Flaring in stages

Esther Bruce and Nikki Jenlink, Zeeco Inc., USA, look at staged flare designs for LNG applications.

Throughout the years, as the understanding of emissions has increased and regulations have become more stringent, flaring technology and methods for relieving process gas have also improved. The goal of flaring technology is to dispose of process gases or liquids in a safe, effective, and environmentally acceptable manner. At the forefront of this technology are staged flare systems.

Figure 1. Enclosed flare systems (foreground) staging to elevated flare system (background).

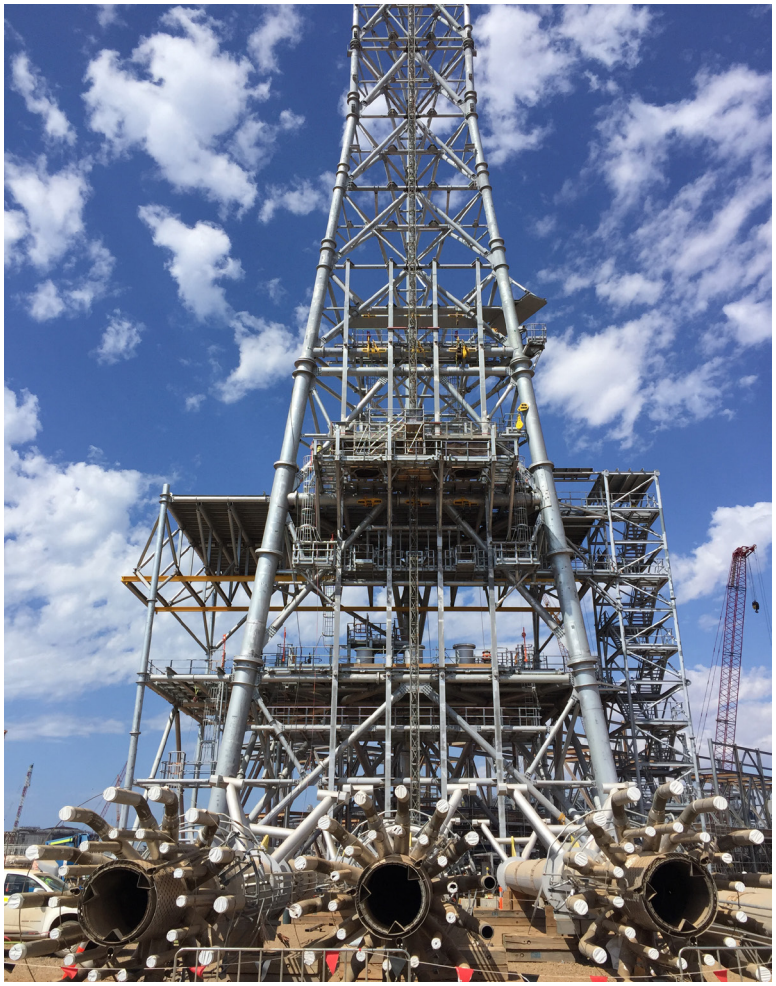

Figure 2. Chevron Wheatstone demountable derrick flare system.

Staged flares are composed of two or more flare systems that are designed to operate in a series of steps or unique 'stages.' In general, staged flares include a first global stage that is designed to burn smokelessly for all of the normal, maintenance, or start-up cases, along with a second global stage designed for emergency flaring cases or uncontrolled reliefs, which could be flared with smoke or combusted smokelessly depending on the specific application, customer requirements, or jobsite location.

Staged flares operate based on pressure or flow, and can utilise a staging valve or liquid seal drum for staging between the first and second global stages. While the first staged flare designs were developed more than 40 years ago, the continual technological advancements make staged flare systems a leading option for flared process gas disposal. Staging provides a variable exit area for combusting flare streams, increasing the design flexibility.

Types of staged flares

Staged flare systems include multi-point ground flares (MPGFs), enclosed ground flares (EGFs), and various types of elevated flares or MPGF/EGF/elevated flare combinations. The most prevalent combinations include the following:

- First stage elevated flare or ground flare staging to a second stage elevated flare.
- First stage EGF staging to a second stage elevated flare (Figure 1).
- First stage MPGF staging to a second stage elevated flare.
- Complete MPGF system for all reliefs and flows.
- Complete EGF system for all reliefs and flows.

Initially, the most common staged flare systems included a small EGF or MPGF staging to an emergency elevated flare. However, complete EGF and MPGF systems designed for all reliefs have become more common over the past 20 years.

Benefit of staged flare designs

The segmentation, or gradual increase in staged operation, provides the opportunity for staged flares to be multi-functional and deliver inherent operational benefits. Some of these benefits include design variability, high turndown capacity, low purge rates, and long equipment service life.

Inherent to the layered approach of staged systems is design flexibility. Each stage can be individually designed to meet the process/staging application requirements. Elevated flare systems serving as a second global stage can be designed as non-assisted when smokeless performance is not required for emergency or high flow cases, or they can be designed for some percentage of smokeless operation. MPGF and EGF flare tips (or burners) can vary drilling patterns and port sizes, making it possible to combust a wide range of gases and to safely operate from purge flowrates through maximum required flows. Tailoring the first stage design also increases the ability to control smokeless flaring or manage exit velocities over greater flows and composition ranges, which is essential for many applications.

A staged system may be advantageous and help to achieve smokeless flaring and/or meet 40 CFR (Code of Federal Regulations, Title 40) exit velocities for a continuous or partial system flow. For operations consisting of both emergency and continuous process gas flows, a staged system makes it possible to design a single first stage flare system that will safely dispose of flows such as start-up, maintenance, normal and continuous flows smokelessly. Similarly, in a staged system, the first stage or stages can be designed to allow 40 CFR exit velocities for a required flow while using the remaining stage or stages to flare under non-40 CFR velocities.

Another advantage of staged systems is the possibility to operate with little to no offline activity. A staged system may be beneficial for plants where it is essential to limit equipment downtime. Since staged systems operate in a stepwise fashion, a system can be designed with a 'spare' stage. When a primary operating stage requires maintenance, inspection, or refurbishment services, flow can be re-directed to the spare

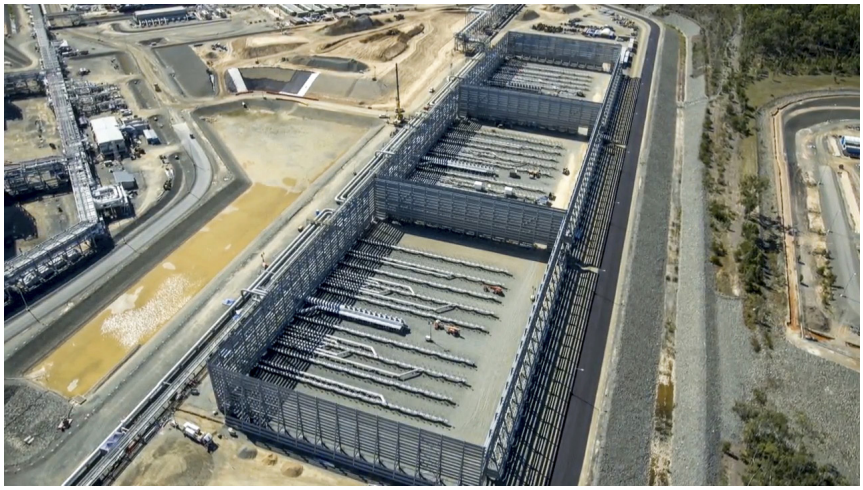

Figure 3. Multi-point ground flares (MPGFs) installed for LNG service.

Figure 4. Darwin LNG MPGF in service.

stage in order for these services to be performed without shutting down the plant (no lost production time). For example, an elevated staged flare can be designed as a demountable derrick structure, which can include a spare elevated flare riser/stage when either of the main operating risers/stages requires maintenance (Figure 2). For an MPGF or EGF system, a spare row of burners can be installed to serve as a spare stage.

To mitigate risk of combustible mixtures in an open flare line, nitrogen or fuel gas is often run through the flare header. This continuous 'purge flow' prevents backflow of oxygen into the system and mitigates the risk of a combustible mixture in the line. The required continuous purge flow for a staged system is generally low. As most stages are typically closed until required to open for an emergency relief scenario, constant purge is not necessary on these stages. A continuous purge is typically only required for the open row or stage on the first global stage of the system. Therefore, a staged system minimises the amount of continuous purge flow required to prevent flashback into the flare system, lowering the purge utility costs for the plant.

Staged flares can also improve equipment lifespan. As the first global stage or a portion thereof is generally the only portion of the unit in ongoing or frequent use, the second and other successive stages undergo far less wear and material damage. Less use mitigates equipment wear of burners, pilots, and associated ancillary items on all intermittently used stages, thus increasing the lifespan of these items. Additionally, burning occurs above the flare tips, maximising tip life.

Opening the valves or breaking the seal in the liquid seal drum and igniting the flare tips in successive stages – only when necessary as system pressure or flow indicates – increases design flexibility, promotes turndown, lowers the continuous purge, and improves equipment service life. Their numerous benefits make staged flares a primary choice for many operations, particularly in LNG applications.

Staged flares in LNG

A typical LNG facility is composed of multiple types of operations (loading/unloading, import/export) with various types of attendant process gas reliefs. The most common relief types are wet/warm and dry/cold reliefs, which operate under high pressure. Many plants also contain a separate marine or boil-off gas (BOG) header, which is utilised when loading or unloading LNG vessels. Unlike the wet and dry reliefs, the marine flare that relieves BOG generally operates under very low pressure. Each of these types of reliefs is routed to the flare separately via individual headers.

Figure 3 shows an example of a flare designed for multiple headers.

The type of flare considered for each header is primarily dependent on the relieving pressure that is available. Due to the high operating pressure of wet/warm and dry/cold reliefs, facilities frequently utilise a staged MPGF or EGF and position the headers in parallel with one another. Alternatively, the MPGF or EGF can be designed to handle continuous, maintenance, or start-up/shutdown cases, and stage to an elevated flare for emergency scenarios. As the pressure for a marine/BOG application is often very low, it is not uncommon for the marine flare to be a separate, elevated system.

The high and low pressure systems generally operate differently. The high pressure systems are typically flared via an MPGF, EGF, or MPGF/EGF in combination with an elevated flare. To handle the continuous purge/header sweep rate and any low flow cases, high pressure reliefs use an open first stage in an MPGF or EGF. This stage consists of a small number of pressure-assisted or air-assisted burners without a

staging valve. An MPGF can be designed to handle all relief cases, with emergency or non-continuous cases handled by a field of burners over one or more additional stages instead of a separate elevated flare. As flow and pressure build, the exit velocity at the burners increases and the gas entrains ambient air. The mixing of the high pressure relief gas with ambient air is enough to maintain smokeless combustion without any additional assist medium. Therefore, on staged high pressure systems, stages two and higher generally do not require any assist medium for smokeless performance.

While MPGF systems can require a large plot space – depending on the design flow case and number of burners required – they can be designed to operate 100% smokelessly, with the flame partially or completely hidden behind a combustion fence. Aside from plot space restrictions, the amount of flow and number of burners for an MPGF is unlimited (Figure 4).

Similar to an MPGF, an EGF can be designed for 100% smokeless operation. The smokeless performance of an EGF is achieved via pressure-assist through harnessing natural draft in the base of the unit, or by adding assist media to one or more stages of burners. Additionally, the flare flame is completely hidden within the combustion chamber. A noise-reducing shroud can be incorporated outside the chamber to assist with noise attenuation if needed. An EGF is limited by the total heat release and, subsequently, by the maximum flow and number of burners in a single unit. Multiple units can be utilised to handle large flow cases. The largest EGF systems in the world are 20.7 m dia. (68 ft dia.).

The staging logic for an MPGF, EGF, or between an MPGF/EGF and an emergency elevated flare, is crucial to the proper operation of the unit due to the variety of waste gas pressures that the system must handle. Figure 5 shows a typical staging curve for an LNG facility, indicating the set point for the opening of the valves, and Figure 6 shows a typical staging curve for a ground flare staging to an elevated flare.

Unlike the high pressure wet and dry reliefs, the marine flare or low pressure flows are typically directed to an elevated system and assisted with air. The air is injected near the tip in an effort to promote gas/air mixing and meet any smokeless requirements.

While MPGFs and EGFs are standalone staged systems, they can also run in series with an elevated flare as a combined staging system. A typical staged arrangement with an elevated flare would include a first stage MPGF or EGF staging to an emergency second stage elevated flare, or a first stage elevated flare staging to an emergency second stage elevated flare. Depending on the particular staging function of the system, air-assist may be utilised to enhance the smokeless performance.

When an elevated flare is incorporated into a system, it can be supported by any typical means, including self-supported, guy-wire supported, or fixed or demountable derrick support. Fixed and demountable derrick supports are common for LNG facilities, since they allow a single structure to support multiple flare systems. An elevated flare requires less plot space than an MPGF or EGF, but always has a visible flame, which can be an issue for LNG plants located near populated areas or in aircraft flight paths. Figure 2 shows the staged high pressure wet, dry, and spare flare system for Chevron Wheatstone; this is an elevated, demountable derrick type system using a pressure-assisted flare.

The inherent flexibility of staged flare systems in LNG applications can reduce the number of individual relief systems in a facility, reduce plant utility costs, enhance efficiency, and improve equipment life. Multiple types of staged flare configurations, including MPGF, EGF, and elevated flares, are possible, making them a suitable choice for many applications and a leading option for flared process gas in LNG facilities. **LNG**

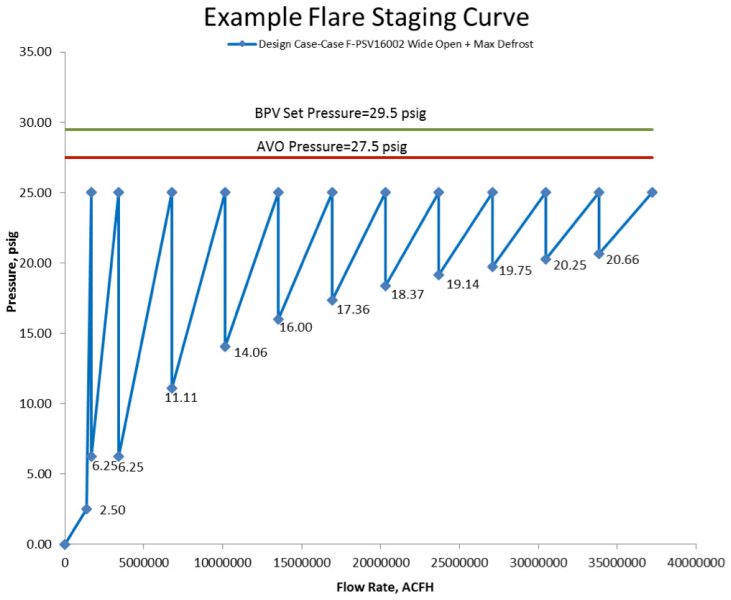

Figure 5. Example of an MPGF or enclosed ground flare (EGF) staging curve.

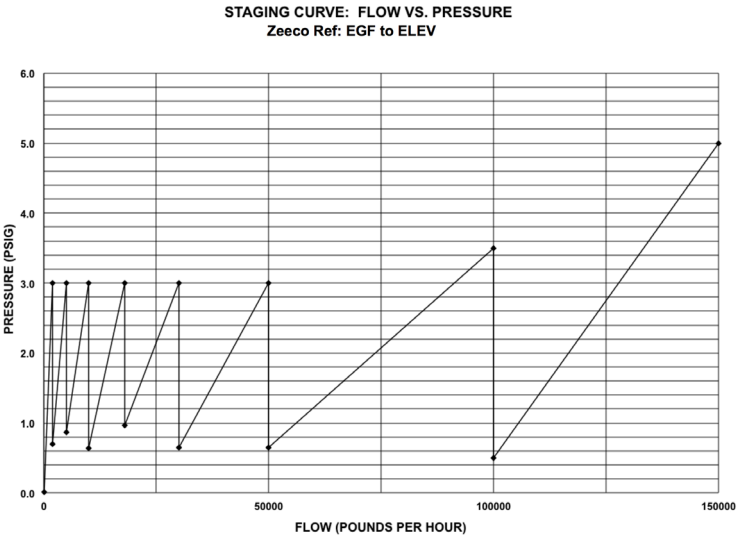

Figure 6. MPGF or EGF staging to an elevated flare.