PRESSURE RELIEF THROUGH REDUNDANCY

Kumar Dinesh, Baker Hughes Valves, UAE, examines methods to protect tanks and pipelines from the risks of overpressure.

In applications requiring the operation of tanks, overpressure protection is crucial for safety, preventing catastrophic failures and ensuring operational efficiency. At worst, a tank rupture can lead to explosions, fires or fatal injury to personnel and at best uncontrolled release of process media can be an environmental risk. Redundant pressure relief devices can prevent the system from exceeding the maximum allowable operating pressure (MAOP). This article will discuss the potential causes and risks of overpressure, and some common methods for protecting the safety and integrity of tanks and pipelines.

Some of the critical relief scenarios related to overpressure in tanks and pipelines are surge, thermal expansion, and vacuum relief.

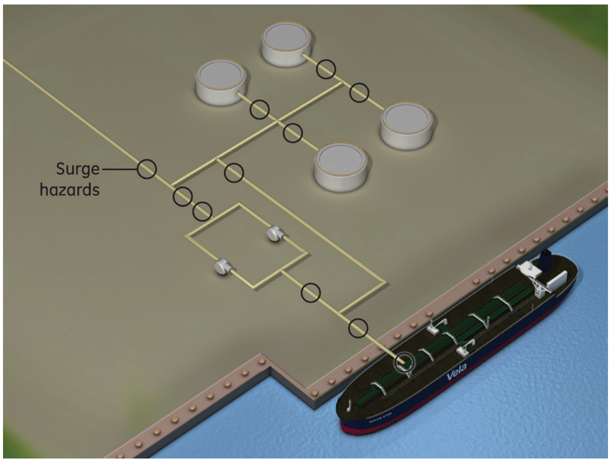

Figure 1. Typical storage tank farm and terminal has multiple areas where surge relief protection is critical.

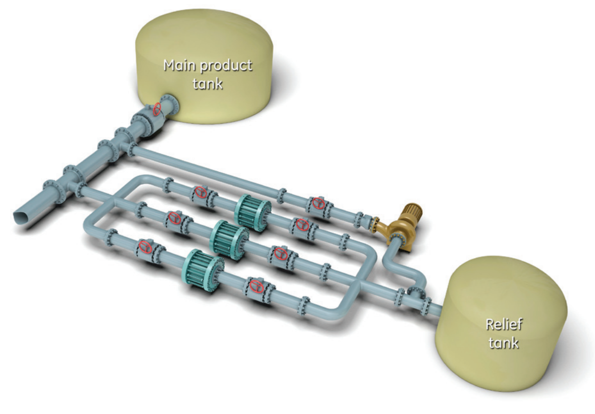

Figure 2. Example of set up for surge relief valves on a bypass line leading from the main pipeline.

Surge scenario

When discussing surge scenarios, the primary concern is with the rapid changes in fluid pressure, often referred to as 'hydraulic transients' or 'water hammer'. These surges can pose significant risks to the integrity of tanks and pipelines. Rapidly shutting a valve can abruptly stop fluid flow generating a pressure wave that propagates through the system. Or changes in pump operation can cause rapid fluctuations in fluid velocity and pressure. Basically, any event that causes a sudden change in the speed of fluid movement can induce a surge.

When one of these events occurs, surge waves can create pressure spikes that exceed the design limits of pipelines and tanks, leading to ruptures or leaks. Surge events also generate significant vibration and noise, resulting in equipment damage or environmental concerns.

To mitigate these risks, a surge reliever in a storage tank farm is a crucial safety device designed to protect tanks and pipelines from damage caused by pressure surges. Transient pressure surges, also called 'water hammer', can occur when there is a sudden change in the velocity or flow rate of liquid, such as when a valve is closed quickly, or a pump is started or stopped. The greater the change in flow velocity, the higher the pressure will rise. These pressure surges can travel through a pipeline at sonic velocities, and if left unabated, can cause serious damage and costly inspection of the line.

Surge relief valves are designed specifically to protect against damage from high-speed transient pressure surges. As fluid is being pumped in and out of storage tanks, both the pumps and the valves have the potential to be subjected to a surge event, and the surge relief valve will mitigate that risk. Terminals, often near bodies of water, critically require surge relief protection to prevent pipeline breaks. Figure 1 illustrates the multiple points in a typical storage tank farm and terminal where surge relief may be required.

Surge relief valves are typically installed as close to the surge potential as possible, on a bypass line leading away from the main pipeline (Figure 2). When the main pipeline pressure exceeds the jacket pressure in the surge relief valve, the inner tube is forced away from the core of the device, allowing for fluid media to pass through the barrier to a downstream line and be captured in a collecting tank.

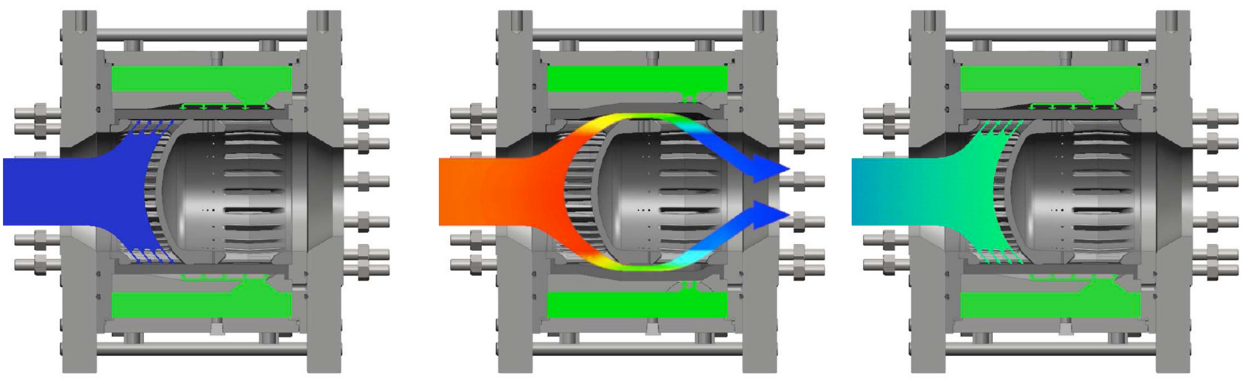

Figure 3. Illustration of how a surge relief valve works.

The fluid can be pumped or trucked back into the main line at lower pressure once the surge subsides. Any transient pressure surges should be analysed for root cause.

How the surge relief valve works

Under normal operation, the pipeline pressure (blue) is less than the jacket pressure plus cracking pressure. The jacket pressure (green) forces the tube against the core of the device and the valve is closed (Figure 3, left).

When the valve set point is reached, the pipeline pressure exceeds the jacket pressure, the tube is forced away from the core, permitting fluid to flow around the barrier into a a downstream line (Figure 3, centre).

When the surge event passes and the main pipeline pressure returns to normal, the jacket pressure reseats the tube against the core, closing the valve (Figure 3, right).

Thermal expansion scenario

Thermal expansion is often caused by changes in ambient temperature, which can cause liquids within tanks to expand and increase pressure. Most substances expand when heated and contract when cooled. This is due to the increased kinetic energy of the molecules, causing them to move further apart or closer together. Liquids in particular can experience substantial volume changes with temperature variations. In a closed tank or section of pipe, temperature variations due to ambient conditions, but also solar radiation or process heating, can all contribute to thermal expansion when the liquid is heated, leading to a significant rise in pressure.

Thermal relief valves offer overpressure protection when a closed tank or section of pipe is exposed to temperature changes. These changes create a slower but substantial increase in internal pressure. Typically, very little liquid needs to be redirected to relieve the pressure, and a direct spring thermal relief valve can be installed for this purpose.

Under normal conditions, the valve spring pressure is higher than the system pressure, keeping the valve in a closed position. When the system pressure reaches the set point, the pressure of the fluid will lift the internal disc off the seat, allowing the fluid to pass through the valve to relieve the pressure. Thermal relief valves (Figure 4) are typically rated to fully open to 10% over set point pressure. As the system pressure decreases comparably to the spring pressure, the disc sets against the seat, closing the valve.

Vacuum relief scenario

There are several causes for vacuum situations in tanks and terminals. Vacuums can occur when liquid is pumped out of a tank, when the liquid or vapour within the system is cooled to a point of contraction, or there are changes in atmospheric pressure. If the internal pressure drops significantly below the external atmospheric pressure, the tank can collapse. Even minor vacuum conditions can cause stress and damage to a tank's structure over time.

Weight-loaded pressure vacuum vent valves are safety devices used on storage tanks and vessels to protect them from over pressure or vacuum conditions. They are designed to automatically release pressure or allow air to enter the tank when the pressure or vacuum

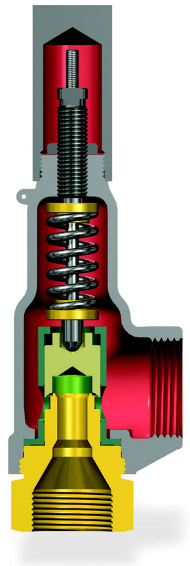

Figure 4. Consolidated 19000 Series Thermal Relief Valve. Image courtesy of Baker Hughes.

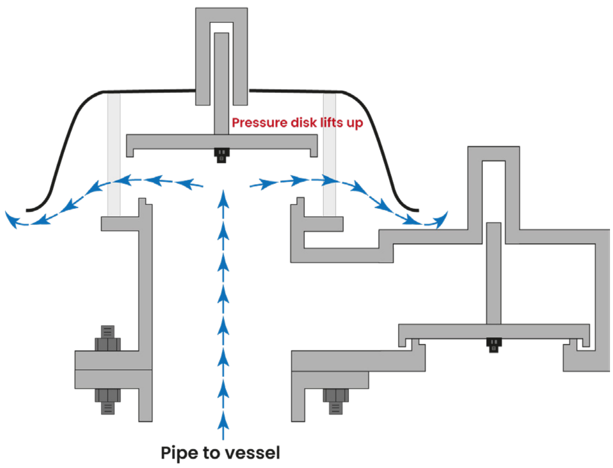

Figure 5. Relieving excess pressure.

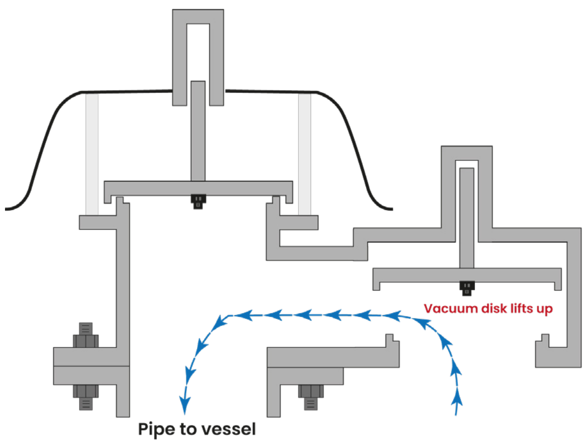

Figure 6. Relieving excess vacuum.

exceeds a predetermined limit. These valves are essential for preventing structural damages to tanks caused by excessive pressure or vacuum.

Pressure vacuum vent valves use a weighted pallet that is held in place by gravity. When the pressure or vacuum inside the tank reaches the set point of the valve, the pallet lifts, allowing pressure to escape or air to enter (Figure 5 and Figure 6). The weight on the pallet determines the pressure or vacuum setting at which the valve will open. These weighted pallet valves are also known as conservation vents or breather vents. This is because one of the primary uses of these devices is to protect low pressure storage tanks that have fixed roofs. Since the design pressures are very low, the simple pumping in of product or increased ambient temperatures can raise vapour pressures in the tank and cause weight loaded valves to 'breathe' and discharge the pressure. The sizing and selection of these weight loaded valves is often done per API 2000.

They are very effective at relieving low vacuum situations and are not suitable for high pressure or vacuum applications such as when an external heat source is applied to the vessel contents. For these situations, an additional pressure relief device maybe required to alleviate higher pressure than allowed for by the weighted pallet valve. These devices are simply tank hatches, also called 'manways', that normally have hinged covers. The covers have a calibrated weight, moment arm and possibly a counterweight to provide the required set pressure. These emergency relief devices are set at higher pressures than the weighted pallet valves. If called upon to open and relieve pressure, they are designed to stay open until manually closed.

Closed tanks and pipeline systems present multiple risks, requiring redundant over pressure protection devices and systems to prevent exceeding the maximum allowable operating pressure. By specifying and installing the right pressure relief devices, operators can effectively mitigate these risks and ensure safe and efficient operations.

Conclusion

In summary, this article has underscored the potential causes and risks associated with overpressure in tanks and pipelines, while also emphasising the importance of specific critical relief scenarios such as surge, thermal expansion, and vacuum relief. Effective protection hinges on a deep understanding of these factors and the diligent implementation of appropriate mitigation strategies. This includes not only general safety protocols and pressure relief devices but also tailored solutions designed to address the unique challenges posed by these critical relief scenarios, ultimately ensuring the safety and longevity of these essential systems.