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Flaring Emissions: Pilot-Operated Safety Relief Valves as an Emission Abatement Solution

Baker Hughes

COVER STORY

MINIMISING FLARING EMISSIONS

Jason Knudson, Baker Hughes Valves, USA, explores how pilot-operated safety relief valves serve as an emission abatement solution.

The term 'net zero' has gained recognition in the past decade, referring to when the produced greenhouse gas (GHG) emissions are offset by those removed from the atmosphere. Many countries aim to reduce GHG emissions by 2050, but face challenges in addressing industrial processes and emissions. According to the Environmental Protection Agency (EPA), industrial facilities account for 30% of the total GHG emissions in many countries, leading to increasingly stringent emission regulations.[1] Governments worldwide are thus implementing tighter emissions regulations in various industries.

For instance, the EU has set ambitious targets for reducing GHG emissions and introduced regulations such as the Industrial Emissions Directive. In the US, the EPA has introduced stricter emissions regulations for industrial plants, vehicles, and other sources.

Flaring regulations and the role of pressure relief devices (PRDs)

Flaring in refineries is frequently observed as emissions to the public eye, making it a target for regulations. Flaring is a common practice in the oil and gas industry, but not necessarily the worst offender of GHG emissions in industrial plants, considering that not all fluids that are burned convert to air pollutants. Routine flaring is one of the easiest processes to reduce emissions output when compared to other industrial sources, according to the American Institute of Chemical Engineers. Most refineries are taking steps to reduce emissions voluntarily, partly in response to public perception and regulations, but also internally to meet sustainability and production goals.

The latest EPA ruling on emissions limits and flares is aimed at reducing harmful air pollutants released by industrial flares. The new rule requires refineries to limit the amount of flaring they conduct and decrease the amount of emissions released during flaring events.

PRD Type	Performance		
	Before	During	After
Rupture Disc	+	→	–
Spring Loaded	→	→	→
Pilot Operated	+	+	+

Figure 1. Pressure relief device (PRD) performance (before, during, and after a relief event) by type.

Figure 2. Typical gas flaring at a refinery.

Flares and other control devices must achieve at least 95% reduction in methane and volatile organic compound emissions. The rule also requires facilities to monitor and report their emissions to the EPA, which will help the agency enforce the regulations and ensure compliance. This ruling is a significant step forward in reducing emissions, asserting industrial companies to adopt more sustainable practices.

To meet these new regulations and improve perceptions of flaring, refineries are integrating additional safeguards and technologies to minimise flaring. Routine flaring events can be captured by a flare recovery system; however, these systems are not typically designed to manage unpredictable emergency conditions that usually result from PRDs, such as safety relief valves (SRVs), rupture discs, and control valves. When unplanned scenarios arise, pressure-relief system designers and plant operators rely on the flare to mitigate unsafe conditions such as over-pressurisation beyond the design limits of piping, flanges, and vessels. PRDs are critical components in refineries that help prevent equipment from over-pressurising and causing potentially catastrophic accidents such as explosions, fires, and other safety hazards.

While PRDs are essential for maintaining safe operating conditions in refineries, they also contribute to the flare header system, which conflicts with emission and flare reduction directives. Emergency flaring because of a relief event is difficult to predict and typically, when PRDs open, they release large amounts of media, depending on their size and flow characteristics.

Despite these challenges, PRDs are a necessary evil to prevent accidents and ensure the safety of workers and the surrounding area. When evaluating the impact of PRDs on flaring, pressure-relief system designers and plant operators will consider various types of PRDs to fit their specific applications as PRDs come in more than one design, with each one having unique features. Preventing leakage and limiting the duration and flow of these devices is a top priority for plant operators in refineries as it relates to emission reductions for relief events to flares.

Comparing PRDs

Rupture discs, spring-loaded SRVs, and pilot-operated SRVs are all essential PRDs used in various industrial applications to protect equipment and personnel from overpressure events. Each type of PRD has unique characteristics and functionalities, making them suitable for different operating and process conditions.

Rupture discs serve as non-reclosing PRDs designed to burst at a predetermined pressure, providing instantaneous overpressure protection. They are tailored to operate optimally during normal operating pressure, with no leakage into a flaring system before reaching the burst/set pressure. Rupture discs offer a high coefficient of discharge and reach full-rated flow immediately after opening due to their flowing characteristics. Unlike other PRDs, reseating pressure or blowdown does not apply to rupture discs as the disc is destroyed and there is no

mechanism to reseat. Flow/leakage will continue until the process is shut down and the disc is replaced.

On the other hand, spring-loaded SRVs are reclosing PRDs that utilise a spring to counteract the force of inlet pressure at the valve's seat. These valves typically remain leak-tight for up to 90% of the set pressure for metal seated valves and up to 95% of the set pressure for soft seat valves. At set pressure, spring-loaded SRVs typically reach 50 - 70% lift, thereby relieving most of their rated capacity without additional overpressure. The blowdown of spring-loaded SRVs depends on the relieving medium and trim selected, ranging from 5 - 25% of the set pressure.

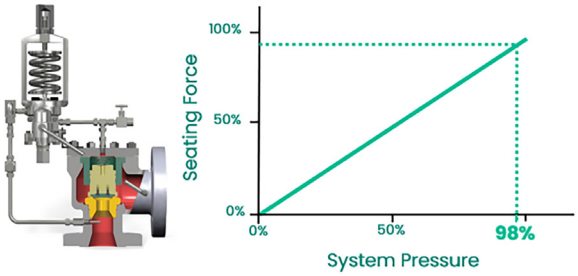

Figure 3. Pilot-operated safety relief valve (SRV) seating force curve.

Figure 4. Consolidated 3900 Series Pilot-Operated SRVs can enhance operational effiency where high pressures and back pressure need to be controlled.

In some cases, incorporating a rupture disc at the inlet of the spring-loaded SRV can present a viable solution for ensuring process stability and mitigating potential leakage issues associated with spring-loaded SRVs. However, it is not always ideal to shut down the process for replacing rupture discs in most applications.

Pilot-operated SRVs are another type of reclosing PRD that employs a pilot valve to load operating pressure into the main valve dome, allowing the main valve seat to remain tight until the set pressure is reached. These valves are typically leak-tight from 95 - 99% of the set pressure. Pilot-operated SRVs offer two pilot types, pop-action or modulating which influence the flowing characteristic of the valve. Pop-action pilots enable the main valve to achieve full lift/flow at the set pressure, while modulating pilots open proportionally to the relief demand, only flowing what is necessary. Typical blowdown for pilot-operated SRVs can range from 2 - 10% of the set pressure.

Pilot-operated SRVs present a superior solution for mitigating leaks and managing flow before, during, and after a relief event, when contrasted with the other PRD types. While their applicability may not extend to all processes and applications, consideration of pilot-operated SRVs as an alternative to conventional, reclosing spring-loaded SRVs is warranted due to the several advantages they offer in reducing process loss to the flare.

Maximising operational efficiency

Pilot-operated SRVs have traditionally been favoured as an optimal valve solution for enhancing operational efficiency within refineries. Presently, pilot-operated SRVs are strategically employed by refinery operators for high operating pressure, inlet line loss, and back pressure applications. The following list outlines the advantages of utilising these SRVs to mitigate both process loss and emissions.

No main valve leakage

It is imperative to prevent seat leakage during normal conditions to minimise unnecessary process loss to the flare. Unlike conventional spring-loaded SRVs, the seating force of a pilot-operated SRV is distinct in that it directly corresponds to the increase in system pressure. Consequently, as the system pressure rises, the seating force of the main valve also increases. Pilot-operated SRVs can provide a maximum seating force of up to 100% of the set pressure, thereby eliminating seat leakage and process loss to the flare header system. Additionally, pilot-operated SRVs generally come standard with soft seats and are tested to API 527 standards for seat leakage of zero bubbles per minute at 90% of the set pressure. Most PRD manufacturers conduct more rigorous testing for these PRDs by surpassing 90%, with testing extending

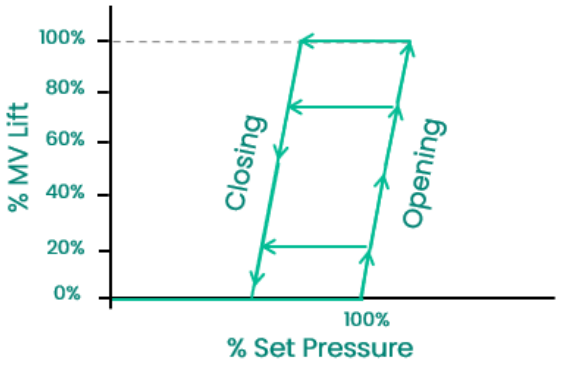

Figure 5. Pilot-operated SRV lift curve.

to 96% of the set pressure, affirming the seat leakage performance of pilot-operated SRVs.

Limit pilot venting

The pilot valve is responsible for regulating the pressure in the dome above the main valve's seat. When the pilot senses the set pressure, it vents the dome pressure to facilitate the main valve lift. Pop-action pilots do not initiate venting until the set pressure is at 100%, ensuring optimal leakage performance before reaching the set pressure. However, these pilot types enable the main valve to achieve full lift and rated capacity which is not ideal for minimising process loss during a relief event. Modulating pilots offer an improved solution for mitigating excessive process loss during a relief event, although it is important to understand the operational principles of these valves.

Modulating pilot designs maintain a specific amount of dome volume to aid in main valve modulation. A traditional modulating pilot design initiates operation before the set pressure by securing dome pressure at approximately 95% of the set pressure, known as the 'null' zone. Operating pressure beyond this threshold triggers the pilot to start venting prior to set pressure, to prepare the main valve for opening. Alternative modulating pilot solutions, such as bolt-on modulators that exhibit no leakage up to the set pressure or pilots that enter the null zone above 95%, should be considered especially when high operating pressures are close to the set point of the pilot. These modulating pilot types prevent unnecessary leakage before set pressure to the flare header system.

Modulating flow

Regulating the flow rate during a relief event is crucial to comply with the latest EPA regulations and flare monitoring is increasingly utilised. Pilot-operated SRVs, outfitted with a modulating pilot, function to open and close in response to fluctuations in the upstream pressure. When the upstream pressure nears the valve's set pressure, the modulating pilot valve incrementally opens, discharging dome pressure and prompting the main valve to modulate. This design characteristic enables the modulating pilot-operated SRVs to deliver the necessary capacity for upset conditions, rather than the full rated flow, thereby avoiding substantial process loss to the flare header system. Additional benefits of these pilot types include noise reduction and stable relief cycles for challenging applications.

Short blowdown

After a pressure relief event, it is important to have a valve with an optimal blowdown to minimise product loss when system pressure decreases. Pilot-operated SRVs reseat the main valve at pressures close to the pilot valve's set pressure, but also offer adjustable blowdowns to meet specific normal operating parameters. With adjustable blowdowns as low as 2%, pilots offer excellent reseat performance to prevent excessive flow to the flare and help normalise system pressure.

Optimising efficiency and cost savings

Pilot-operated SRVs offer a practical solution for pressure-relief system designers and plant operators looking to comply with new emission directives for flare systems. By using pilot-operated SRVs, operators can save costs by preventing leakage, regulating flow, and reducing the amount of emissions released. This can help avoid hefty regulatory fines, estimated to be in the hundreds of thousands of dollars per release. Additionally, the use of pilot-operated SRVs is expected to decrease product loss expenses by tens of thousands of dollars per relief event and improve overall system efficiency, thereby increasing profitability for refineries.

The transition from an existing spring-loaded SRV installation to a pilot-operated SRV will require consideration of the product cost and associated piping modifications. Commissioning a full-nozzle pilot-operated SRV that aligns with the API 526 spring-loaded SRVs centre-to-face dimensions presents a cost-effective alternative by avoiding the need for piping changes. Furthermore, pilot-operated SRVs offer additional advantages that can contribute to overall cost savings, offering a short payback period on upfront costs. Implementing any modifications to the existing process system requires a thorough consideration of management of change (MOC). PRD manufacturers offer various tools and resources, including product catalogues, whitepapers, sizing programmes, and service partners, to facilitate the transition and alleviate the MOC process.

In conclusion, the global movement towards achieving net zero GHG emissions has led to stricter regulations for refineries and other industrial facilities, with a focus on minimising flaring and emissions. PRDs such as pilot-operated SRVs should emerge as a favoured solution for minimising process loss and emissions. They offer several advantages and cost savings for end users, making them a promising option for refineries striving for process loss reduction.

Reference

1. 'Industry Sector Emissions', *United States Environmental Protection Agency*, (March 2025). https://www.epa.gov/ghgemissions/industry-sector-emissions

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