GROUND FLARES – OUT OF SIGHT, OUT OF MIND?

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ABSTRACT

Ground flares have been used or are being installed in several LNG facilities. The ground flares serve the same primary purpose as an elevated flare stack, which is disposal of flammable material by combustion. However, ground flares have key differences from elevated flares that make them attractive for some reasons, and a real challenge for other reasons. It is important for a project team to know what lies ahead when deciding on the flare type in early project phases. The purpose of this paper is to provide insight on the implementation of a ground flare, and the factors for consideration before selecting this technology.

This paper covers the following design and decision factors:

- Comparison of space and cost requirements
- How wind impacts ground flare operations and design:
  - Avoiding exposure of control systems to radiation and hot gases
  - Maintenance work
  - Location of ground flares relative to other facilities
- Staging methods
- Purging
INTRODUCTION

OVERALL ISSUES

Ground flares are often considered as an easy solution to flaring in a populated or industrial area, but there is a great amount of misunderstanding related to substituting a ground flare for an elevated flare in an LNG plant. At first glance, ground flares offer some very attractive benefits relative to their standard elevated counterparts:

- Elimination of visual pollution from that burning ball of fire in the sky
- Smokeless operation over entire range of flow rates
- Low noise (on some designs)

So why don’t we see more of these systems being installed in lieu of the elevated flares seen in the vast majority of cases? The answer lies in the rest of the story, which delves into the following areas:

- Wind – a breeze may do more than bend the flame.
- Cost – CAPEX is king on most projects.
- Plot impact – both area and location are impacted.
- Maintenance – can you fix it on the fly?

TYPES OF GROUND FLARES

There are two distinct types of flares that are commonly referred to as “ground flares”:

- Enclosed ground flare – similar to a fired heater, the flame area is surrounded by an enclosure that provides shielding against noise and radiation as shown in Figure 1.
Open ground flare – a series of headers spaced across open ground with multiple burner tips to distribute the flame with a radiation fence typically surrounding the area as shown in Figure 2.

Enclosed ground flares by their nature tend to be limited in capacity (~100,000 kg/hr or less) due to the cost of providing an enclosure around the flame. Open ground flares can handle high capacities, but require a sizable plot area to do so. Each of these flare types will be discussed on its own merits.

EXECUTIVE SUMMARY

The foremost driving force for employing ground flares is visual pollution. Ground flares can obscure the flame from the surroundings and provide smokeless operation over a wide range of operating scenarios. These capabilities can be of vital importance when near populated or environmentally sensitive areas. By bringing the flame down to ground level it also provides a remedy for sites with height limitations due to aircraft flight patterns.

Noise can be attenuated by enclosed ground flares since the enclosure mitigates a lot of the noise. Open ground flares provide much less noise mitigation even when surrounded by a radiation fence. The fence is intentionally not a solid barrier and provides little noise attenuation.
Wind can have a significant impact on both types of ground flares, but in different ways. Enclosed ground flares rely on natural draft to draw the flame up through the enclosure. The design must be carefully evaluated for varying wind conditions to ensure that there are no situations that would draw the flame out the bottom of the enclosure through the air intake. Care should be taken to make sure that none of the associated flare instruments or controls are in close proximity to the base of the flare in the unlikely event that such a flame excursion occurs.

Open ground flares have very different, but equally important, wind issues to address. First, it is likely that under certain wind and environmental conditions that the flare plume will dip back toward the ground outside the flare burn area. These conditions must be carefully studied to ensure that the plume never intersects areas at grade or elevated platforms where personnel can be present. This may require that the flare area be placed remotely from the operating facility, which is not possible for some sites. Also, the radiation fence around the flare burn area will have to be designed for hurricane or cyclone force winds in many locations, which adds greatly to the structural costs due to the large surface area involved.

Capital costs are a high priority on every project and ground flares invariably end up at the high end of the range. On a cost per capacity basis the relative costs of ground flares vs. elevated flares are as follows:

- Elevated flare: 100% (base)
- Open ground flare: 200%
- Enclosed ground flare: 650%

Ground flares are equipped with staged headers delivering waste gas to the burners to ensure efficient smokeless combustion. One header is always open while the remaining headers are activated using fast acting high performance valves located outside the radiant barrier. This sequencing approach keeps the flare burners in an operating range that ensures proper mixing with air for complete and smokeless combustion as well as minimizing the need for purge gas when flare loads are low. Staging controls can be based off of either header pressure or flow.

With traditional elevated flares, the part of the system requiring most frequent maintenance is the flare tip. It is common in these systems to have a spare flare tip and a method for replacing the spent flare tip without having to shut down the plant. Unfortunately, this type of approach is not available on a ground flare. To perform maintenance on a ground flare will require that it be shut down entirely, which necessitates a plant shutdown.

**FIRE, SMOKE AND NOISE**

There is no question that visual and noise pollution have become issues of increasing importance of late. This sensitivity is due to the push for LNG plants in more populated or environmentally sensitive areas. The traditional elevated flare approach can effectively result in the sun seemingly rising in the middle of the night. Also, many elevated flare designs cannot provide smokeless flaring over their full range of operation without additional air or steam to assist. Finally, there are many cases where the height of the flare can be a problem for aircraft flight patterns approaching an airport.
Ground flares address these aspects of flaring in two ways. First, they bring the flame down to ground level where it can be largely hidden by an enclosure or radiation fence. Then, they spread the combustion of waste products between a number of smaller burners that provide thorough mixing with air and promote smokeless combustion. The burners are divided between several headers that are activated based on flaring load. This ensures that each burner is always operating in an optimal range to assure best performance and smokeless flaring over its entire operating range without air or steam assist.

Noise is a different issue and the two types of ground flares have different strengths and weaknesses. Enclosed ground flares are effective at attenuating noise because of the inherent noise mitigation of the enclosure surrounding the flame. This effect can be enhanced by the use of noise mitigating materials. However enclosed ground flares are limited in capacity due to the size and cost of providing an enclosure, therefore an additional flare will be required to handle the full emergency flaring load. The enclosed ground flare can provide adequate capacity for minor upsets or commissioning and startup loads.

Open ground flares can handle any desired flaring load by simply adding more burners and headers. However, the only noise mitigation they provide is the barrier fence around the burn area. In most cases the radiation fence encircling the burn area is slatted to allow air passage, which allows much of the noise to pass through. Also, a substantial portion of the noise passing over the fence can refract back to grade level. The net result is that this arrangement provides only a modest amount of noise attenuation. If there is enough space available to provide a solid fence and still have adequate air flow to the burn area then more substantial noise mitigation is possible.

**WIND**

Varying wind conditions have relatively little impact on the performance of an elevated flare. Wind affects the position of the flame center, which in turn must be accounted for in the radiation exposure calculations, but that is about it. With ground flares the impact can be much more significant than for a traditional elevated flare.

Open ground flares have both the flame and plume originating at ground level. They have a lot of wind exposure despite the radiation fence around the burn area. When doing wind modeling of the flare it is necessary to assume the worst case despite what the wind rose data says because sooner or later that worst case will happen. This scenario can allow the plume of hot gases to dip down to grade or equipment platforms in the operating area with potentially disastrous consequences for personnel caught in its path. For this reason it is often necessary to separate the flare area from the rest of the plant and provide a restricted area around it to ensure the safety of plant personnel. The potential temperature profile shown in Figure 3 illustrates the problem of an open ground flare under adverse wind conditions. The plume of hot gases can hug the ground for some distance around the flare posing a potential danger for personnel in the area.
Enclosed ground flares by definition provide a protective radiant barrier and the plume is elevated, potentially making it suitable for close placement to the remainder of the plant in all wind conditions. Still, it can be vulnerable to wind conditions in a different way. This type of flare relies on natural draft to contain the flame within the enclosure and direct the plume out the top. The design must ensure that strong wind conditions cannot draw the flame out the air inlet path at the base of the flare. As a further precaution, any instruments or controls associated with the flare should be positioned far enough away from the flare that they will not be damaged should such an event occur.

**COST**

Capital cost is of vital importance to every project. The fact that ground flares tend to be more expensive than elevated flares is an important factor in determining whether or not to apply them to a particular project. As mentioned earlier, the relative costs for a given capacity fall in the following range:

- Elevated flare: 100% (base)
- Open ground flare: 200%
- Enclosed ground flare: 650%

Note that these figures are based on comparisons of systems with specific configurations and there are a number of options that can drive these figures up or down. They do not include factors such as land costs, variances in required feed header length, special smokeless assist or noise mitigation options, specialized tips, ground flare sparing for maintenance, etc. It is also, to a great extent, comparing apples and oranges since each approach offers certain advantages that the other options may not have. Therefore, these comparative costs should simply be regarded as order of magnitude figures providing some indication of what to expect.

**PLOT IMPACT**

Traditional elevated flares require a certain amount of area around them dictated by thermal radiation levels at ground level. Increasing the height of the flare decreases the radiation level at ground level trading off flare cost vs. size of the radiant dead zone around the flare. Ground flares deal with radiation exposure differently by bringing the flame down to ground level and putting radiant barriers around it.

Open ground flares spread the flame over a large area and limit the radiant exposure to the surroundings using a fence around the burn area. The size of the burn area is dictated by...
spacing for air flow plus some additional distance around the perimeter to the radiant barrier. It is roughly proportional to the flare flow rate. In many cases the required area for the flare itself would be comparable or less than that required for a conventional elevated flare. However, it is likely that a protected zone will be required around the flare which would negate any plot advantages.

The design of enclosed ground flares provides noise and radiant heat mitigation and allows them to be placed in close proximity to other plant equipment. This type of unit has the smallest footprint of the various flare options, although one enclosed ground flare cannot handle the full emergency flaring capacity of an LNG liquefaction plant.

**MAINTENANCE**

Since a functioning flare is required for the plant to be operating, the ability to maintain the flare relates directly to the downtime for the entire facility. Conventional elevated flares have addressed this need by allowing for spare flare tips coupled with the ability to replace a tip while the plant is in operation.

Tip or burner maintenance while operating is not a viable option for ground flares. This is offset by following:

- All equipment is at grade for easy access during maintenance
- Burners can typically go for at least 4 years between maintenance and inspections
- Other components outside of burner area are serviceable while operating

Open ground flares can address the need for periodic maintenance in the burn area by dividing the flare into zones having a fraction of the total capacity. Adding a spare zone allows any zone to be brought offline for maintenance without impacting the operation of the rest of the facility.

Enclosed ground flares, due to their capacity limitation, are normally not intended to handle the full emergency flare load. Therefore, it is often possible to take them down for maintenance while maintaining protection elsewhere. The net result is that the choice of ground flare will have little impact on the overall availability of the facility.

**STAGING**

Ground flare staging refers to the setup where different burner headers are activated or deactivated based on the flare load. This activation/deactivation is accomplished by opening and closing a metal seated butterfly valve at the inlet to the header when the upstream header pressure reaches a certain point. Since this is a safety system that must be nearly 100% reliable, it is necessary to put a bypass with a relief device around the staging valve. In previous times it was common to use a rupture disk for this service. Current suppliers generally use a buckling pin valve to achieve a more precise activation point, with easier and less costly maintenance. Once this valve opens, it stays open until it is manually reset. The valve has limit switches to alert the operator whenever it has been activated.
The first header is typically open to the main flare header without a staging valve in between. The sizing of this header is based on the intent to make it as small as possible to reduce purging requirements, but large enough that most minor loads can be handled without opening any of the staging valves.

PURGING

The staging setup of ground flares allows them to reduce their purge rate far below what is required for a normal elevated flare. Purging is intended to prevent air ingress into the flare. For an elevated flare that usually means purging out a large diameter flare tip. For a ground flare only the portion of the system that is open to the main flare needs to be purged.

The staged headers normally have no flow other than possible leakage around the staging valves. Air ingress through the burner tips is very slow. Several recent designs employ a periodic burst of nitrogen to protect these headers, which is sufficient.

CONCLUSIONS

Ground flares offer solutions to certain flaring problems, but with costs or limitations. In relative terms elevated vs. ground flares can be characterized as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>Elevated</th>
<th>Open Ground</th>
<th>Enclosed Ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>&lt;100 tonnes/hr</td>
</tr>
<tr>
<td>Smokeless Capability</td>
<td>Limited with assist</td>
<td>Full without assist</td>
<td>Full without assist</td>
</tr>
<tr>
<td>Flame Visibility</td>
<td>High</td>
<td>Low</td>
<td>None</td>
</tr>
<tr>
<td>Noise</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Plot Space</td>
<td>Base</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Cost/Capacity</td>
<td>Base</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>Availability</td>
<td>Very High with spare</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Purge Rate</td>
<td>Base</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

The primary niche where ground flares excel is where flare height, flame visibility, and smokeless operation are key considerations. Outside of this niche ground flares will have difficulty being competitive vs. a traditional elevated flare. Open ground flares can provide full replacement of elevated flares at the expense of higher cost and plot area requirements. Enclosed ground flares offer superior radiant heat and noise mitigation in a much tighter plot space at the expense of much higher cost and limited capacity. Though cost remains an issue for both types of ground flare, they still can provide the best solution for certain design constraints.