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The Advanced PRV Stability Issue

Methods, Tools, and Resources

Analysis of PRV Stability in Relief Systems: Part V Get a Handle on PRV Stability

By G.A. Melhem, Ph.D., FAIChE

3% Inlet Pressure Loss Does Not Guarantee PRV Stability

There is general agreement that the 3% inlet pressure loss rule (IPL3) is not sufficient to guarantee PRV stability and does not work all the time. This is confirmed by recent findings from actual PRV stability measurements and dynamic modeling [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15].

IPL3 only considers irrecoverable pressure loss. IPL3 assumes that the fluid dynamic pressure is ultimately recovered at the disk surface as the PRV is closing. This recovery of fluid dynamic pressure can keep the PRV open, even at reduced lift. But this is only possible if the inlet line length is less than the "critical length". In other words, the returning pressure wave can keep the PRV open before the PRV reaches full closure only if it can get there before the PRV closes. One might even argue that as long as the "total" wave/dynamic pressure drop in the

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inlet line is less then PRV blowdown, the PRV can operate in a stable manner, even at reduced lift. The pressure wave travel time depends on the speed of sound of the fluid/pipe system and the presence of any acoustic barriers.

This creates a predicament for spring loaded pressure relief valves users and manufacturers worldwide. Although we now know that IPL3 is not sufficient to guarantee PRV stability, new facilities and modifications to existing facilities continue to be designed with IPL3 requirements for stable PRV operation. Despite recent advances and confirmations of how and why different PRV instability mechanisms occur, industry standards and guidelines continue to consider IPL3 as a sufficient requirement for PRV stable operation because of only historical legacy. There are installations where PRVs will be unstable despite an IPL of 3% or less. The opposite is also true where PRVs will be stable with an IPL in excess of 3 %. Simple and dynamic PRV stability analysis can and should be used to confirm that PRV installations are stable, whether they are designed to meet the 3% IPL requirement or other company specific requirements.

This white paper illustrates important concepts associated with PRV stability through the use of one dimensional (1D) fluid dynamics and a single degree of freedom (SDOF) representation of a spring loaded pressure relief valve. SuperChems™ Enterprise, a component of Process Safety Office® is used to perform the detailed 1D flow dynamics throughout the paper. A primary objective of this work is to provide the reader with a clear understanding of how and why PRV instability occurs through animation of key concepts, flow variables, and PRV lift under a variety of scenarios, configurations, and conditions.

This paper is the fifth installment in a series of white papers written by this author on the subject of PRV stability [16, 17, 18, 19, 20].

Additional PRV Stability Analysis is Required

Most operating companies calculate fluid IPL using simplified steady state methods. In many instances such methods only use the momentum equation to establish the flow hydraulics. Additionally, IPL requirements are sometimes evaluated at 16 or 21% overpressure.

First, we should confirm that any identified stability or instability by such simple steady state methods is real. Coupled mass, momentum, energy, PVT, and phase equilibrium equations should be used. This can be important because, for example, the change of density with respect to pressure (temperature and quality also) for steady state flow imputes/implies a specific value of the mixture speed of sound. Systems handing fluids that have high speeds of sound (hydrogen for example), can tolerate longer inlet lines and more pressure drop 1. Where numerous relief scenarios are considered for emergency relief with different fluids, PRV stability has to be evaluated for those scenarios where the speed of sound is different and scenario dependent.

The discharge piping backpressure also impacts PRV stability because it alters the force balance on the PRV disk. Steady state methods assume the discharge piping is initially packed with fluid. As a result higher backpressures are calculated than would actually be developed which reduces PRV disk lift. If the discharge line is initially empty or at a lower pressure before relief starts, it has to be filled as the PRV lifts. Therefore more flow can be achieved and sustained, especially if the PRV can be pushed into full lift before the discharge piping is filled.

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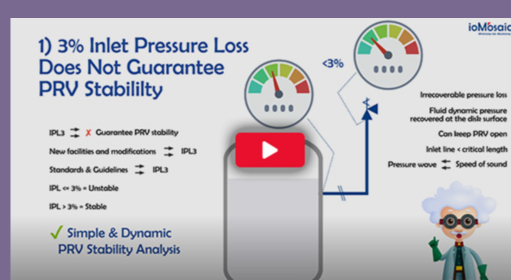

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Learn practical methods for the identification and evaluation of high risk relief systems installations where potential PRV instability requires evaluation by engineering analysis. The workshop will review advanced developments in PRV stability and a worked example on how to evaluate and perform an engineering analysis when PRV instability is suspected will be presented. Facilitated and led by Georges A. Melhem, Ph.D., FAIChE.

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