Cost Effective Solutions for Pressure Relief Valve Deficiencies

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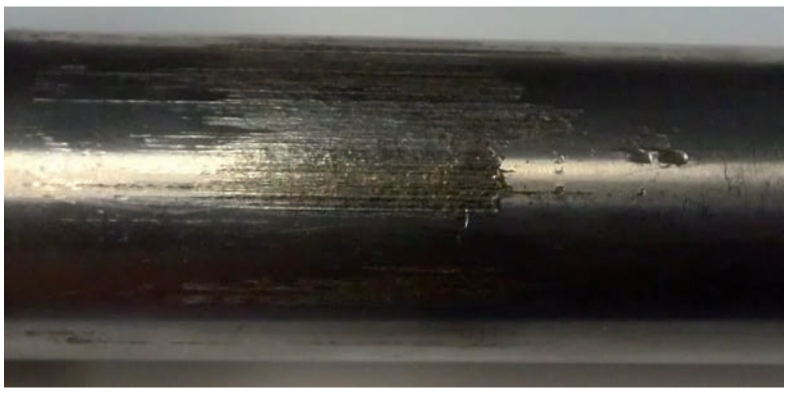
When a pressure relief valve (PRV) shows chronic maintenance issues such as leakage, galling, bellows integrity failure or even catastrophic failure, often it is assumed that the PRV is the issue. Chronic maintenance issues can be an indication that there are deficiencies in the relief system itself, attributable to the sizing, specification, installation, overall system design, disregard of best practices and code, or some combination of these. This situation can be further complicated if the deficiency is incorrectly identified and the mitigation implemented causes issues with other equipment or systems.

Deficiencies must be corrected to ensure the safety integrity of any pressure relief system. Safety relief valve instability, ranging from minor fluttering to severe chattering, can prevent valves from functioning as designed. These deficiencies increase maintenance expenditures and, in worst case scenarios, can cause catastrophic failure of a protected system during a relief event. Proper analysis of a relief system requires evaluation of all applicable overpressure scenarios, including piping hydraulic calculations. Engineering analysis performed during a plant or system wide audit of the safety relief system offers an ideal time to investigate deficiencies. A well-executed engineering audit will ensure that the ultimate causes of deficiencies are fully understood.

Following the deficiency assessment process, a safe and cost effective mitigation strategy should be defined. Mitigation solutions have a vast range of cost implications, from the relatively low cost of changing the set pressure of a relief valve to the higher cost alternatives of changing piping or installing a High Integrity Pressure Protection System (HIPPS). Decision makers should take time to understand the cost implications of the various mitigation strategies available to them. In some cases the engineering 'quick-fix', such as making piping modifications, can be the most costly to implement. Outlined below are common deficiencies and guidelines that can be used to help understand economical options from a hardware standpoint.



1. Inlet Pressure Drop – According to API recommendations, the inlet piping between the protected equipment and the inlet flange of the PRV should be designed so that the total pressure drop does not exceed 3% of the valve's set pressure. This limit is intended to ensure high inlet losses do not cause excessively high accumulated pressures in protected equipment as well as to ensure the spring loaded PRV does not operate in an unstable region i.e., chatter or flutter. For compressible service, the evaluation of piping pressure losses is required to be performed at the maximum real capacity of the installed valve(s). For non-compressible service, the piping hydraulics are performed at required capacity. When inlet pressure drop is found to be greater than 3%:
   a. The least expensive option may be to reduce the set pressure of the PRV. A comprehensive review of all relief scenarios must be conducted.
   b. Area calculations should be performed to determine if a smaller orifice PRV is acceptable. Piping hydraulic calculations must also be addressed for all possible relief scenarios, as the scenario which requires the largest orifice may not produce the highest inlet pressure drop due to the stream state. If a smaller PRV is not an option, consider installing a remote sensed pilot operated valve. Remote sensing of a pilot valve ensures that the equipment is protected and that the valve functions properly.
   c. Modify the inlet piping by shortening the inlet run or increasing the pipe diameter. This may require modification of the protected equipment to accommodate increased nozzle and piping diameter. Often, this is likely to be the most costly option but in some cases, the only solution.

2. Incorrect Pressure Relief Valve Sizing – A PRV having an orifice which is "oversized" can introduce valve instability issues. These issues can result in increased maintenance costs and/or potential catastrophic failures during relief events. A PRV having an orifice that is "undersized" requires immediate attention as the integrity of the protected equipment is in jeopardy. PRVs, in general, have pressure limitations based on model config-

uration options and materials of construction. Particular attention to a PRV's maximum pressure/temperature limitations must be reviewed during the selection process. Various solutions may be available including the use of pilot valves in lieu of spring loaded valves.

a. If an undersized PRV is found, perform a more rigorous engineering analysis of the protected systems, such as dynamic simulation of a fire event. This may reduce or eliminate potential overpressure scenarios and allow you to keep the existing pressure relief valve. If after analysis a larger orifice is still required, this typically calls for a larger valve configuration and expensive piping changes. A pilot valve, which offers more orifice area per body size, may provide the required additional capacity with little or no expensive piping changes.

b. A second option for incorrectly sized PRVs is to consider installation of multiple valves. ASME relief sizing allows evaluation at 16% overpressure for multiple valve applications compared to 10% for single PRV applications, thus reducing final relief required area. Multiple valve configurations can be uniquely designed to address the particular needs of any protected system. ASME code requires that only one device be set at or lower than the established maximum allowable working pressure (MAWP) of the protected equipment. The additional valves are then set at no more than 5% higher than the MAWP. In many applications, the "worst case scenario" is typically a case that may happen infrequently, where other smaller relief scenarios may happen on a more frequent basis. Selection criteria would allow for one PRV to be set at or lower than the established MAWP. This PRV size could also be configured to satisfy the majority of the scenarios not considered the worst case scenario. Although introduction of a second valve is a more expensive option, this option optimizes the performance of the pressure relief system to its overpressure scenarios and will minimize PRV performance and maintenance issues.

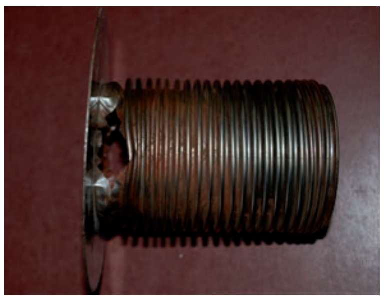
3. Backpressure Issues – The pressure existing at the outlet of a PRV due to pressure in a discharge system is defined as backpressure. Since back pressure can have serious effects on the performance of a safety relief valve, it must be reviewed and properly addressed. Backpressure can be categorized two ways - superimposed or built-up. Superimposed is static pressure that exists at the outlet of a pressure relief valve at the time the valve is required to operate. It can be either constant or variable. Built-up backpressure is variable pressure existing at the outlet of a pressure relief valve due to the flow through the particular device into the discharge system. Limits on built-up back pressure for conventional valves are based on the set pressure and the sum of all back pressure, and should be less than or equal to the accumulation pressure - 10% for a single valve, 16% for multi-valve or 21% for fire. When backpressure is not correctly identified, several deficiencies can result:

a. Conventional spring loaded valve experiencing built-up or variable superimposed backpressure above the limits will cause PRV instability which may result in a reduction of capacity. The recommended options are to convert the PRV to a bellows construction or to replace it with a pilot operated relief valve, where process conditions permit.

b. When backpressure, whether superimposed, built-up, or a combination of the two, exceeds the design pressure of the bellows, deformation of the bellows can occur. This will render the bellows inoperable or if the damage is severe enough, it may cause leaking to atmosphere. Options for mitigation include installation of a bellows with a higher design pressure, replacement of the PRV with a pilot-operated relief valve or installation of a rupture disc.

c. For fire scenarios where 21% overpressure is utilized, there may be issues with excessive built-up back pressure. Consider evaluating fire cases at 10% overpressure to determine if equipment can be protected and not cause back pressure issues. This has added benefit of reducing loading on collection/flare systems during relief events.

4. Set Pressure Too High - A PRV's set pressure is set too high when it exceeds the MAWP of the equipment it is protecting. When this is the case, the PRV may fail to prevent over pressurization of the system.



a. ASME code requirements ensure the certified PRV's set pressure does not exceed the MAWP of the coded pressure protected equipment. Mitigation requires lowering of the PRV set pressure. A proper engineering analysis requires recalculation of all relief scenarios and subsequent piping pressure loss calculations based on the new lower set pressure.

5. Operating Too Close to Set Pressure – If a PRV's set pressure is too close to the system's maximum operating pressure, the valve may simmer or leak, making it susceptible to premature wear and damage to the seats. Product loss is also associated with this leakage. Consider the following:

a. Lower the system operating pressure to increase the pressure differential.

b. Consider installing a pilot operated PRV. The pilot operated valve design uses system pressure to keep the main valve closed and soft seats to enhance the seat tightness. As a result, when the system pressure approaches set pressure, the main valve seat will get tighter. This is ideal for applications where the operating to set pressure differential is small.

c. If a valve is used in a vapor application, it is possible to use an ASME Section I valve which has tighter blow down capabilities, maximum 4%. Keep in mind that Section I valves also require minimal inlet piping drop to function properly due to the short blow down. The operating pressure, inlet piping pressure drop, as well as the valve's expected blow down all need to be considered.

6. PRV Not Certified for Installed Service–PRV's are ASME code certified for either vapor or liquid applications. Often, cases have been found where the PRV's certification, either vapor or liquid, does not match the actual service of the valve. For example, a PRV certified in vapor service but put into a liquid service application will not be sized correctly and will have performance issues.

a. In this case, the PRV will likely need to be replaced. However, a pressure relief system engineering analysis should be done prior to valve selection as it is very important to ensure all overpressure scenarios are calculated using the correct formula, methodology and the certified RV parameters.

b. PRV's with special trim design can be certified on both vapor and liquid service and can be used in both applications, thus allowing sizing for liquid, vapor or 2-phase flow scenarios.

7. General Maintenance Issues - Like all operating equipment in a plant, PRVs require routine preventative maintenance at regular intervals. When a PRV's maintenance frequencies surpass the expected regular intervals, this indicates the issues may reside at the protected system level rather than at the PRV level. Chronic maintenance issues that may be indicators of this problem include bellows integrity failures, galling, internal part failures, and overall erosion/corrosion issues.

a. The entire protected system should be re-evaluated including its piping pressure loss calculations.

b. Examination of damaged PRV parts may reveal the causal effect. For example, severe galling of internal parts bellows fatigue failures and nozzle/disk damage typically indicate valve chattering. Chattering is symptomatic of a broader system issue similar to those we have described in this article.

Summary

Pressure relieving systems are installed in process and power plants to protect process equipment and their surroundings from the effects of an overpressure situation. Pressure relief systems are extremely critical safety elements as they are the final line of protection against equipment failure and catastrophic overpressure events. Protected systems that may have relief valve deficiencies jeopardize the integrity of these critical safety elements and all efforts to mitigate these efficiencies must be addressed.

About the authors

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He has been with Farris Engineering for over 16 years and has served in various roles, including Applications Engineer, Regional Manager, Pilot Valve Product Manager and now Engineering Manager.