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Addendum 2

Section 3.2 Specific Terms and Definitions: The following Terms and Definitions shall be added, and all subsequent Terms and Definitions shall be renumbered:

Extended operation
Combustion using the flare for a continuous period longer than 12 hr and generally associated with startup or shutdown operation.

maximum heat release:
The maximum heat liberated from the flared gas, expressed as units of energy over time (e.g. MW, kcal/hr, Btu/hr).

process licensor
The party that provides licensed or proprietary technology information typically in the form of a process design or licensor package.

row
A single line of burners that can consist of one or more stages / runners.

runner
A set of burners on a single header that consists of all or part of a single stage.

stage
A set of burners supplied by a single staging valve and designed with a specific flow area to allow proper control across all operational scenarios.

staging valve
An open / close device allowing flare gas to flow to a set of burners and used to control the header pressure.

NHV_{vg}:
Net heating value of the vent gas

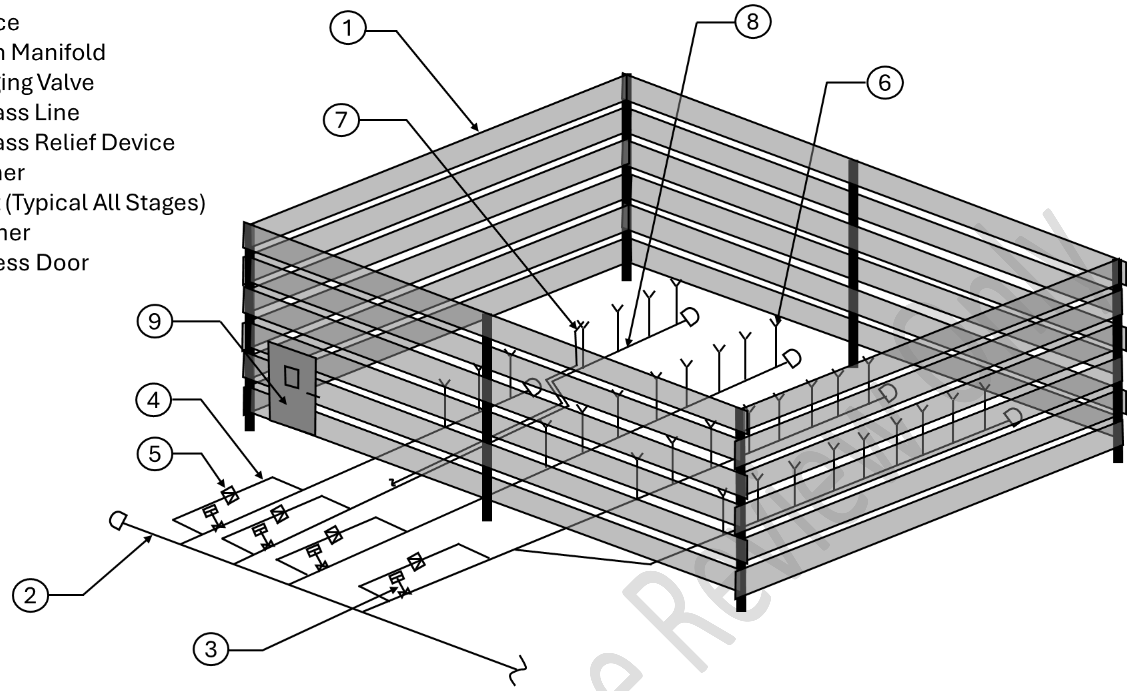
Section 3.3 Acronyms and Abbreviations: The following Abbreviations shall be added to this section:

MPGF	Multipoint Ground Flare
NHV_{vg}	Net heating value of the vent gas

Figure A.9: The current figure shall be replaced with the figure below:

Key

1 Fence
2 Main Manifold
3 Staging Valve
4 Bypass Line
5 Bypass Relief Device
6 Burner
7 Pilot (Typical All Stages)
8 Runner
9 Access Door



Annex K: The following new annex shall be added to the document:

ANNEX K

(normative / informative)

Multipoint Ground Flares for Ethylene Production Facilities

K.1 General

Multipoint ground flares (MPGF) are critical components in ethylene production facilities, designed to effectively burn off excess flare gases and maintain operational safety. However, these systems are prone to mechanical damage and failures, which can lead to extensive repairs and significant downtime during both planned and unplanned shutdowns. Experience among MPGF end-users has shown that a MPGF can be subject to damage caused by overheating, as well as gas coking inside the runners, risers, and burners.

Overheating is one of the primary causes of mechanical failures in MPGF systems. The high temperatures involved in the flaring process can lead to thermal stress and material degradation. Prolonged exposure to extreme heat can cause warping and cracking of components, particularly in the runners, risers, and burners.

The potential for mechanical damage and failure of mechanical components in a MPGF is exasperated by the following:

- excessive flaring during conditions where gas-containing equipment is above the coking temperature threshold.
- insufficient MPGF total firing area in relation to the design heat release.
- insufficient runner-to-runner spacing.
- insufficient burner elevation which restricts the air supply to the root of the flames.
- insufficient air flow through the fence, particularly near the bottom of the fence.
- insufficient space between the fence and the burners, causing hot spots and damage to the fence, as well as potentially restricting air flow to the burners.
- insufficient spacing between burners, causing increased flame length resulting in flame overlap and smoke.

This annex provides guidance, recommendations, and requirements for the process definition, system design, mechanical design, operation, and troubleshooting of a MPGF in ethylene production facilities.

This annex may be applicable to a MPGF used in process pressure relief service with extended continuous operation other than in ethylene service.

K.2 Process Definition

K.2.1 General

The process definition for a MPGF is consistent with the requirements as specified in 4.2 and 4.3 of this standard together with the datasheets in Annex F. Considering the uniqueness of several aspects of the system design and mechanical configuration of a MPGF, some additional information and guidance in preparing the process definition/process design cases relative to other flares is warranted.

K.2.2 Maximum Emergency Relief Design Case

The maximum emergency flaring scenario is anticipated to produce peak flow rates for a duration of several minutes. The flare system shall be designed to accommodate this peak hydraulic flow condition. Additional high flaring rates, within 10 percent of the maximum emergency flaring rate, are expected to occur for brief intervals, of approximately ten minutes. These rates typically decline rapidly over an extended period of approximately one hour. Long-term flaring at 70 percent of the maximum emergency flaring rate is also anticipated. Based on these projected flow rates, it is recommended that the purchaser or process licensor supply the expected blowdown curve for the emergency scenario (flow versus time) to enable the vendor to integrate these characteristics into the flare system design.

K.2.3 Startup and Other Long Duration Cases

It is anticipated that the startup case(s) or other scenarios may result in significant flows for a period of several days or even weeks. Experience indicates that substantial mechanical damage can occur during an extended startup period.

To supplement the datasheet process definition, the owner or process licensor should provide the expected duration of time for all startup cases ranging from 10% to 100% (specified in nominal increments) and long duration cases.

K.2.4 Continuous Sweep and Purge Gas

The first stage shall be designed to accommodate the continuous low pressure sweep and purge gas.

K.2.5 Maintenance Cases

In many instances, maintenance operations may result in the release of low to medium flows of gases with varying calorific values at low pressure. Typically, such flows are not compatible with the MPGF staging curve and cross-lighting requirements. Therefore, the following options are recommended:

- A larger dedicated low pressure runner or runners equipped with assist media and additional pilots.
- A separate elevated flare.
- A separate enclosed ground flare.

Each option should be thoroughly evaluated based on specific operational needs and constraints, including space availability, environmental regulations, and other individual user considerations.

K.2.6 Other Flaring Cases

In addition to the flare gas relief cases stated above, other various non-controlling relief cases should be considered in the flare system design. These cases may include:

- Relief scenarios with higher molecular weight than the maximum emergency flaring case.
- Cases with significant benzene concentrations.
- Instances with notable hydrogen concentrations.
- Flows containing high concentrations of olefinic, diolefinic, or aromatic hydrocarbons that produce smoke.

These non-controlling relief cases have the potential to influence the overall design of the flare system and should be thoroughly evaluated and documented on the purchaser's or process licensor's datasheet.

NOTE Comprehensive detailing of flare gas flow, composition, temperature, and pressure on the flare datasheet is essential to ensure the proper design from a heat flux standpoint.

K.2.7 Flare Gas Composition Considerations

It is important to consider the specific composition of flare gases for each design case during the initial stages of a MPGF design. Compositions with greater that 60% inerts reduce burner-to-burner spacing which increases likelihood of soot formation and coking of burner associated with higher density flare gases and flare gases with a relatively high lower heating value (LHV).

It has been demonstrated that flare burner cross-lighting performance is significantly affected by changes in the flare gas composition.

NOTE Governmental environmental regulations frequently reference flare gas lower heating value as a determining factor in multi-burner staged flare flame stability and burner cross-lighting performance. Some environmental regulations set a minimum net heating value of the vent gas (NHV_{vg}) required to operate a MPGF. However, it has been demonstrated that flare gas lower heating value correlates poorly with flame stability across different hydrocarbon mixtures. For example, a methane-nitrogen mixture with an NHV_{vg} of 29.81 MJ/SCM (800 BTU/SCF) is more stable and will more reliably cross-light than a butane-nitrogen mixture with that same NHV_{vg} value. For binary mixtures consisting of various hydrocarbons and a nitrogen diluent, the volume % of nitrogen diluent inversely correlates with cross-lighting performance and is a better indicator of performance than NHV_{vg}.

K.3 MPGF System Design Considerations

NOTE Refer to Annex B for a general description of the main components, related equipment, operation, maintenance, and troubleshooting of a MPGF.

K.3.1 MPGF Plot Area During Conceptual Planning

K.3.1.1 For conceptual planning purposes early in the plant design phase, the MPGF fence area shall be approximated based on the maximum heat release per inside fenced area at emergency (design) condition to not exceed 1.7 MW/m^2 (550,000 BTU/h*ft^2).

K.3.1.2 The MPGF burner heat release at design condition per individual burner surface area shall not exceed 3.1 MW/m^2 (1.0 MMBTU/h*ft^2).

• **K.3.1.3** The owner / purchaser shall specify any required process design margins.

• **K.3.1.4** The owner / purchaser shall specify when no visible flame is required for any specified operating cases.

NOTE 1 The individual burner surface area is defined as the distance between two neighboring burners along a runner length multiplied by the runner centerline-to-centerline spacing.

NOTE 2 The heat release requirement applies to a single burner at design conditions.

NOTE 3 The heat release requirement applies to every burner.

K.3.2 Runner Sparing Philosophy

Runner sparing philosophy is typically specified by the owner.

Considerations for runner sparing should include:

- plot space.
- limiting flare field layout (one runner per staging valve).
- turnaround / maintenance frequencies.
- operating / spare philosophy, such as:
    - 3 x 50% (three flare fields at 50% capacity each)
    - spare row / runner
    - backup elevated flare.
- visible emissions constraints.
- operational flexibility, i.e., used for multiple process units / lines.

NOTE 1 An arrangement with three flare fields at 50% capacity each is typically considered for LNG or other process facilities that want to limit the number of process units shut down during a turnaround.

NOTE 2 A back-up elevated flare would be used only temporarily for a small flaring capacity which occurs during a plant turnaround. A back-up elevated flare would not be used as a permanent flare and would not be designed for the full relieving capacity of the MPGF.

K.3.3 Flare Gas Supply Pressure

The available flare gas supply pressure at the MPGF manifold during the unassisted maximum volumetric flow case should exceed 124 kPa (g) (18 psig) to ensure adequate performance.

MPGF performance improves with an increase in flare supply pressure. The optimum supply pressure has been identified as 138 kPa (g) to 172 kPa (g) (20 psig to 25 psig). High gas pressure at the burner inlet significantly reduces flame length and radiative fraction.

NOTE 1 MPGFs have operated successfully with inlet pressures of 3.45 kPa (g) (50 psig) and higher.

NOTE 2 For performance considerations, the available flare gas supply pressure at the MPGF inlet during the unassisted maximum volumetric case should be sufficient to achieve sonic gas velocity at all burner ports.

K.3.4 Low Pressure Stages

The first stage of a MPGF is often designed for turndown operation with very low purge gas flow rates and inlet pressures near atmospheric.

NOTE There can be more than one low pressure stage.

The first stage may be designed with variable orifice type burners or may be designed to use an assist medium. Variable orifice burners allow the open area to vary in the burner as the pressure increases. This allows the burner to control turndown performance without additional staging valves.

For fixed orifice burners, an assist medium (steam, air, or gas) may be used to generate mixing energy at the burner exit. Mixing energy forces enough air into the combustion zone to ensure the flares operate without smoke at low pressure. Steam is the preferred assist medium.

Steam assist reduces the flame length, reduces the amount of radiant energy released, and reduces flame “lean” at low burner exit velocities. The results of using steam assist reduces the risk of heat damage to the burners in use during extended periods of time. Steam assist can be provided to all burners / stages used in the startup phase and in routine low pressure flaring as desired by the owner.

When steam is not available or practicable, low pressure air can be used as an alternate assist medium to minimize the risk of smoke formation and control the flame shape. A local VFD-controlled air blower supplying air < 0.034 kPa (g) (< 0.5 psig) is commonly used, but other solutions are available.

High pressure gases such as methane, natural gas, compressed air, or nitrogen can also be used as the assist gas. However, high-pressure gases are generally less effective than steam.

K.3.5 Liquid Removal from Flare Gas

K.3.5.1 The knock-out drum in the flare header of the MPGF shall be designed with sufficient capacity to ensure the effective separation of hydrocarbon liquids from the flare gas together with a safety margin to account for unexpected liquid surges. Refer to Annex A.8

K.3.5.2 High liquid content in the flare gas can provide significant operational challenges for MPGFs. Increased density due to liquids can elevate the burner heat release, contributing to higher thermal radiation and greater flame luminosity. This, in turn, enhances the propensity of the burner to produce smoke. Moreover, the increased heat release and radiant fraction can cause thermal stress which can lead to coking, both internal to the burner components and accumulation of carbon deposits on surfaces. Over time, coking can impede the functionality of the various components of a MPGF, ultimately risking mechanical failure and potential shutdowns.

K.3.5.3 To mitigate the risks associated with condensation of any hydrocarbons or other liquids within the MPGF manifolds, at least one low point drain shall be provided on each flare manifold. These drains should be strategically placed to collect and remove any condensed liquids, particularly when the flare gas flow rate falls below 4 m/s (13 ft/s).

K.3.5.4 The collected liquids shall be routed back to the knock-out drum or an alternate collection system,

K.3.6 Runner/Stage Purging

K.3.6.1 The closing of a staging valve shall be immediately followed by an adequate post-purge of the respective stage runner(s) to prevent air ingress and subsequent combustion inside the runner.

K.3.6.2 A post purge procedure also limits the amount of smoke produced since the remaining flare gas inside the runner exits through the burner at low pressure.

NOTE Air will ingress into the runners when the system sits idle unless there is a continuous purge in the runner.

K.3.6.3 The preferred gas for post purge is nitrogen or any other non-flammable, non-condensable gas that does not contain oxygen.

K.3.6.4 The supplier shall provide design information for post purge volume and duration.

K.3.7 Multi-burner Stage Flare Temperature Monitoring

K.3.7.1 The owner may consider installing thermocouples on one riser for each stage which is operated during the startup phase.

K.3.7.2 Thermocouples may also be installed on the runners designed to be in operation during the start-up cases.

K.3.8 MPGF Design Validation

• K**.3.8.1** When specified by the purchaser, computational fluid dynamics (CFD) modeling shall be used to validate the MPGF design

NOTE CFD modeling can be employed to validate the MPGF design by evaluating dispersion characteristics, heat plume, flame length, incident heat flux on the runners, risers, and gravel temperature.

• **K.3.8.2** When CFD modelling is specified, the purchaser shall specify the process cases for evaluation.

K.3.8.3 The process cases for evaluation should, as a minimum include:

- startup.
- a number of long duration flaring cases.
- maximum emergency relief design case.

K.3.8.4 Dispersion analysis shall be performed if flare gas composition includes toxic material.

K.3.8.5 Radiation line of sight shall be considered for elevated structures or equipment near the flare field that have exposed surface area above the fence.

NOTE Methods other than using CFD are available for modeling flame length and heat flux.

• **K.3.8.6** When specified by the purchaser, MPGF performance testing shall be performed at the supplier's facilities. Tests shall be performed with a minimum of three burners.

K.3.8.7 Performance tests can be used to provide the following performance information and measurements:

- acceptable cross-lighting between burners (note time required to cross-light).
- repeatability of three minimum consecutive cross-light trials.
- flame length.
- any excessive flame overlap.
- presence or absence of visible emissions such as smoke or NO_x plume.

- combustion efficiency and destruction efficiency in the flare plume, when required by the environmental authorities.
- flame radiation at various distance from the burners (up to the runner-to-runner spacing).

K.4 Mechanical Details

K.4.1 Runner-to-Runner Spacing

K.4.1.1 Burners on separate runners should be no closer than 7.6 m (25 ft) from the nearest adjacent burner measured parallel to the inlet manifold.

K.4.1.2 Full length runner centerlines should be no less than 7.6 m (25 ft) apart.

NOTE 1 Runner-to-runner spacing of 7.6 m (25 ft) spacing isn't a fixed value since different burner geometries and technologies have different spacing requirements. Burners with a higher heat output are typically spaced farther apart than burners with lower heat outputs.

NOTE 2 A lower heat release limit (see K.3.1.2) may be appropriate for startup burners during extended startup.

K.4.1.3 Sufficient runner spacing should be provided to minimize the incident radiative heat flux on the runners, as well as to ensure adequate air flow is provided to the individual burners.

K.4.2 Burner-to-Burner Spacing

K.4.2.1 The burners shall be spaced along a runner to allow cross-lighting for all required cases.

K.4.2.2 The burner-to-burner spacing should be maximized to minimize flame-to-flame interaction, production of soot, and extension of flame length.

K.4.2.3 Spacing the burners too closely can cause the flames to coalesce and produce a soot plume, which in turn increases the radiative fraction, flame height, and the incident heat flux at grade.

K.4.2.4 The burner-to-burner spacing may be increased by offsetting the burners in a staggered manner on both sides of the runner centerline.

K.4.2.5 Experimental and theoretical studies have shown that fewer, higher flow burners further apart allow for better flame-to-flame separation; however, these generally produce longer flame lengths.

NOTE The optimum burner-to-burner spacing cannot be specified in this standard as it depends on the flare burner design, heat release, drilling pattern, gas composition, and potential use of assist media.

K.4.3 Runner to Fence Spacing *(K.8)*

The distance between the outside runner centerline and the fence should be at least 12.2 m (40 ft).

NOTE 1 Adequate spacing between the fence and the burners helps increase the air flow to the burners and reduces the risk of hot spots on the fence.

NOTE 2 Experience has shown that at least 13.7 m (45 ft) is the preferred runner to fence spacing to reduce downwash and improve air flow to burners closer to the fence. This spacing will also minimize potential fence damage due to flame impingement or overheating.

K.4.4 Burner Spacing on Single Runner

The distance between the first and last burners along a single runner shall not exceed 54 m (177 ft).

NOTE The limit on runner length is intended to minimize thermal growth, to lower incident heat fluxes on burners and risers, and to reduce the distance that combustion air must travel to reach burners near the center of the fenced area.

K.4.5 Runner Protection

K.4.5.1 Unless otherwise specified, runners shall be protected from flame radiation by one of the following methods:

a) covered with a stainless steel shield or other suitable material.
b) buried under gravel.

NOTE Refer to Table K.1 for runner protection choice considerations.

Table K.1 – Runner Protection Choice Considerations

Stainless Steel Shields	
Advantage	**Disadvantage**
Potentially less complex based on the local availability of suitable gravel. Allow for a broader range of design temperatures as the runners have more flexibility for thermal expansion. During downtime, easier access for runners, pilot gas lines, thermocouples, etc. for inspection and repair. Less stress on riser / runner joint connection. More airflow around the runner to allow for cooling of the runner. To protect the runners from corrosion, the runners can be painted with high temperature paint.	Vents need to exist and be maintained to allow for cooling of the shield. Thermal exposure causes the need for additional attention to design and installation for all components within the fence. Potential for reflection of radiation which heats the underside of the runner. This heat has the potential to overheat instrumentation and auxiliary equipment inside the fence (T/C wiring, pilot lines, HEI, FFG, etc.) Higher heat exposure / impact on adjacent non-flaring runners when others are flaring.
Cover with Gravel	
Advantage	**Disadvantage**
Higher protection from heating of the runners and other utilities along runners (T/C wiring, pilot piping, HEI, FFG piping) inside fence due to the runner and / or adjacent runners firing during short term flaring. During long term flaring events the temperature profile on runners and utility piping is more uniform. Simpler installation in the field (shorter installation duration). Utilities are continuously supported along the length of the runner.	Potentially more complex based on the local availability of suitable gravel. Narrower range of design temperatures allowed due to reduced thermal expansion flexibility at cryogenic temperatures. Inspection and maintenance of the runners and other buried auxiliary equipment requires extra work to have the runners exposed. Higher stress on runner / riser joint due to thermal expansion of the runner into the gravel. This is an inspection consideration. Increased monitoring of gravel to ensure proper coverage / avoid exposure of runners. To protect the runners from corrosion the runners may need special considerations (wrapping, cathode protection, etc.).

K.4.5.2 Examples of suitable gravel material for runner protection and the ground within the fence area are nominal 32 mm (1.25 in) of igneous rock (quartzite, trap rock, white granite or red granite) or metamorphic rock with no fines.

K.4.5.3 Sedimentary rock, limestone, volcanic cinder, scoria, oyster shell, or sandstone should not be used for runner covering nor for the flare floor.

K.4.5.4 The following guidelines should be followed when determining gravel depth:

- minimum of 150 mm (6 in.) covering entire flare field.
- minimum of 300 mm (12 in.) covering fence and runner support foundations.
- for runners that are using gravel as shielding, a minimum of 450 mm (18 in.) of igneous rock covering runners.

K.4.6 Runner Analysis

K.4.6.1 The supplier shall provide the runner stress and flexibility analysis (including thermal growth). The analysis shall be based on the relief conditions specified on the relief cases on the datasheet.

K.4.6.2 The supplier shall provide the design basis for temperature used in runner growth calculations.

NOTE Off-line runners are most exposed to thermal growth in runners.

K.4.7 Burner Elevation

K.4.7.1 The burner gas exit shall be at least 2.4 m (8 ft) above grade.

K.4.7.2 The burner elevation should be high enough above grade to allow adequate air flow supply to the burners and to reduce the incident heat flux on the runners and gravel.

NOTE The 2.4 m (8 ft) elevation was chosen for in-shop fabrication welding of risers and logistics / shipping containers for suppliers. Burners at higher elevation will result in fabrication / welding of risers and burners at site.

K.4.8 Pilots

K.4.8.1 For burners that are not designed to cross-light on low pressure runners, the minimum number of pilots shall be one pilot per burner to ensure all burners will ignite.

K.4.8.2 For burners that are designed to cross-light on low pressure runners, the minimum number of pilots shall be two pilots per runner.

K.4.8.3 The minimum number of pilots on pressure assisted stages shall be two pilots per runner.

K.4.9 Fence Panels

K.4.9.1 Fence panels shall be designed to reduce radiant heat from the MPGF to outside the fence while still allowing cooling air flow through the fence. It is common to stagger the fence panels on the vertical fence supports to allow air flow though the fence while minimizing the line of sight to the flame.

K.4.9.2 Large ground flares should include fence features that allow additional air flow through the lower portion of the flare fence.

NOTE In some cases, ground flare fences often have large air flow openings at the base of the fence. Shorter secondary fences or other features may be installed to reduce or eliminate radiant heat through any openings near the base of the main fence.

K.5 Troubleshooting

The design guidance and recommendations provided in this annex are provided to improve the long-term operability and reliability of a MPGF.

Refer to Table K.2 for design and operational troubleshooting problems and possible causes.

Table K.2 –Troubleshooting MPGFs

Problem	**Probable Causes**
Smoking flames	Insufficient surface area in relation to the heat release Insufficient burner-to-burner spacing Low gas pressure upstream of flare burners Excessive flare gas flow per burner Gas composition not per original design conditions Liquid entrainment Insufficient row to row spacing Damaged or plugged burners Insufficient assist media
Flames exceeding design height	Liquid entrainment Exceeding design pressures Incorrect staging set points Burner deterioration Flare gas composition / heat release outside the spec of flare design Abnormal flame-to-flame interaction / overlap Inadequate assist media on low pressure stage(s)
Constant flame on burner with staging valve closed	Insufficient purge flow after destaging Leaking non-reclosing pressure relief device and / or staging valves Improper programing staging logic (i.e., too many runners in operation)
Coking inside burners and risers, leading to reduced pressure at the burner exit and / or mechanical failure of the burners	Excessive heat flux, causing the flare gas to coke when exposed to excessive temperatures Insufficient row to row spacing or fenced surface area in relation to the heat release Operation of runners / flare header below minimum burner pressure Insufficient purge flow after destaging, allowing air to enter the risers and runners, allowing combustion inside the risers and runners Deterioration of burner casting and welds over time Leaking non-reclosing pressure relief devices and / or staging valves, allowing hydrocarbons to coke inside the runners, risers, and burners Gas composition or liquid release exacerbating coking in burners Inadequate burner drilling size or plugging restricting gas flow to burners
Runner lifted off their supports / warped / portion of runner off the saddles	Excessive thermal expansion of the runner, often the result of excessive runner length and excessive heat fluxes Runner overheated by flames from adjacent runners Insufficient venting in the runner heat shields Insufficient shielding with respect to gravel cover Improper runner support design or damage Mechanical hammer due to liquid slug sent to flare field Binding due to improper installation / maintenance

Combustion or explosion inside the runners	Insufficient purge flow after destaging, allowing air to enter the risers and runners, allowing combustion or flashback inside the risers and runners Leaking or damaged non-reclosing pressure relief devices and / or staging valves, allowing flammable mixtures to form inside the runners Non-reclosing pressure relief device open at low flow conditions without adequate purge flow
Rock or runner protection material turning to dust or settling	Insufficient surface area in relation to the heat release Excessive heat flux, causing the cover material to breakdown and turn to dust. Improper cover quality and composition
Runner or fence foundation damage	Improper cover or shielding of foundations
Damage to flare fence	Insufficient surface area in relation to the heat release Insufficient distance from flames to fence Improper fence materials and/or coatings for environment Operation of runners / flare header outside minimum burner pressure