MAINTENANCE & REPAIR

Common Bellows Failures and Suggestions for Mitigation

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While it is an extremely rare event, bellows can and do fail. But bellows failures are often wrongly attributed to the quality of the valve or the bellows while in reality, a more likely scenario is operating conditions or an improperly specified valve that contributed to the failure. Still, whenever a failure occurs, analysis of what happened and why is critical.

THE USE OF BELLOWS

A spring-loaded pressure relief valve (PRV) is a device that reacts based on the amount of static pressure force pushing up on the disc. In normal processing conditions, the valve will remain shut because the upward force on the disc is less than the closing spring force. When the force from the process fluid pushing up and the force of the spring pushing down are at equilibrium, the disc of the valve will begin to lift from the nozzle, and the valve will begin to "simmer." At this point, a slight increase in process pressure will cause that valve to "pop" open (its set point), thereby relieving the overpressure.

A bellows is typically specified for applications when a spring-loaded PRV will experience backpressure (which can impact the valve's ability to open at the correct set pressure) or when the internal components of the valve must be isolated from the processing fluid. When selecting the bellows material, consideration of the process material discharging into a common header must be made.

While it is possible for a bellows to fail because of an imperfection in its

Figure 1. Galling on the stem due to an oversized valve or operating the PRV too close to set pressure.

Figure 2. Bellows rupture likely because of excessive backpressure.

fabrication, this is not common. Quality control during assembly of a PRV would prevent a faulty bellows from being installed. Bellows failure can more commonly be attributed to the operating conditions of the PRV or an improperly specified valve.

Listed below are four scenarios that are common reasons a bellows might fail. Each assumes that a thorough review of the engineering sizing and specifications for a given PRV has been completed since these calculations will aid in diagnosing the problem.

EXCESSIVE BACKPRESSURE

One clue that indicates a valve has been exposed to excessive backpressure is when the bellows has been crushed. There are two types of backpressure in process systems: constant and variable. Variable can be further divided into two subgroups: superimposed and built-up.

Built-up backpressure is defined as the pressure at the outlet of the PRV based on the discharge piping configuration, i.e., pressure that occurs only after the valve has opened. For applications where the flow is compressible, built-up backpressure is based on the piping hydraulics at the accumulation pressure using the maximum *actual* capacity for the PRV. All too often engineers perform this calculation at the *required* capacity for the given scenario, not at the device's actual capacity.

When a bellows failure can be attributed to excessive built-up backpressure, the following options will mitigate the problem:

a) Use a bellows with a higher pressure limit.
b) Use a pilot valve balanced against backpressure.

c) Modify the outlet piping by making it larger or shortening the length of pipe, thereby reducing the effects of built-up backpressure.

OVERSIZED VALVE

While most PRVs are protecting equipment for more than one relief event, the size of the valve is based on the scenario requiring the greatest relieving capacity. An example would be when a PRV is sized for both *fire* and *blocked outlet scenarios.* The *fire* sizing requires significantly greater orifice area than the *blocked outlet* sizing. However, since the *blocked outlet* scenario is more common and more likely to occur, then the PRV will be potentially starved for capacity, causing the valve to "chatter" (rapidly opening and closing). Valve chatter, as well as flow instability, could inevitably cause valve damage such as premature fatigue failure of the bellows, as well as galling of guiding surfaces. In our experience, a PRV should not be specified that has an actual orifice area more than 3 to 5 times larger than the required area.

Mitigation strategies for failure in this scenario include:

a) Install multiple PRVs and stagger the set pressure for each of the scenarios. Ensure the small valve is properly sized based on the lowest required capacity relief scenario.
b) Install a modulating pilot-operated relief valve.

HIGH INLET PRESSURE DROP

When the length of pipe leading to the inlet of the PRV causes an excessive pressure drop to a level below its reseat pressure, the valve will begin to oscillate open and closed, potentially leading to chatter. This situation can lead to bellows failure caused by premature fatigue. A bellows with this type of failure will typically have a horizontal crack along its convolutions or a complete fracture.

Mitigation strategies in this case include:

a) Use a pilot valve and remote sense the pressure-pickup point, locating the pickup directly on or closer to the equipment under protection. This will ensure the valve function is based on the pressure at the equipment and not the inlet of the PRV.
b) Install a modulating pilot-operated valve that will open in proportion to the upstream pressure and be less susceptible to chatter from inlet line losses.
c) Lower the set pressure of the PRV, which will reduce the capacity of the PRV. Keep in mind the operating pressure and the typical blow-down may not allow this.
d) Modify the inlet pipe to reduce inlet line pressure losses.
e) Raise the blow-down ring, which lengthens the blow-down time. While it is difficult to quantify the increase in blow-down, in general, raising the ring will reduce chatter.

OPERATING TOO CLOSE TO SET PRESSURE

Operating a system too close to the set pressure of a PRV can cause a valve to be in a state of simmer. When the valve is between simmer and fully open, this can be classified as "flutter." Although this state is neither open nor closed, the disc of the valve will have a very small oscillation and may cause galling in the guiding surfaces, as well as fatigue failure of the bellows. The American Petroleum Institute recommends a 90% operating-to-set pressure ratio.

Recommendations for mitigating this type of failure include:

a) Reduce the operating pressure.
b) Install a pilot-operated relief valve, since it has a much tighter tolerance associated with the differential between the system pressure and the set pressure of the valve.

For the cases described in this article, we assumed that all calculations have been reviewed by a qualified engineer. Prior to implementing any of these recommendations, please consult an applications engineering team to verify acceptable mitigation strategies. **VM**

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