Specifying control valves for severe-service applications

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If you use the wrong valves in severe-service applications, you could face costly premature failures.

A large number of the process control valves used in fossil-fired power plants must operate under severe-services conditions—that is, in high-pressure and/or high-temperature applications. When specifying valves for such applications, extreme care must be taken to avoid costly premature failures (Fig. 1).

The following discusses the stringent requirements that valves must meet to safety operate and deliver long-term performance under severe-service conditions. Requirements are examined for both generic and specific applications.

Generic requirements: Liquid

For valves used in liquid service, the liquid velocity through the valve inlet and outlet shouldn't exceed 60 ft/s (18 m/s). By keeping the fluid velocities at or below this level, you'll achieve greater control over the fluid. You'll also minimize piping and valve vibrations, along with early erosion of the valve internals.

The liquid velocity exiting the trim shouldn't exceed 100 ft/s (30 m/s). The trim is defined as the parts internal to the valve in which the pressure drop takes place. Higher velocities will result in shortened trim life. In addition, you should make sure the valve has a sufficient number of discrete pressure drop stages to avoid cavitation.

To minimize the potential for flow-induced vibration and the entrapment of pipeline trash between the closure member and the valve trim, specify the flow direction as flow-to-close (over-the-seat).

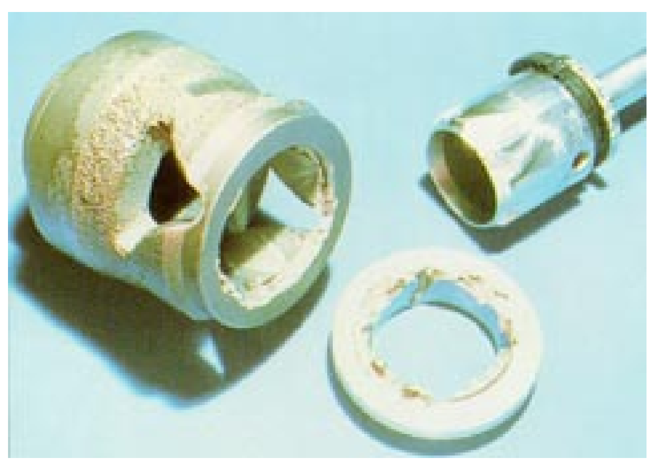

FIG. 1: Improperly specified valves can lead to premature valve failure. Being aware of the many different valve requirements can help you avoid the type of valve damage shown here.

Generic requirements: Gas and steam

For valves used in gas and steam applications, the fluid velocity exiting the trim should result in a velocity head that's less than 70 psi (480 kPa). You can calculate this from the trim exit velocity (v) and the outlet fluid density (rho) using the following equation:

$$P_{vh} = \text{rho}\ (v^2/2)$$

Higher velocities will result in vibration, noise, erosion, and premature failure.

Also, the noise measured at a location 3 feet (1 m) downstream from the valve and

Table 1: Leakage rating classes and seat loading

Class	Maximum Seat Leakage	Suggested Seat Loading
ANSI/FCI 70-2, CL IV	0.01% of rated valve capacity	7 kg/mm (400 lb/in.) of seating circumference.
ANSI/FCI 70-2, CL V	5×10^{-4} ml/min/in. of orifice diameter/psi differential	13 kg/mm (700 lb/in.) of seating circumference.
ANSI/FCI 70-2, CL V	Bubble tight	2 kg/mm (100 lb/in.) of seating circumference assuming resilient seating.
MSS-SP61	10 ml/hr/in. of nominal valve size	18 kg/mm (1000 lb/in.) for shut-off pressures less than 21 MPa (3000 psi). 27 kg/mm (1500 lb/in.) for greater shut-off pressures.

FIG. 2: This valve features a valve him of the quick-change type, which makes it easy to take apart and reassemble.

three feet away from the pipe (without thermal insulation) shouldn't exceed 85 dBa. In addition to being an environmental pollutant, noise is a symptom of high energy vibration, which can shorten valve life and damage downstream piping.

Finally, to avoid erosion by high velocity moisture content, make sure enough discrete pressure drop stages are provided to ensure isenthalpic pressure drop. This, in turn, ensures smooth temperature profiles of the fluid as it passes through the valve. Also, it keeps the fluid temperature above it's dewpoint—i.e., the point at which liquids will fall out of the fluid and become erosive.

For both liquid and gas services, make sure all velocities throughout the valve are met without the use of downstream orifices, mufflers, diffusers, or other fixed flow devices, since these devices are not effective at low-flow conditions.

Other generic requirements

In some cases, it's possible for the valve plug to be bounced back-and-forth at high rates within the cage. This can cause the plug to stick or vibrate and, in extreme cases, lead to stem breakage. To prevent the plug from sticking or vibrating, there should be a means to assure equal pressurization around it.

You also must be aware of the service-condition flow rates when specifying and designing control valves for severe-service applications. These valves should have an inherent rangeability to handle both low and high flow rates. Typical rangeability is 30 to 1, although some applications require greater than 100 to 1. This ratio represents the maximum vs the minimum flow. For example, if a valve can handle a flow of 30 gpm. It should be able to control flows down to 1 gpm. Must remember: some valves on the market can only control a very narrow range of flow rates.

An option used to meet wide ranging flow requirements is to install two or more valves in parallel—a larger valve to handle the higher flow rates, and smaller valves to handle the lower. However, you can eliminate the need for multiple valves by selecting a properly designed valve with good rangeability and excellent control. Often, the proper valve will be a custom design rather than an off-the-shelf model. For ease of maintenance, look for valve trims that are of the quick-change type, so they can be easily rebuilt (Fig. 2). In these types, the parts often are held into position by the bonnet bolting, with no internal components, such as seat rings, screwed or welded into the valve bodies or bonnets.

Tight shutoff is another key requirement—one that can improve plant efficiency and increase valve life. A constantly leaking valve causes energy from the system to be lost, increasing plant costs. Excessive leakage is a sign that there are uncontrolled velocities flowing through the valve. In liquid service, a high velocity leak will cut through the seat, causing wire drawing. In gas or steam applications, leaking fluid will damage the seat. Even a minute leak can quickly grow into a large one, eventually affecting the valve's internal parts and performance.

The best way to assure that the valve provides the required shutoff is to specify the amount of force for seat loading. Seat loading is usually expressed as force per linear inch (or mm) of seat joint circumference. As shown in Figure 3, leakages reduced or eliminated with seat loading.

Table 1 (p 100) shows four different leakage rating classes with their suggested seat loading. New valves will meet these requirements at the factory. However, once a valve begins operating in the field, it often won't shut off as well as it did in the factory, when all of the parts were new.

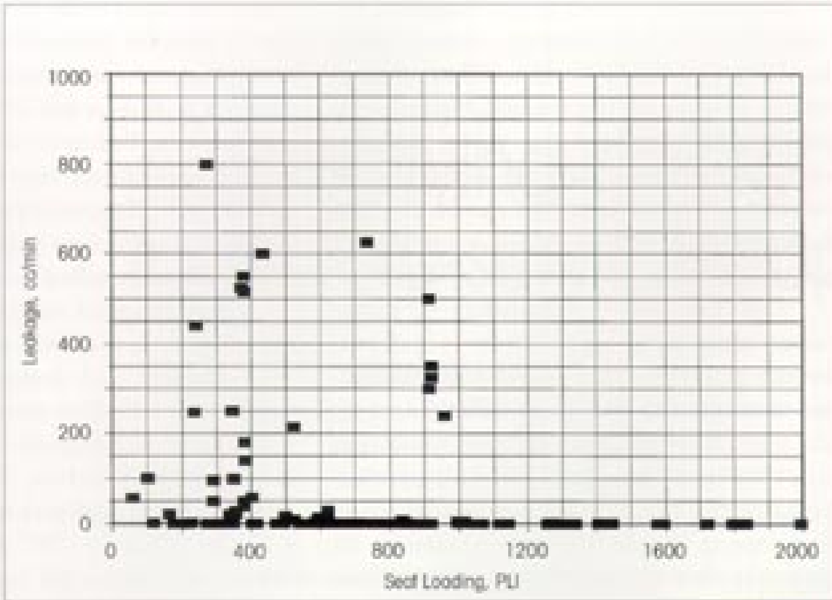

FIG 3: Tight shutoff is an important requirement for increased valve life. This graph shows that higher seat loading reduces or eliminates seat leakage that can erode a valves performance.

The first rating class listed in table 1 state that there should be 400 lbf/in (7kg.mm) of actuator force for each inch of the seat circumference. For example, for a valve with a one inch seat (25.4 mm), the circumference would be about 3.14 in. (80 mm). If you multiply the seat circumference by the actuator force you find that slightly more than 1,200 lb (560 kg) of force pushing down on the plug are required to get the proper shutoff.

If you follow these guidelines for applying force to the seat of the valve, you'll be assured that seat leakage requirements are met in field conditions. To ensure long shut-off life, insist on a guarantee that the suggested seat loading will be provided by the actuator. Choosing the proper actuator, including velocity-controlled internals, ensures the long-term survival of the valve (Fig. 4).

Specific requirements

In addition to the generic requirements for severe-service control valves, specific requirements are often associated with certain applications. When specifying control valves for these, more stringent criteria, beyond the minimum specifications stated above may be required. For example, when determining liquid exit velocities, if the conditions of the application lead to a prediction of cavitation, lower the liquid velocity-even though the valve meets the specified velocity requirements.

Let's look at a few of the applications that typically call for more stringent selection criteria:

• ***Recirculation or leakoff valves***—To eliminate cavitation damage in recirculation valves, which include booster feed pump recirculation and main feed pump recirculation valves, make sure the liquid velocity exiting the cage doesn't exceed 75 ft/s (23 m/s).

To assure minimum fluid velocities during the pressure reduction, specify at least 12 pressure drop stages. For straight through globe configurations, the valve body material should be A21 7-C5.

FIG 4: Choosing the proper actuator and including velocity-controlled internals, assures the long-term survival of the valve.

On modulating valves, provide a relay to apply full actuator thrust when the control signal calls for the valve to operate at less than 5% of the valve stroke. This protects against positioner calibration drift, which may leave the valve closed without proper actuator loading. With proper design, the valve and actuator should provide continual operation for a period of 24 months, without requiring disassembly for maintenance. These valves require MSS-SP61 seat-leakage ratings.

• ***High-pressure regulation valves***—With these valves, which include start-up and main feedwater regulator valves, make sure the liquid velocity exiting the cage doesn't exceed 100 ft/s (30 m/s).

Referencing ISA S75.05 1983 Standard for Control Valve Terminology, these valves should have a linear installed flow characteristic. This means the relationship between the flow rate through the valve, and the travel of the closure member as the closure member is moved from the closed position to rated-travel, will be linear, even though the pressure drop across the valve varies.

The inherent rangeability of these valves must be at least 100 to 1, and you should give favorable selection consideration to single valve bodies meeting startup and main-flow conditions. Their resolution must be less than 1.5% of full stroke. Actuator resolution is the smallest discrete movement made by the actuator in response to a signal change. The valves should meet ANSI/FCI 70-2, Class IV seat leakage requirements.

• *Low-pressure regulation valves*— With low- pressure regulation valves, including deaerator level control and condensate flow control valves, the liquid velocity exiting the cage shouldn't exceed 100 ft/s (30 m/s). The inherent rangeability of the valve should be at least 100 to 1. However, give favorable selection and design consideration to single valve-bodies meeting start-up and main-flow conditions.

It is imperative that the actuator resolution be 1.5% of full stroke or better. These valves also require a seat leakage rating of ANSI FCI 70-2, Class IV or better.

• S*tart-up bypass valves*—These valves include Babcock & Wilcox 202 primary superheater bypass valves, Babcock & Wilcox 207 secondary superheater bypass valves. Combustion Engineering boiler extraction valves and boiler extraction bypass valves, and Foster Wheeler P valves. With these, the liquid velocity exiting the cage shouldn't exceed 100 ft/s (30 m/s). But, if the nonflashing liquid is causing cavitation, lower the velocity to eliminate cavitation damage. For flashing liquid conditions, keep the exit velocity below 75 ft/s (22 m/s).

These valves should control upstream pressure to within 3% of setpoint pressure and require an actuator resolution of 1.5% or better. To produce reliable seating, make sure the closure member and the seat interface are composed of stellited material, and specify MSS-SP61 seat leakage requirements.

• Start-up valves to the turbine—These valves, which include Babcock & Wilcox 201 secondary superheater pressure control valves, Babcock & Wilcox 401 sliding pressure control valves, Babcock & Wilcox 501 secondary superheater stop bypass valves, and Combustion Engineering boiler extraction and boiler extraction bypass valves, should have a linear-installed flow characteristic.

Their inherent rangeability must be at least 100 to 1, and you should give favorable selection and design consideration to single valve bodies meeting start up and main-flow conditions. To eliminate the need for block valves, these valves must meet MSS-SP-61 seat-leakage requirements.

• *Foster Wheeler "W" pressure reducing valves*—With these, the liquid velocity exiting the cage shouldn't exceed 100 ft/s (30 m/s). But, if the nonflashing liquid is causing cavitation, this should be lowered to preclude cavitation. For flashing liquid conditions, keep the exit velocity below 75 ft/s (22 m/s).

These valves should also have a linear installed-flow characteristic and their inherent rangeability must be at least 50 to 1. Give favorable selection and design consideration to single valve bodies meeting start-up and main-flow conditions. The actuator resolution for these valves should be 1.5% or better, and they need to meet ANSI/FCI 70-2, Class IV seat leakage requirements.

• *Reheat bypass valves*—These need to meet ANSI/FCI 70-2, Class IV seat leakage ratings.

• *High-pressure turbine bypass*—To minimize the potential tor flow induced vibration and the entrapment of pipeline trash between the closure member and the valve trim, it's best if the flow direction be flow-to-close (over-the-seat). To eliminate the need for block valves, these valves must meet MSS-SP6I seat-leakage requirements.

• *Attemperator spray valves*—These must meet ANSI/FCI 70-2, Class IV seat-leakage ratings.

• *Auxiliary steam*—The inherent rangeability of these valves must be at least 50 to 1. The first 10% of the closure member travel should result in less than 3% of the total valve flow capacity. In addition, auxiliary steam valves must meet ANSI/FCI 70-2, Class IV seat-leakage ratings.

• *Soot-blower flow control*—These take high pressure steam and blow soot off of the boiler tubes. To minimize the potential for flow-induced vibration and the entrapment of pipeline trash between the closure member and the valve trim, the flow direction must be flow-to-close (over-the-seat).

It is essential that these valves be capable of controlling downstream pressure to within +/- 70 kPa (10 psi). Also, they must meet ANSI/FCI 70-2, Class IV seat leakage ratings.

Custom can cost less in the long run

Particular care should be taken to choose the proper valves tor severe-service. Often, off-the-shelf models won't work and a custom-design velocity control valve will be needed. Although the custom valve may cost more up front than a conventional valve, it can be the most cost-effective choice due to the increased maintenance and operating costs associated with misapplied valves.

About the authors

Larry Stratton is the manager of technical support and automation for Control Components, Inc. His background includes all phases of valve and actuator design, including standardization and automation to factory and field service support and product improvement. Stratton has a bachelors degree in Engineering from California State University, Fullerton.

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