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Specifying Control Valves for Severe Service

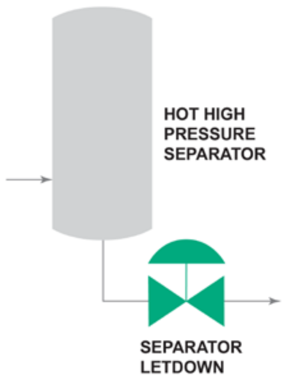
By Justin Goodwin, Emerson Automation Solutions

The best severe service application solutions can be found with research, process knowledge, and SME advice.

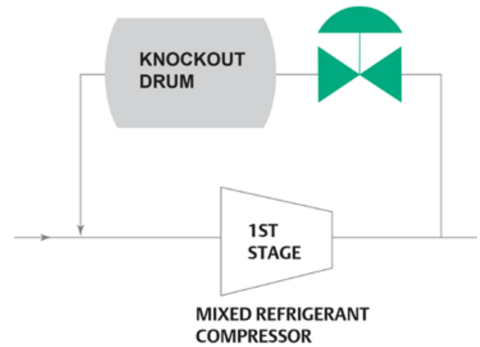
Severe service applications can be the bane of an automation engineer's existence because they often have higher than necessary maintenance and repair costs. The process or application is particularly punishing and almost always critical to plant operation, so getting it right is paramount. This article demystifies the severe service control valve selection process and provides advice to help end users make the right choice.

What severe service is

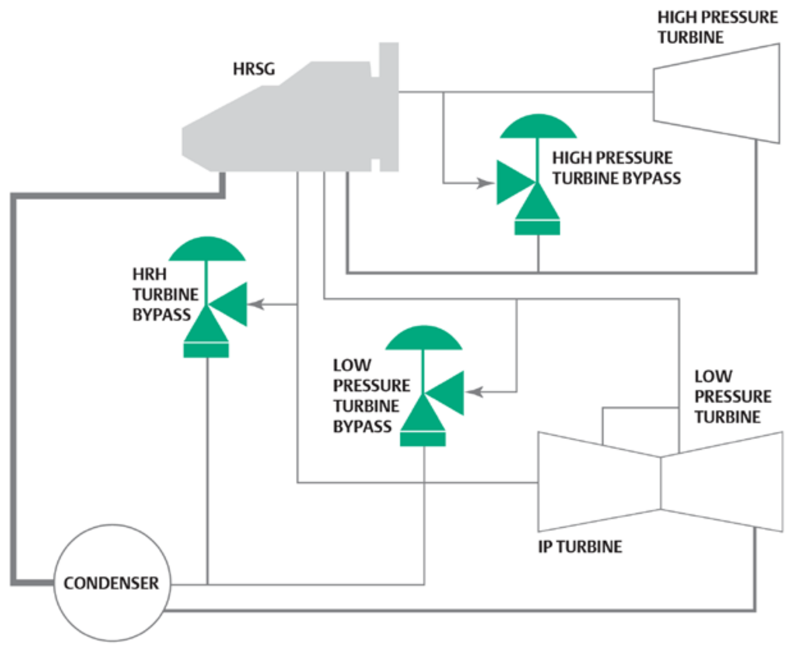
Severe service can mean different things to different people, but there are common themes to these types of applications. They usually involve high pressure drops that generate high noise and vibration in vapor service; flashing, cavitation, or outgassing in liquid service can occur as well. Temperature extremes, mixes of vapors, liquids, and solids, which tend to plug passages and erode internal components, and corrosion might also be encountered.



Refinery hot high-pressure separators



Compressor anti-surge valves



Turbine bypass valves

Figure 1. Three difficult control valve applications include refinery hot high-pressure separators (top left), compressor anti-surge valves (top right), and turbine bypass valves (right).

While this article discusses the severe service valve selection process in general, it focuses on three applications that most engineers would designate as severe service (figure 1). These include:

- Hot high-pressure separator (HHPS) letdown valves in a refinery
- Compressor anti-surge valves
- Turbine bypass valves

HHPS valves must endure very high pressure drops and high temperatures, and often involve a corrosive liquid entrained with solids, flashing, and outgassing through the valve. Anti-surge valves can go for months without opening, then suddenly be required to pass large flows at very high pressure drops with tight control. Turbine bypass valves usually face very high pressure drops, high steam flow rates, and large temperature swings.

Not one of these applications is easy, but each has solutions that can minimize maintenance, repair, and operational costs by following a step-by-step methodology.

Step 1: Evaluate the process

The severe service selection process starts with a solid understanding of the application, and many poor control valve choices can be attributed to a failure to perform this critical step. Often, the user has the normal process conditions well defined, with a solid understanding of the inlet and exit pressures, process temperatures, and process media characteristics.

However, users often get tripped up by the unexpected process conditions. What happens during upset conditions or when the plant is starting up? Must the valve handle markedly different flows or pressure drops at this time? Will temperatures range higher or lower than expected?

Changes in the process fluid itself are another major source of problems. During abnormal situations, the valve may need to pass impurities, or it may be prone to flashing or more outgassing than normal. Any of these situations could destroy a valve quickly if it is not designed appropriately.

Step 2: Understand the valve challenges

With a sound knowledge of the range of process conditions the valve will face, the user now needs to evaluate what impacts those conditions have on the valve. Following is a partial list of potential valve challenges:

- High pressure drop, vapor service: The valve is subjected to very high velocities, high noise levels, and high vibration. Sound levels of more than 110 to 115 dB will damage the valve.
- High pressure drop, liquid service: In this case, the liquid tends to flash, cavitate, or outgas. Eventual valve damage may be unavoidable in some cases, but better designs can dramatically extend the service life.
- Cryogenic temperatures: These temperatures can both embrittle metals and make valve sealing difficult, so special materials for construction and body designs are necessary.
- Very high temperatures: High temperatures require specialized alloys to maintain strength, while thermal expansion and thermal gradients can cause valve components to bind and stick. Packing designs also must be carefully tailored to suit the application.
- Two-phase flow: Liquid/vapor combinations subject the valve to cavitation and choked flow.
- Solids/particulates: Entrained particles in either liquid or vapor commonly cause issues such as erosion and plugging.
- Corrosion: Corrosion comes in many forms, and each must be handled differently. Identifying the method of attack can be difficult because there are often multiple types of corrosion occurring simultaneously.

Most severe service applications involve some combination of these challenges, and all must be accounted for during valve selection.

Step 3: Consider solution options

Once a user is armed with a complete understanding of both normal and abnormal process conditions and has identified the challenges those conditions pose to the valve, the correct valve can be chosen. The user is typically faced with a dizzying array of options, but only a few of them will perform well in their specific application.

So how to choose? Some vendors offer customized solutions, which may well provide superior performance, but one should evaluate those options carefully. Users should look for a valve partner with an established track record of proven designs, and a history of supporting its products after the sale with engineering support and local service.

A starting point is evaluating the body design itself. It should be appropriate for the application, and some body styles have distinct advantages. For example, angle valves (figure 2) are often the best choice for two-phase liquid cavitating/outgassing service because this design can minimize damage to the seat and valve body as the liquid/vapor combination exits the valve. Angle valves also are commonly used in turbine bypass applications because the design allows compact incorporation of desuperheating water sprays for efficient steam temperature control.

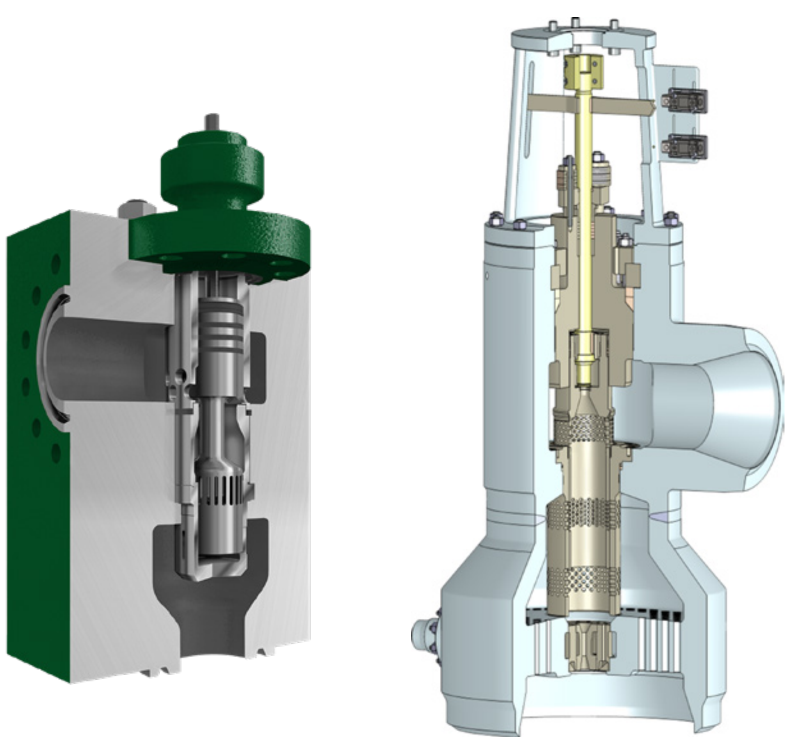


Figure 2. Angle-body style valves have inherent advantages for some severe service applications. The dirty service trim valve (left) handles outgassing liquids with entrained solids common in HHPS applications. The turbine bypass valve (right) has an integrated desuperheater to control steam temperatures.

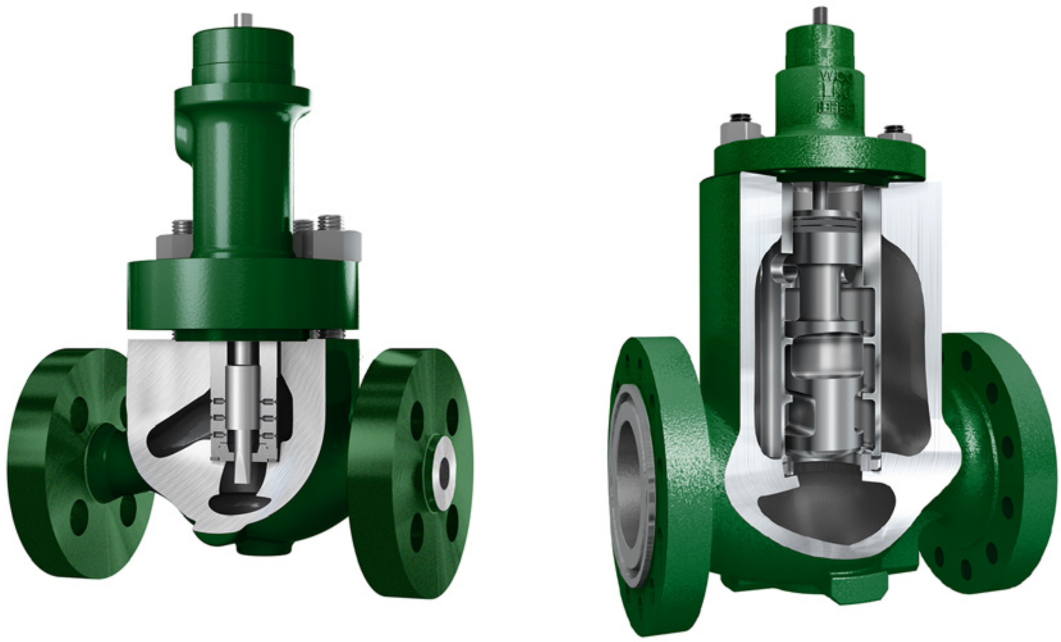


Figure 3. Anti-cavitation trims are also available in globe valves, as well as angle valves. Simpler designs (the trim on the left) use small holes to absorb multiple pressure drops and direct cavitation away from the seat and body. More complex designs (right) have larger openings to handle entrained solids.

In some cases, the piping configuration does not easily accommodate angle-style valves, so globe-body styles are a better option. Fortunately, there are anti-cavitation trim designs (figure 3) suited for these applications as well.

Valves in high-pressure-drop vapor applications, such as compressor anti-surge valves, are designed to handle high-velocity vapor flows, while reducing the noise and vibration that would otherwise result. Low-noise trims (figure 4) incorporate slots or holes to separate the flow into smaller parallel paths, and they may also use a series of pressure stages to manage pressure drops and reduce sound power level.

Figure 4. Low-noise trims vary from single-stage trim (left) to multipath (middle) to multipath and multistage (right). Higher pressure drops and vapor velocities typically require these types of complex trim designs.

Figure 5. Additive manufacturing has made a whole new generation of innovative designs possible. Additively manufactured noise trim (left) controls valve noise with increased flow capacity, and the anti-cavitation trim (right) allows rotary valves to be installed and perform well in cavitating applications.

Low-noise trims reduce noise and shift noise frequency into ranges that are less detectable to the human ear. As valve pressure drops increase, low-noise trim designs tend to get more complex because multiple stages are required to achieve the required noise reduction.

Anti-surge valves pair low noise trims with specialized high-capacity, intelligent digital valve positioners to achieve the extremely fast response required by this application. These valves also can incorporate engineered deadband to allow partial stroke testing without passing significant flow, as well as diagnostic capabilities in the digital positioner to ensure reliability.

Additive manufacturing, in this case 3-D metal printing, has made a host of new designs possible that were either not economical or feasible to manufacture using conventional techniques (figure 5). These types of designs can incorporate high-strength alloys in novel configurations to create new solutions for a variety of applications.

Step 4: Use suitable materials

Material selection is critical for success in severe service applications. Trim and body components often are subjected to damage from cavitation, flashing, and erosion. Packing materials are subjected to high temperatures and pressures, and all wetted parts are subjected to corrosive attack. A severe service valve incorporates a variety of materials for different components to best address the conditions each is expected to encounter.

Fortunately, additive manufacturing has improved this area of valve design as well. These manufacturing techniques allow very high-strength alloys to be used where they could not be employed before, resulting in longer service life and reduced maintenance.

Step 5: Seek advice

It should be clear from this article that the number of valve component options can be overwhelming. When faced with evaluating the best solution, it is advisable that the user seek help and advice. Corporate engineering may have some suggestions, as may sister plants that encounter similar applications. Peer recommendations from end users at other companies can be helpful, and these types of discussions are common at International Society of Automation (ISA) meetings. It also may be wise to engage your control valve partner, who will typically have a good understanding of the myriad alternatives and can help users make informed decisions.

Severe service applications are not insurmountable problems, but considerable effort is required to thoroughly research them before the best solution can be found. Taking the time to fully understand the details and to seek guidance from knowledgeable peers and partners can go a long way to ensuring a wise and successful decision.

All figures courtesy of Emerson.

ABOUT THE AUTHOR

Justin Goodwin is the director of the steam conditioning group at Emerson. He has a BS in mechanical engineering from Iowa State University and a BA in applied math from Grand View University. Goodwin has been responsible for the design and technical support of steam conditioning and desuperheating equipment since 2005. Today, he provides direction, technical oversight, and training for Emerson's global steam conditioning business.