (or other) thermocouples, optical, ionization, acoustic detectors or as appropriate.
Line 14	Retractable pilots	This information is used primarily for enclosed flares. Indicate whether pilots should be removable while the flare is in service.
Line 15	Retractable thermocouples	Indicate whether pilot thermocouples should be removable while the flare is in service.
Line 21	Distance from stack	Indicate the distance in terms of piping length from the ignition panel to the flare stack. This can be substantially longer than simple radial distance if the piping runs along a pipe rack.

D.2.5 Form Gen 5

Form Gen 5		
Line 4	Integral/separate from stack	Indicate whether it is required that this vessel be integral with the stack or separate from the stack. It is often more economical to build the vessel into the base of an elevated structure. However, high corrosion rates or a requirement to bypass and isolate the vessel while the flare is in service can require a separate vessel.
Line 10	Seal depth	Seal depth determines the inlet pressure at which the first bubble of gas flows through the vessel. Design seal depth varies depending on the purpose of the liquid seal. Simple maintenance of a positive upstream header pressure can require only a few centimetres of depth. Flare-gas recovery systems often require 500 mm to 750 mm (20 in to 30 in) of seal depth to ensure adequate suction pressure for the compressor. Liquid seals used for staging between multiple flares can have seal depths of 2,5 m (100 in) or more.

Line 11	Max. vacuum	Flare-gas recovery systems or hot-gas thermal contraction and/or condensation can result in substantial vacuums in the flare header. A vertical section of piping in the liquid-seal inlet line can allow seal fluid to be drawn up by the vacuum without drawing air in through the flare burner. This protects the plant against a potentially dangerous situation. To achieve this level of protection, it is necessary to design the vessel with sufficient liquid volume in the normal seal-depth area to fill the vertical section of piping. Safe design of this liquid volume should take no credit for the addition of supplemental liquid. Operationally, it is necessary to maintain the proper liquid level in the liquid seal and to restore that level promptly after any hot relief and before the vacuum forms. The maximum vacuum protection achievable can be limited by piping or vessel elevations.
Lines 13, 17 to 28	Various connections	Each of these lines asks for a description of a vessel connection, including the type of connection (flanged, threaded, welded), the size in millimetres (inches) and the number of these connections.

D.2.6 Form Gen 6

Form Gen 6		
Line 5	Integral/separate from stack	Indicate whether it is required that this vessel be integral with the stack or separate from the stack. It is often more economical to build the vessel into the base of an elevated structure. However, high corrosion rates or a requirement to bypass and isolate the vessel while the flare is in service can require a separate vessel.
Line 6	Design code	The purchaser shall specify.
Line 11	Max. liquid level	Maximum liquid level may be defined either as a distance above bottom tangent or as an absolute elevation. The vendor may define this value to prevent re-entrainment of accumulated liquid in the waste-gas stream.
Line 12	Liquid holdup volume	The purchaser, based on the anticipated liquid volumes that can be sent to the flare system, may define the liquid-holdup volume. Sufficient volume should be provided to prevent overfilling of the knockout drum, which can lead to liquid carryover to the flare burner, smoke, flaming rain and other hazardous conditions.
Lines 14, 18 to 29	Various connections	Each of these lines asks for the description of a vessel connection including the type of connection (flanged, threaded, welded), the size in millimetres (inches) and the number of these connections.

D.2.7 Form Gen 7

The “Page No.” and “Note No.” columns are intended to allow all notes associated with all pages to be collected on a single set of pages appended to the back of the data sheet package. “Page” and “note” numbers should precede each note to indicate the location in the data sheet package to which the note refers. Notes can be several lines long and require the “page” and “note” references only on the first line.

D.3 Elevated-flare forms — Instructions

D.3.1 Form Elev 1

Form Elev 1 Radiation and noise performance is often specified in terms of the maximum flaring rate. Similarly, smokeless-performance specifications require smokeless operation up to some specified flow rate. In practice, it is often the performance of the flare at rates substantially below maximum and below peak smokeless capacities that actually determines whether the flare is acceptable to the user or the community. Some representation of these turndown conditions can be provided as an additional gas stream on Form Gen 3. Performance expectations for these conditions can be specified either by using one of the blank lines on Form Elev 1 or through the use of General notes.		
Line 13	SPL at flare base	Unless otherwise specified, noise at the base of the flare is defined at a point 1,5 m (5 ft) above grade and 10 % of the flare-stack height distance from the flare-stack centreline. Nearby noise sources, such as blowers or steam-control valves, should be identified and a general note should indicate whether or not these nearby sources are included in the noise prediction.
Lines 14, 15	SPL at distance	Noise at a distance is measured 1,5 m (5 ft) above grade at the specified distance from the flare-stack centreline. If typical background noise levels in the target area are known, they should be indicated with a general note.
Line 27	Smokeless definition	Environmental regulations usually specify that a flare may not exceed some opacity level for more than a certain amount of time. That opacity level defines the smokeless criteria. An opacity level of 20 % corresponds to Ringleman 1,40 % to Ringleman 2. Zero opacity is Ringleman 0.

D.3.2 Form Elev 2

Form Elev 2 In some cases, it can be necessary to add a general-notes page to include any clarifications in the areas of predicted system performance.		
Line 2	Static inlet pressure	Normally, this should be based on the specified flare inlet diameter (Form Gen 3, Line 5). If the vendor is proposing a different flare inlet diameter, the proposed diameter should be clearly defined on this line such as “20 kPa @ 600 mm” (“3 PSIG @ 24 in inlet”).
Line 11	(blank)	Some vendors provide radiation information in the form of graphical outputs. Such outputs should be appended to the data sheets and may be referred to here by filling in “Radiation plot” as the description and “See attached” as the value.
Lines 13 to 17	Noise performance	Some vendors provide noise information in the form of tables showing octave band breakdowns. These can be appended or included as general notes.
Line 27	S/HC ratio	Steam consumption has often been characterized in terms of mass ratios of steam to hydrocarbon required for smokeless performance. The value provided on this form is based on operation at or near the smokeless capacity. The purchaser is cautioned that the ratio necessary for waste-gas flows in the turndown range can exceed the ratio near the smokeless capacity.
Lines 32, 33	Air capacity and pressure	The vendor should clearly indicate whether the pressure basis is static or total pressure at the blower outlet. If static pressure is used, the outlet area of the fan shall be indicated.

D.3.3 Form Elev 4

Form Elev 4		
Line 8	Loop-seal depth	Some purge-conservation devices, such as buoyancy seals, include a drain to continuously remove rainfall, steam condensate or other liquids that can enter the seal. A loop seal, similar to that used for an API knockout drum or liquid-seal skimmer, should be used to prevent flare gas from migrating into the drainage system. Refer to ISO 23251 for further information on determining this depth. The required depth of this loop seal should be defined on this line.
Line 12	Stack design pressure	Purchaser is cautioned against excessively high design pressures as the combination of stack loadings from wind, earthquake and internal pressure can result in much thicker walls than are actually required.
Line 13	Stack design temperature	When gas temperatures differ substantially from ambient temperature, a significant heat transfer rate can exist between the waste gas and ambient air. This heat transfer can affect stack-design temperatures in two ways. First, heat transfer to or from the waste gas while it is flowing from the plant to the flare stack generally causes the waste-gas temperature to move closer to ambient temperature. Second, the steel temperature is somewhere between the waste-gas temperature arriving at the flare stack and the ambient temperature. Both of these effects should be considered when establishing the stack design temperature to avoid over-specification. The vendor and purchaser can work together to specify this temperature if so noted on the data sheet.

D.3.4 Form Elev 5

Form Elev 5		
Line 10	Max. motor current – winter	As discussed in A.9.3, flare fans deliver a certain maximum volumetric flow of ambient air to the flare burner. At minimum ambient temperatures, the density of this air is the highest. As a result, the motor horsepower required is highest in winter. The electrical current required to drive the motor under these conditions usually dominates the design requirements for the switchgear and substation that delivers this power to the fan motor.

D.4 Enclosed-flare forms — Instructions

D.4.1 Form Enc 1

Form Enc 1		
Line 1	Enclosed capacity	Indicate the maximum continuous flow rate that the enclosed flare shall handle without visible flame, excessive temperature or noise.
Line 7	SPL at windfence	Noise at the wind fence is measured 1,5 m (5 ft) above grade at a distance of 0,9 m (3 ft) from the major bounding surface at the base of the flare. This is usually the windfence. Nearby noise sources, such as blowers or steam-control valves, should be identified and a general note should indicate whether or not these nearby sources are included in the noise prediction.
Lines 8, 9	SPL at distance	Noise at a distance is measured 1,5 m (5 ft) above grade at the specified distance from the flare stack centreline. If typical background noise levels in the target area are known, they should be indicated with a general note.
Lines 27, 28	Purge gas	Staging is often used in enclosed flares to improve turndown performance. A continuous purge is recommended to keep the flare header swept clear and to prevent air ingression through the first stage of burners. In many cases, a brief, relatively high purge flow is injected downstream of each staging valve to flush out residual waste gases after that staging valve is closed. If there are purge-gas-capacity limitations, these should be specified by the purchaser.

D.4.2 Form Enc 2

Form Enc 2		
Line 1	Enclosed capacity	Vendor should indicate maximum enclosed capacity for the specified composition from Form Enc 1. If there are multiple flow streams, the vendor should indicate maximum enclosed capacity for each stream as a general note. Any discussion relating to the interpretation of enclosed flaring should be included as a general note.
Lines 7 to 11	Noise performance	Some vendors provide noise information in the form of tables showing octave band breakdowns. These can be appended or included as general notes.
Line 12	Smokeless capacity	The vendor should indicate smokeless capacity for the specified composition from Form Enc 1. If there are multiple flow streams, the vendor should indicate smokeless capacity for each stream as a general note.
Line 19	S/HC ratio	Steam consumption has often been characterized in terms of mass ratios of steam to hydrocarbon required for smokeless performance. The value provided on this form is based on operation at or near the smokeless capacity. The purchaser is cautioned that the ratio necessary for waste-gas flows in the turndown range can exceed the ratio near the smokeless capacity.
Lines 27, 28	Purge gas	The vendor should indicate both the continuous purge requirement and the maximum intermittent purge flow requirement during staging operations.
Line 33	Supplemental gas	If supplemental fuel gas is used to maintain a minimum temperature in the firebox, the vendor should indicate the flow rate necessary in cold weather.

D.4.3 Form Enc 3

Form Enc 3		
Lines 21-29	Firebox and windfence dimensions	Most enclosed flares fall into one of the following shape categories: rectangular, round or polygonal. The purchaser should indicate any preferences regarding shape. The vendor should indicate selected shape and associated dimensions.
Line 30	Refractory material	The purchaser should indicate any requirements or limitations on refractory material.
Line 32	Max. service temperature	The vendor should indicate service temperature of the proposed refractory.
Line 33	Max. shell temperature	The vendor should indicate expected shell temperature for ambient conditions of 27 °C (80 °F) and still air. This calculated temperature is used to select the paint system for the outside of the firebox. The purchaser should indicate hot-face temperature basis for calculation as either max. allowable temperature for the refractory or calculated operating temperature at the enclosed flaring capacity. Significant cost savings can accrue with the use of a lower hot-face temperature basis.
Line 35	Max. expected flue-gas temperature	The vendor should indicate expected flue-gas temperature for ambient conditions of 27 °C (80 °F) and still air.
Line 39	Max. personnel-exposure temperature	The vendor should indicate the maximum temperature on any surface where personnel exposure can occur. This is often limited to the outer windfence surface when access to the upper stack platforms is not necessary during maximum operation.

D.4.4 Form Enc 4

Form Enc 4		
Line 4	Heat shielding	Any material or equipment with a view of the burner windows can be exposed to high heat radiation. Heat shielding is often used to reduce metallurgical requirements and piping stresses.
Lines 19, 25, 31, 37	Air valve	If air-assisted burners are being used, the purchaser should indicate any preferences for either a large, single blower with distribution by manifolds and valves vs. individual blowers for various stages or sections of burners. The vendor should indicate proposed/actual method for distributing air. Use general notes, if necessary, to clarify the issue.

D.4.5 Form Enc 5

Form Enc 5		
Line 5	Damper control required	The vendor should indicate whether any air dampers/valves are modulated (based on temperature or flow), automatically opened/closed or manually set.
Line 11	Supplemental requirements	The purchaser should indicate the existence of any special requirements, such as explosion-proof motors or inlet filters, for the air blowers.

Annex E
(informative)

Flare data sheets

E.1 SI units

a) General data sheets, containing the following 7 sheets:

Gen 1 — Purchaser Supplied — General Information (Site Specifics)

Gen 2 — Purchaser Supplied — General Information (Utilities)

Gen 3 — Process Design Conditions — Purchaser (Flare Gases)

Gen 4 — Mechanical Design Data (Pilots and Ignition System)

Gen 5 — Mechanical Design Data (Liquid Seal)

Gen 6 — Mechanical Design Data (Knockout Drum)

Gen 7 — Blank for Notes

b) Elevated Flare data sheets (5 sheets)

c) Enclosed Flare data sheets (5 sheets)

E.2 USC units

a) General data sheets, containing the following 7 sheets:

Gen 1 — Purchaser Supplied — General Information (Site Specifics)

Gen 2 — Purchaser Supplied — General Information (Utilities)

Gen 3 — Process Design Conditions — Purchaser (Flare Gases)

Gen 4 — Mechanical Design Data (Pilots and Ignition System)

Gen 5 — Mechanical Design Data (Liquid Seal)

Gen 6 — Mechanical Design Data (Knockout Drum)

Gen 7 — Blank for Notes

b) Elevated Flare data sheets (5 sheets)

c) Enclosed Flare data sheets (5 sheets)

Bibliography

[1] ISO 15649, *Petroleum and natural gas industries — Piping*

[2] AISC S302[8], *Code of Standard Practice for Steel Buildings and Bridges*

[3] AMCA 801[9], *Industrial Process/Power Generation Fans — Specifications and Guidelines*

[4] ASCE 7[10], *Minimum Design Loads for Buildings and Other Structures*

[5] ANSI/ASME B16.47, *Large Diameter Steel Flanges: NPS 26 Through NPS 60*

[6] ANSI/ASME B31.3, *Process Piping*

[7] ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, *Rules for Construction of Pressure Vessels*

[8] ANSI/AWS D1.1/D1.1M[11], *Structural Welding Code — Steel*

[9] ICBO[12], *International Building Code Volume 2: Structural Engineering Design Provisions*

[10] EN 13445 (all parts), *Unfired pressure vessels*

[11] EN 13480 (all parts), *Metallic industrial piping*

[12] ICAO, Annex 14[13] — *Aerodromes, Volume I — Aerodrome Design and Operations*

[13] ANSI/NACE MR0175 (all parts), *Petroleum and Natural Gas Industries — Materials for Use in H_2S-containing Environments in Oil and Gas Production*

[14] 40 CFR PT 60.18[14], *United States Code of Federal Regulations — Standards of performance for new stationary sources*

General Information on Flares and Flare Systems:

[15] BAUKAL, C.E. Jr. Editor, and SCHWARTZ, R.E. Associate Editor, *The John Zink Combustion Handbook*, CRC Press, Boca Raton, FL, 2001, ISBN 0-8439-2337-1

[16] BANERJEE, K., CHEREMISINOFF, N.P., and CHEREMISINOFF, P.N., *Flare Gas Systems Pocket Handbook*, Gulf Publishing Company, Houston, Texas, 1985, ISBN 0-87201-310-3

[17] REED, R.D., *Furnace Operations*, 3rd Edition, Gulf Publishing Company, Houston, Texas, 1981, ISBN 0-87201-301-4

---

8) American Institute for Steel Construction, 1 E Wacker Drive, Suite 3100, Chicago, IL 60601-2001, USA.

9) Air Movement and Control Association, 30 West University Drive, Arlington Heights, IL 60004, USA.

10) American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191-4400, USA.

11) American Welding Society, 550 NW Le Jeune Road, Miami, FL 33126, USA.

12) ICBO – International Conference of Building Officials, 5360 Workman Mill Road, Whittier, CA 90601-2298, USA.

13) International Civil Aviation Organization, 999 University St., Montreal, Quebec, H3C 5H7, Canada.

14) U.S. National Archives and Records Administration, 700 Pennsylvania Avenue NW, Washington, D.C. 20408, USA.

[18] BLUHM, W.C., *Safe Operation of Refinery Flare Systems*, API Proceedings, Vol. 41, 1961, American Petroleum Institute, Washington, D.C.

[19] STRAITZ, J.F. III, Improved Flare Design, *Hydrocarbon Processing*, Oct. 1994

[20] SCHWARTZ, R.E. and KANG, S.G., Effective Design of Emergency Flaring Systems, *Hydrocarbon Engineering*, Feb. 1998

[21] HUSA, H.W., How to Compute Safe Purge Rates, *Hydrocarbon Processing and Petroleum Refiner*, Vol. 43, No. 5, May 1964

[22] KWON, S.H., *et al.*, Improve Flare Management, *Hydrocarbon Processing*, July 1994

Mechanical and Structural:

[23] MOODY, G.B., Mechanical Design of a Tall Stac*k*, *Hydrocarbon Processing*, Sept. 1969, pp. 173-178

[24] BROWN, A.A., How to design Pile-supported Foundations for Flare Stacks, *Hydrocarbon Processing*, Dec. 1969, pp. 139-146

[25] ASLAM, M., How to find.... Minimum Length of Process Piping, *Hydrocarbon Processing*, Nov. 1970, pp. 203-208

[26] BLICK, R.G., How to Calculate Wind-Caused Sway on Slender Columns, *Petroleum Refiner*, Vol. 37, No. 11, Nov. 1958, pp. 237-240

[27] KUONG, J.F., Find Wind-Caused Bending Moment on Tall Vessels by Nomograph, *Hydrocarbon Processing*, June 1969, pp. 192-195

[28] YOUNESS, A., New Approach to Tower Deflection, *Hydrocarbon Processing*, June 1969, pp. 121-126

[29] FREESE, C.E., *Vibration of Vertical Pressure Vessels*, ASME Paper 58-15, ASME Petroleum Mechanical Engineering Conference, Sept. 21–24, 1958

[30] BERGMAN, E.D., *The Design of Vertical Pressure Vessels Subjected to Applied Forces*, ASME Paper 54-A-104, Transactions of the ASME, August 1955, pp. 863-866

[31] BIJLAARD, P.P., Stresses from Radial Loads and External Moments in Cylindrical Pressure Vessels, *The Welding Journal*

[32] WICHMANN, W.R., HOPPER, A.G. and MERSHON, J.L., Local Stresses in Spherical and Cylindrical Shells due to External Loadings, Welding Research Council

Emissions:

[33] BS 2742C, *Ringelmann chart*

[34] BS 2742M, *Miniature smoke chart*

[35] BS 2742, *Notes on the use of the Ringelmann and miniature smoke charts*

[36] ANONYMOUS, *Ringelmann Smoke Chart*, (Revision of IC 7718), U.S. Department of the Interior, Bureau of Mines, Information Circular 8333, 1967

[37] *A Report on a Flare Efficiency Study*, Chemical Manufactures Association, Washington, D.C., March 1983

[38] KELLER, M.R. and NOBLE, R.K., RACT for VOC — A Burning Issue, *Pollution Engineerin*g, July 1983

[39] ROMANO, R.R., Control Emissions with Flare Efficiency, *Hydrocarbon Processing*, Oct. 1983

[40] SCHWARTZ, R.E. and KELLER, M.R., *Environmental Factors Versus Flare Applications*, Paper No. 13d, presented at the Symposium on Loss Prevention in the Chemical Industry, 83rd National Meeting of the American Institute of Chemical Engineers, Houston, Texas, March 22, 1977

[41] U.S. EPA, Compilation of Air Pollutant Emissions Factors, Vol. 1, Stationary Point and Area Sources, AP-42, 4th Edition, 1985 and supplement F: Section 11.5, 9/91, Industrial Flares

[42] POHL, J.H., *Combustion Efficiency of Flares*, U.S. Environmental Protection Agency, Research Triangle Park, N.C., 1985

[43] BRZUSTOWSKI, T.A. and SOMMER, E.C. Jr., *Predicting Radiant Heating from Flares*, Proceedings-Division of Refining, 1973, Volume 53, American Petroleum Institute, Washington, D.C. pp. 865-893

[44] KELLER, J., NOBLE, R. and KELLER, M., *Determining Safe Levels of Thermal Radiation Exposure on Personnel*, presented at the 34th Annual Loss Prevention Symposium, AIChE National Meeting, March 6–8, 2000

[45] SCHWARTZ, R.E. and WHITE, J., *Predict Radiation From Flares*, Chemical Engineering Process, July 1997

ICS 75.180.20

Price based on 155 pages