Relief Valve Opening Characteristic Curves Now Supported in the Symmetry* Process Software Platform

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At first glance, a relief valve might seem like a simple device - it opens when the pressure is too high, and it closes when the pressure is too low. Sure, they come in different sizes and there are different standards that must be followed; there are confusing terms like set pressure, overpressure, accumulation, and MAWP. Well, there is one more piece of complexity: The relief valve isn't just open or closed - it can also be partially open and exhibit a modulating performance!

Traditional steady-state relief scenario analysis makes a key assumption of complete valve opening at required or rated conditions. While this is a conservative assumption for sizing a flare network, it is an optimistic assumption for considering the maximum overpressure which may be reached in a vessel. It will take some time for pressure to build in a vessel to the relief valve's complete opening, which prolongs the duration of the relieving. This complicating dimension – time – comes into play to determine when the flow rate through the network is the highest – known as peak conditions. This is especially important when a flare system is designed for staggered reliving. It is also important for modeling the dynamics of how a process becomes unstable and how recovers from an overpressure scenario.

While all relief valves are designed to open at the set pressure point, how the valve performs depends on the type of the valve. To accurately model what happens when a valve relieves, it is important to know what the valve opening and closing behavior looks like. The curve below is for a liquid service Spring-Loaded Conventional relief valve. The seven stages of opening and closing are as follows. Not every valve type goes through each type.

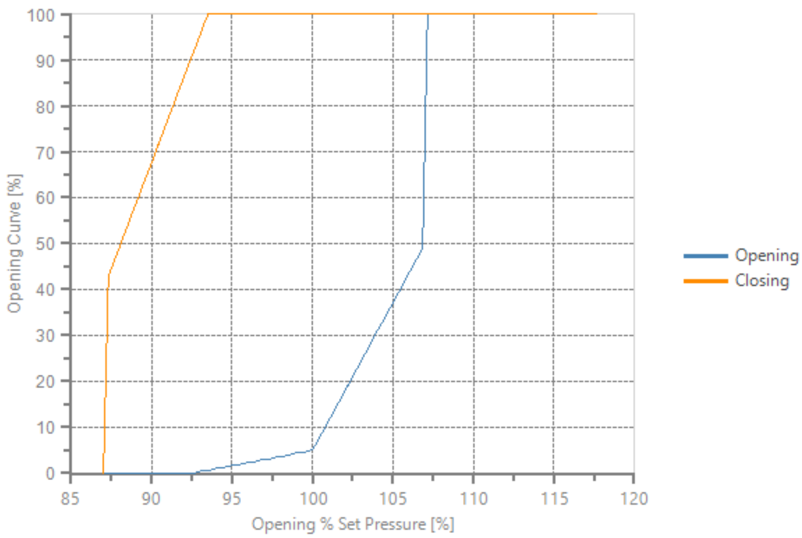


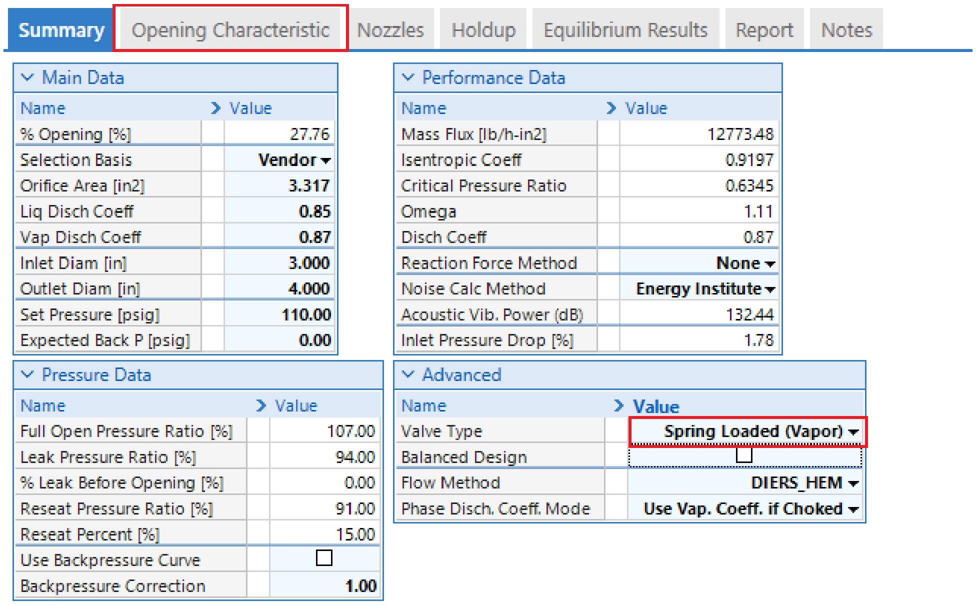
Figure 1. Liquid Spring Loaded relief valve opening and closing stages

- **Fully Closed**
- **Simmering** - The relief valve begins to leak a little (at the set pressure conditions); the valve is open only a few percent. This opening is modeled as linear with increased pressure.
- **Proportional Opening** – With increased pressure, the valve opens proportionally more.
- **Pop** – The valve pops open. This is the ***Set Pressure*** in this plot but in other types the Set Pressure occurs during the Proportional Opening. This is the largest increase in flow area of the valve. Note that as pressure in the relieving vessel increases further, the flow rate through the valve may still increase if density of the fluid increases.
- **Fully Open** – A valve can't really open more than 100% (at the maximum relieving pressure conditions), but they often do not reseat on the same curve that they open. For this type, the valve stays open until the pressure has dropped to 93.5% of its set pressure point. The valve should not experience a pressure higher than its ***Relieving Pressure***, or equipment failure is likely. Peak conditions normally occur when the valve is fully open.
- **Proportionally Closing** – As pressure is decreased further, the valve starts to close, linearly with the decrease of pressure.
- **Snap Closed** – The valve snaps shut, reseating itself. This is known as the ***Blowdown***. The difference between set pressure and closing pressure is blowdown and can be adjusted.

In Symmetry, this feature is available with the Dynamics engine in the Summary tab. The Valve Type controls the opening characteristic of the valve. The exact points that define the opening and closing curve are shown for clarity.

The data is based on API 520 Part 1 9th Edition. A Custom mode is available if it is needed to use different or proprietary parameters.

Included in this article is a description of the curves of each type of relief valve implemented, and a case study showing how the opening characteristics can modify the performance of the valve.



Summary | Opening Characteristic | Nozzles | Holdup | Equilibrium Results | Report | Notes

Main Data

Name	Value
% Opening [%]	27.76
Selection Basis	Vendor
Orifice Area [in2]	3.317
Liq Disch Coeff	0.85
Vap Disch Coeff	0.87
Inlet Diam [in]	3.000
Outlet Diam [in]	4.000
Set Pressure [psig]	110.00
Expected Back P [psig]	0.00

Performance Data

Name	Value
Mass Flux [lb/h-in2]	12773.48
Isentropic Coeff	0.9197
Critical Pressure Ratio	0.6345
Omega	1.11
Disch Coeff	0.87
Reaction Force Method	None
Noise Calc Method	Energy Institute
Acoustic Vib. Power (dB)	132.44
Inlet Pressure Drop [%]	1.78

Pressure Data

Name	Value
Full Open Pressure Ratio [%]	107.00
Leak Pressure Ratio [%]	94.00
% Leak Before Opening [%]	0.00
Reseat Pressure Ratio [%]	91.00
Reseat Percent [%]	15.00
Use Backpressure Curve	☐
Backpressure Correction	1.00

Advanced

Name	Value
Valve Type	Spring Loaded (Vapor)
Balanced Design	☐
Flow Method	DIERS_HEM
Phase Disch. Coeff. Mode	Use Vap. Coeff. if Choked

Figure 2. Relief valve characteristic curve feature in Symmetry

Spring Loaded (Vapor)

A spring-loaded conventional relief valve in vapor service opens rapidly with pop action. They are used where backpressure should not build up in the system. Where the backpressure is too high a Balanced relief valve should be considered.

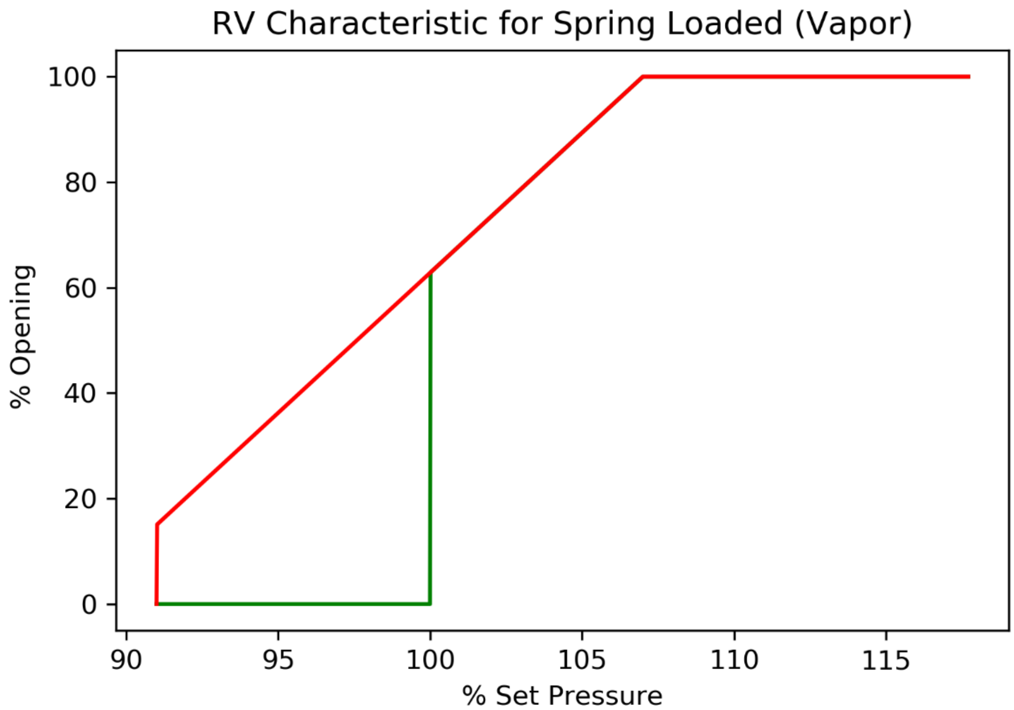


Figure 3. Characteristic curve for Spring Loaded relief valve opening

Fully Closed – Up to 100 % of Set Pressure
Pop – At 100% of Set Pressure and is maintained until the overpressure % is reached
Fully Open – 107% of Set Pressure onwards
Proportionally Closing – Until 91% of Set Pressure
Snap Closed – At 91% of Set Pressure

Spring Loaded (Liquid)

A spring-loaded conventional relief valve has a complicated opening sequence; there is some leakage, followed by proportional opening, and eventually a rapid opening with pop action. They are used where backpressure should not build up in the system. Where the backpressure is too high a Balanced relief valve should be considered.

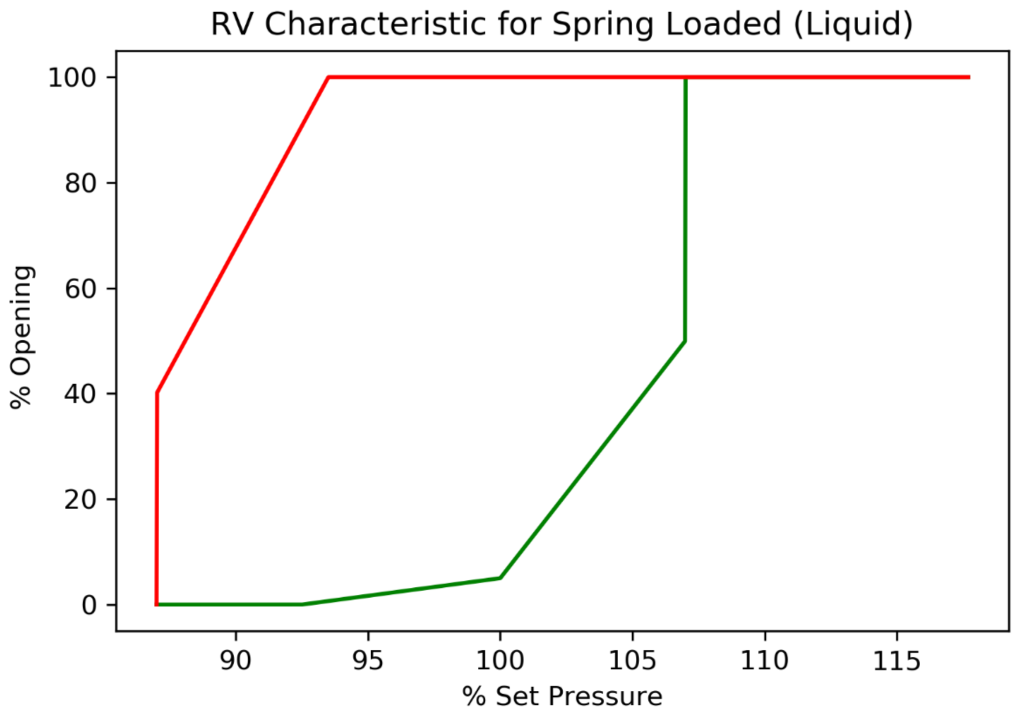


Figure 4. Characteristic curve for Spring Loaded (liquid service) relief valve opening

Fully Closed – Up to 92.5% of Set Pressure
Simmering – Leak Pressure Ratio of 92.5% with % Leak Before Opening of 5%
Proportional Opening – From 5% leak to 50% open
Pop – At 107% of Set Pressure and is maintained until the overpressure % is reached
Fully Open – 107% of Set Pressure onwards and until the pressure falls to 93.5% of Set Pressure
Proportionally Closing – 93.5% of Set Pressure to 87% Set Pressure
Snap Closed – At 87% of Set Pressure

Pop Action Pilot

This valve type opens rapidly and completely at set pressure without overpressure, reseating completely once the pressure has dropped to the operating level. This performance provides extremely high opening and closing forces on the main valve seat. Typically, this opening characteristic is not used for liquid services to avoid valve instability.

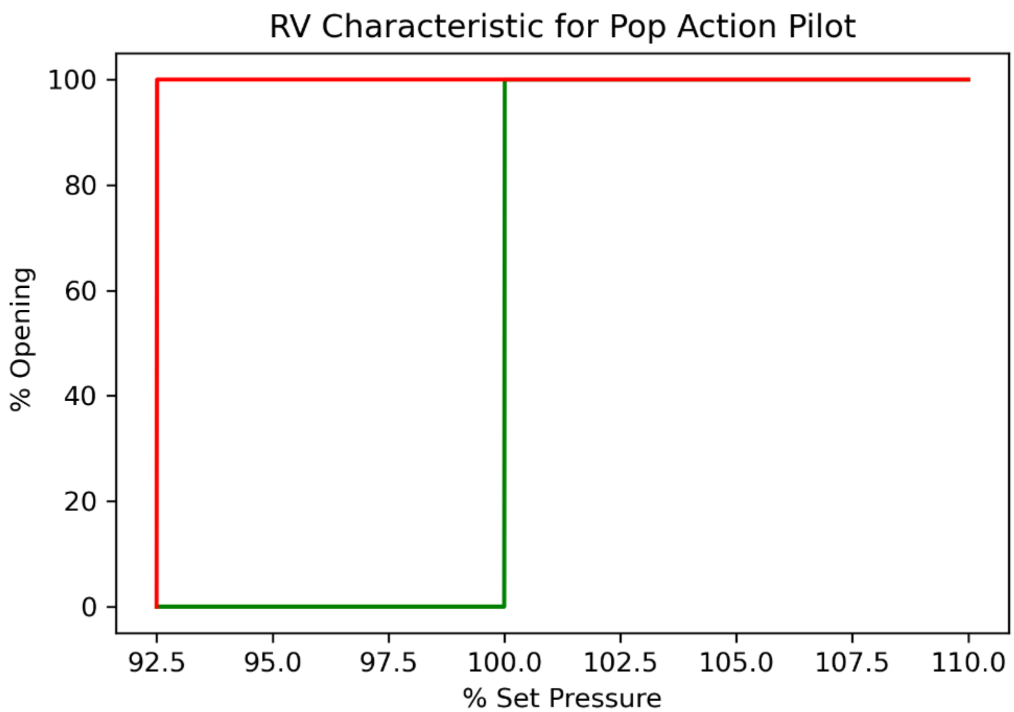


Figure 5. Characteristic curve for pop action relief valve opening

Fully Closed – Up to 100% of Set Pressure
Pop – At 100% of Set Pressure
Fully Open – From 100% of Set Pressure to 92.5% of Set Pressure
Snap Closed – At 92.5% of Set Pressure

Modulating Action Pilot

The modulating action pilot opens only enough to satisfy the required relieving capacity (at peak conditions) and to prevent the pressure from exceeding the allowable accumulation therefore excellent at handling small overpressure fluctuations. Since the modulating pilot valve only releases the required relieving rate the calculation of the backpressure may be based on the peak rate instead of the rated relieving capacity of the valve; can be used for vapor, liquid and (highly recommended for) two-phase services. Also, can reduce interaction with other pressure control equipment in the system during an overpressure scenario, among several other advantages.

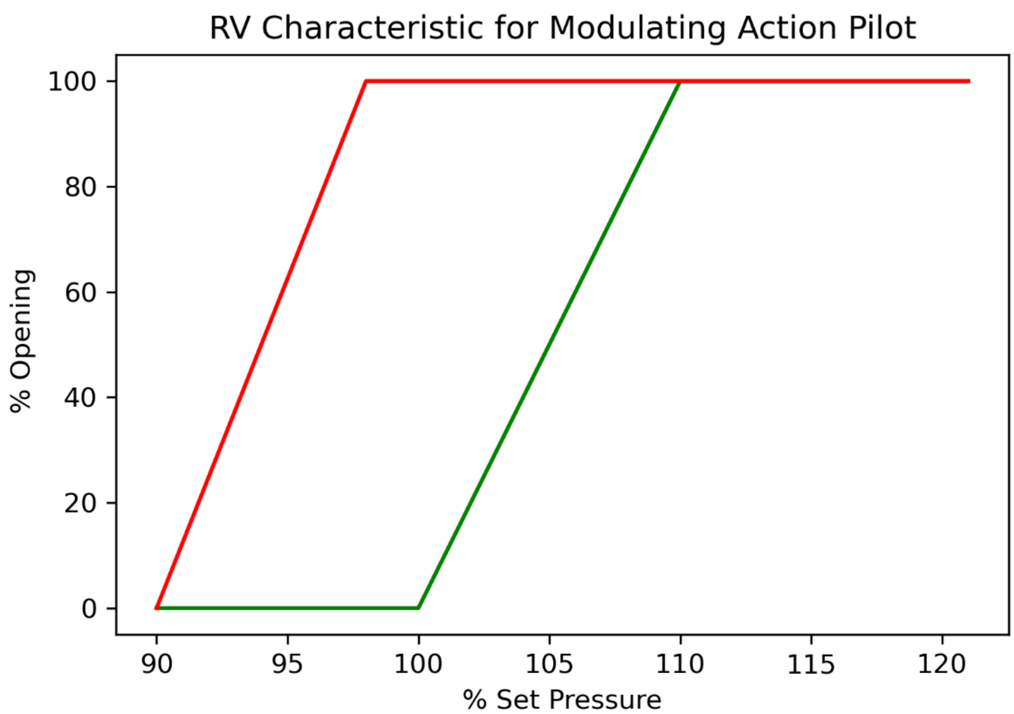


Figure 6. Characteristic curve for Modulating Action Pilot relief valve opening

Fully Closed – Up to 100% of Set Pressure
Proportional Opening – From 100% of Set Pressure to 110% of Set Pressure (editable)
Fully Open – From 110% of Set Pressure to 98% of Set Pressure
Proportionally Closing – From 98% of Set Pressure to 90% of Set Pressure (editable)

ASME VIII

ASME Section VIII Division I Relief Valves are used for ASME Section VIII Division I certified pressure vessels. They are designed to open and close quickly, providing a tight and fast response. They may have a small amount of leak before the valve pops open.

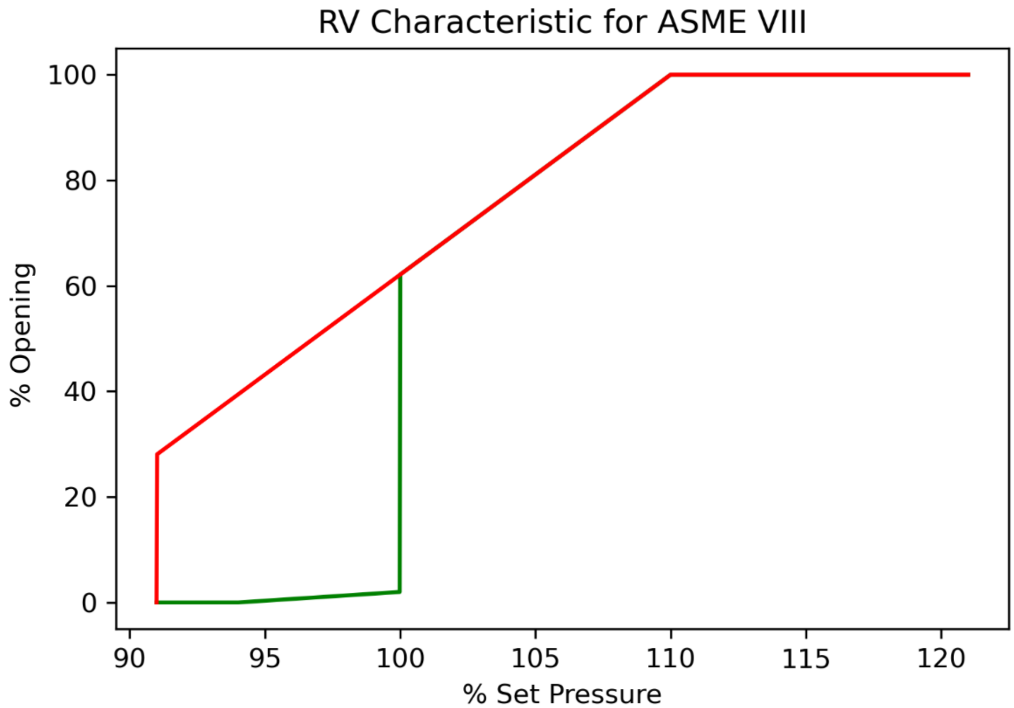


Figure 7. Characteristic curve for ASME Section VIII relief valve opening

Fully Closed – Up to 94% of Set Pressure
Simmering – Leak Pressure Ratio of 94% with % Leak Before Opening of 2%
Pop – At 100% of Set Pressure
Proportional Opening – From 100% of Set Pressure to 110% of Set Pressure
Fully Open – 110% of Set Pressure onwards
Proportionally Closing –110% of Set Pressure to 91% of Set Pressure
Snap Closed – At 91% of Set Pressure

ASME I

ASME Section I Relief Valves are used for ASME Section I certified unfired steam boilers. They are designed to open and close very quickly, providing a tight and fast response.

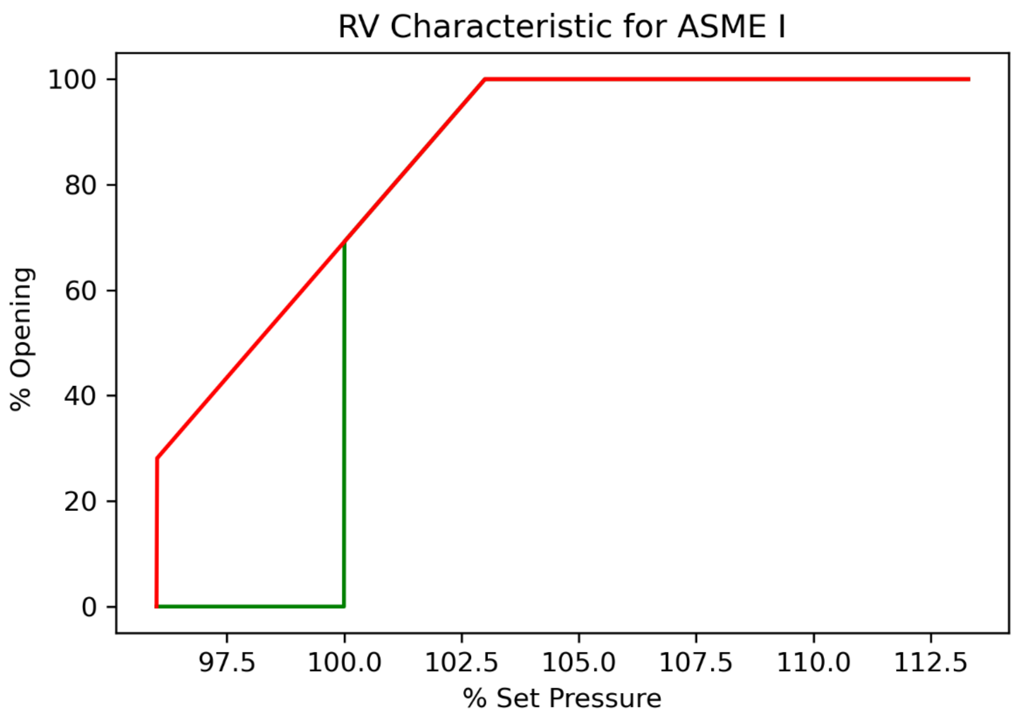


Figure 8. Characteristic curve for ASME Section I relief valve opening

Fully Closed – Up to 100% of Set Pressure
Proportional Opening – From 100% of Set Pressure to 103% of Set Pressure
Pop – At 100% of Set Pressure
Fully Open – 103% of Set Pressure onwards
Proportionally Closing – 103% of Set Pressure to 96% of Set Pressure
Snap Closed – At 96% of Set Pressure

Proportional

The proportional curve does not represent a specific design of a relief valve. Instead, this method offers a simplified opening curve for users.

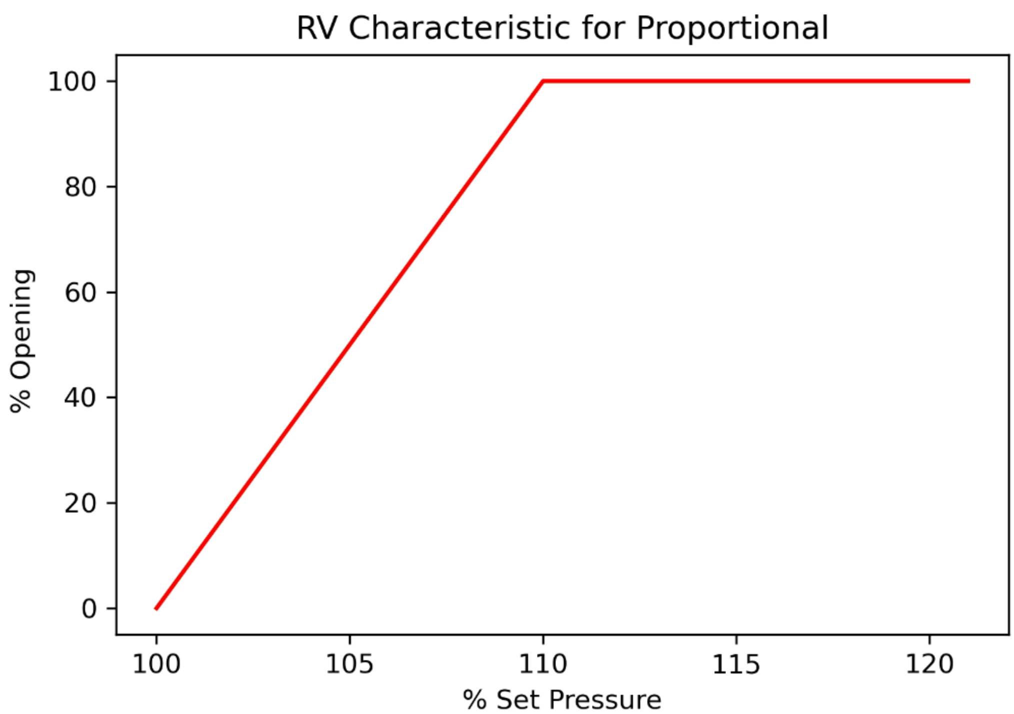


Figure 9. Characteristic curve for proportional relief valve opening

Fully Closed - Up to 100% of Set Pressure
Proportional Opening - 100% of Set Pressure to 110% of Set Pressure (editable)
Fully Open - 110% of Set Pressure and onwards
Proportionally Closing - 110% if Set Pressure to 100% of Set Pressure (editable)

Sample Case

The case Depressuring Example 4-2 from the Depressuring tutorial in the manual was used to show the impact of relief valve type choice. The case is composed of a vessel and a relief valve.

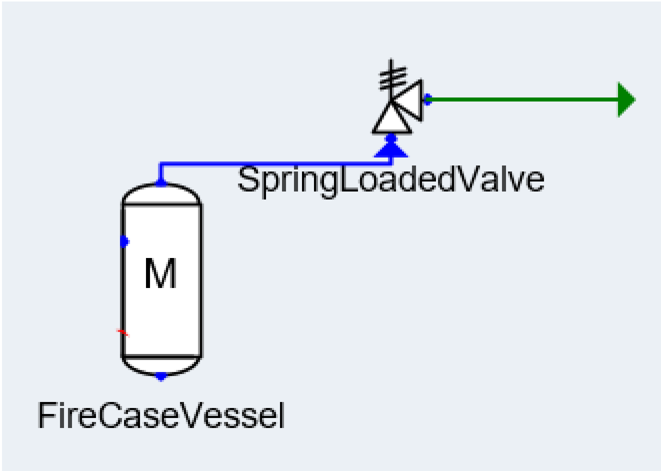


Figure 10. Sample case PFD

For the valve types ASME Section VIII Division I, Spring Loaded (liquid service), Spring Loaded (Vapor service), Pop Action Pilot, and Modulating Action Pilot, the fire case was modeled and the vessel pressures and relief valve opening recorded. As can be shown in the plots below, the maximum pressure experienced by the vessel and the degree of disturbance to the process can vary widely.

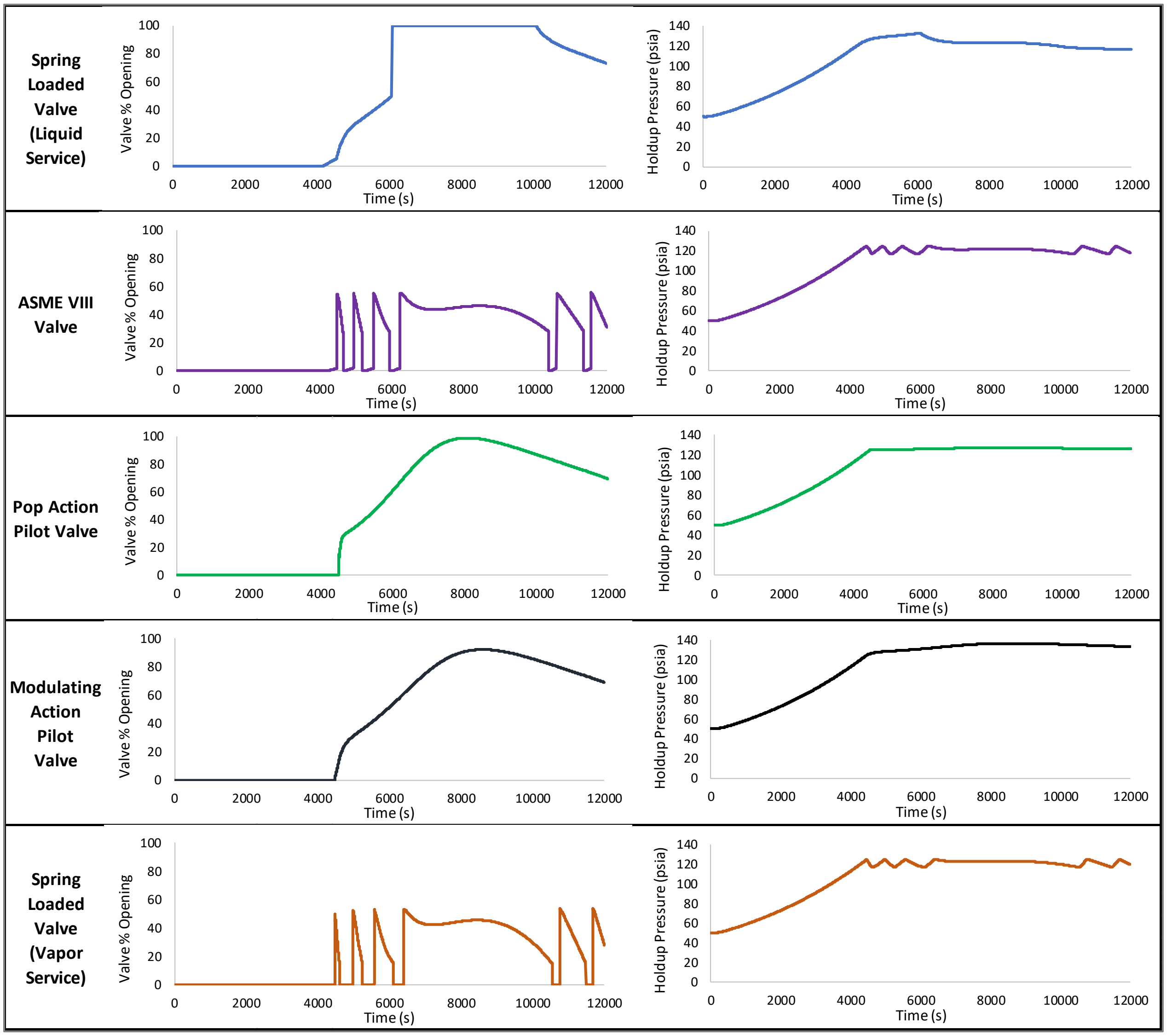


Figure 11. Relief Valve % Opening and vessel pressure curves for various valve types in sample case

Conclusion

By extending Symmetry's pressure relief valve model to accurately predict the performance of relief valves based on the different opening characteristics, Symmetry can now better model the real dynamics of different overpressure scenarios on process equipment. This dynamic analysis can provide a complete idea of what happens when a process becomes unstable and may help to find the main root cause of the operating failure. It can also reduce interaction between the PRV with other pressure control equipment in the system during an upset condition, reduce unwanted atmospheric emissions (optimizing the OPEX), properly calculate the relieving conditions and allow accuracy in sizing the PRV.

To learn more about the Symmetry Process Software Platform please contact your local Schlumberger office.

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