The Ins & Outs of Pressure-Reducing Valves

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Pressures in fire-protection systems that exceed the maximum allowed by NFPA standards must be reduced to acceptable levels for sprinkler systems and fire department hose valves. High-rise buildings, for example, often require pressure-reducing valves. A pump that is capable of supplying the minimum acceptable pressure to the top floor will deliver excessive pressure to lower floors. Pressure reduction should be provided to the lower floors when a building exceeds 15 to 20 floors.

The most-common approach to pressure control is the use of direct acting pressure-reducing valves on each floor. These valves reduce the excess pressure from single zone supply risers and are either adjustable or the fixed reduction type. There are also less common and usually more-costly approaches to high-rise pressure control. One such approach is to use multiple supply zones with separate pump systems for each zone. Another method is to employ a single pump system that supplies multiple risers (zones) with the pressure on each riser controlled by a large pilot operated pressure-reducing valve. This article will concentrate on direct acting pressure-reducing valves.

Standards & Requirements

The standard applicable to the design and manufacture of direct acting pressure-reducing valves is Underwriters Laboratories 1468, Direct Acting Pressure-Reducing and Pressure-Restricting Valves. The standards that provide the requirements for selection and installation of these valves in fire protection systems include NFPA 13, Standard for Installation of Sprinkler Systems; and NFPA 14, Standard for the Installation of Standpipe and Hose Systems. These two installation standards must be used in the design of high-rise fire protection systems, although the resultant "systems" are actually a single well-integrated system. The fact that these two documents exist as separate standards has historical significance, but little technical relevance in today's fire protection design world.

Nearly all high-rise projects today are mandated by code to have automatic sprinkler systems in addition to standpipe systems for fire department use. Such was not the case when the First Interstate Bank building was built in Los Angeles, or the One Meridian Plaza in Philadelphia, or the MGM Grand hotel in Las Vegas, and tragic fires resulted. A thorough understanding of fire-protection system design requirements (including a working knowledge of pressure-reducing valves) is crucial to the long-term fire safety of high-rise buildings being designed today.

NFPA 13 requires that listed pressure-reducing valves be installed in portions of sprinkler systems where all components are not listed for pressures greater than 175 psi, and the potential exists for normal water pressure in excess of 175 psi. Commonly referred to as floor control valves, these PRVs must be set to provide an outlet pressure not greater than 165 psi at the maximum inlet pressure. In order to prevent the PRV outlet pressure from creeping beyond 175 psi over time, the standard requires the installation of a 1/2 in. or larger relief valve on the discharge side of the valve. The relief valve must be set to open at a pressure no greater than 175 psi. Also, pressure gauges must be installed on both the inlet and outlet sides of the PRV to satisfy inspection and testing needs.

Sizing and selection of hose PRVs is governed by the requirements of NFPA 14, and those requirements are based

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Table 1
Sizing & Selecting Pressure-Reducing Valves

System Type	Hose Connection Size	Intended Application	Min. Design Pressure	Max. Allowable Pressure
Class 1	2 1/2	Trained firefighters	100 psi	175 psi
Class 2	1 1/2	Trained building occupants	65 psi	100 psi
Class 3	2 1/2 & 1 1/2	Trained firefighters & trained occupants	100 psi & 65 psi	175 psi & 100 psi

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on the class of service the hose valves are intended to provide. Table 1 describes those classes and their pressure-control requirements.

Class II & III systems require hose stations, equipped with the hose valve, a hose storage device, hose and nozzle for use by trained building occupants. Prior to the One Meridian Plaza fire, the maximum allowable hose valve outlet pressure was limited to 100 psi regardless of system type. In that fire, the limited pressure on the standpipe system did not allow the automatic type nozzles used by the Philadelphia Fire Department to flow at an effective rate. Recognizing that fire departments nationwide and throughout the world were using similar type nozzles and hose lines smaller than 2-1/2 in. size, the NFPA 14 committee increased the Class I valve outlet pressure range to 100-175 psi.

Terminology & Definitions

Effective communication is critical to successful fire protection system design. When specifying pressure-reducing valves it is crucial that the system designer, valve supplier and valve manufacturer have a common understanding of pressure terminology. An understanding of the following terms and their definitions will help to ensure that valves are correctly sized and adjusted.

Static inlet pressure. The supply riser pressure at the floor level of the valve with no water flowing.

Residual inlet pressure. The supply riser pressure at the floor level of the valve while the required flow rate is being delivered by the valve. For Class I hose valves, this flow rate is normally considered to be 250 gpm, but the minimum system flow rate is 500 gpm for the hydraulically most remote standpipe. For Class II hose valves it is 100 gpm, and for sprinkler floor control valves, it is the calculated demand for that floor.

Static outlet pressure. The normal outlet pressure on the sprinkler system with no flow. For sprinkler floor control valves, it is a maximum of 165 psi, and may be as low as the water supply and chosen valve type will allow and still provide the required demand. For Class I hose valves, the static outlet pressure must not exceed 175 psi, and for Class II hose valves, the maximum allowable static outlet pressure is 100 psi. Considering that hose valves are normally manually closed, static outlet pressure is only an issue during use of the standpipe system; when firefighters close a nozzle shutoff with the standpipe valve open, the static pressure on the hose line must be limited to the specified maximums.

Residual outlet pressure. For floor control valves, the calculated sprinkler demand pressure for that floor. For Class I hose valves, it is between 100 psi and 175 psi with 250 gpm flowing. For Class II hose valves, it is between 65 psi and 100 psi with 100 gpm flowing.

NFPA 14 uses the term "pressure-regulating device," the definition of which includes all types of devices that might be used to restrict water pressure. It is important for fire protection system designers to understand that listed pressure-reducing valves are not regulators in the sense that they can provide a constant static or residual outlet pressure as inlet pressure varies. This is because of the incompressibility of water. Actually, a given PRV "type" or adjustment setting will provide a fixed pressure reduction ratio, meaning that the outlet pressure will always be a fixed percentage of inlet pressure.

The nonadjustable, fixed ratio type is the simplest of PRVs, with a resulting lower cost, and smaller size than adjustable types. Further, they have no means for anyone to tamper with adjustment setting in the field; once the valve is properly selected and installed, its long-term performance is highly predictable.

Adjustable vs. Fixed Ratio Pressure Reducing Valves

Direct acting pressure-reducing valves are available in two basic types: adjustable or nonadjustable (fixed ratio). Each type has its advantages. The nonadjustable, fixed ratio type is the simplest of PRVs, with a resulting lower cost, and smaller size than adjustable types. Further, they have no means for anyone to tamper with adjustment setting in the field; once the valve is properly selected and installed, its long-term performance is highly predictable.

Adjustable PRVs can be factory set or they can be adjusted in the field, thereby allowing a single model valve to be ordered for an entire job. Although more costly than nonadjustable PRVs, their ability to be adjusted in the field allows distributors to maintain valve stock, thereby reducing delivery times. The adjustability feature also allows a valve to be easily modified to accommodate future changes in water supply or system configuration.

Listed direct acting pressure reducing valves are offered in both 1-1/2 in. and 2-1/2 in. angle (90E) body style, with female pipe thread inlet ports and either male hose thread or female pipe thread discharge ports. Straight (globe) pattern valves are offered in 2-1/2 in. size with female pipe threaded ports on both ends. Note: As with basic shutoff valves, straight pattern bodies allow in-line installation, but offer no advantage in hydraulic efficiency.

How PRVs Work

Direct acting PRVs are quite simple in design concept, but its hydraulic performance can be a bit confusing for the inexperienced system designer. If we have an understanding of how they work, it is easier to effectively apply them in fire systems. The simplest PRV is the nonadjustable type, as represented in Figure 1. This cross section view reveals the key parts of the valve, and the blue shading represents the portions of the valve interior exposed to water pressure. The dark blue area is the higher inlet pressure, and the light blue areas are at the reduced outlet pressure.

The key functional parts are the seat and floating stem assembly; the manual stem and hand wheel; and the piston. The fluid passage within the floating stem allows valve outlet pressure to reach the top side of the piston. The piston is forced downward against a shoulder on the floating stem. With the manual stem in the fully open position, the piston hydraulic area, together with the hydraulic area of the seat disc holder results in a net force in the closed direction such that the valve operates in a self-throttling mode. The degree of throttling (pressure reduction ratio) is determined by the diameter of the piston and corresponding cylinder within the valve bonnet. These nonadjustable PRVs are available in multiple versions, each with a different piston diameter, to provide the range of reduction ratios needed for various supply pressure conditions. The degree of throttling increases as the piston diameter increases. Under static conditions, such as when the sprinkler system is in normal standby mode, or when a hose nozzle shutoff is closed, the hydraulic area differential causes the seat to automatically close, and the required pressure reduction is maintained.

The adjustable direct acting pressure-reducing valves are slightly more complex than the nonadjustable types. Figure 2 is a cross section view of the latest type adjustable PRV. This valve contains all the major functional components of the nonadjustable valve, but in addition, contains a pair of nested compression springs and a means to adjust the compressed height of the springs. The load developed by the

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Figure 1

Nonadjustable Pressure-Reducing Valve

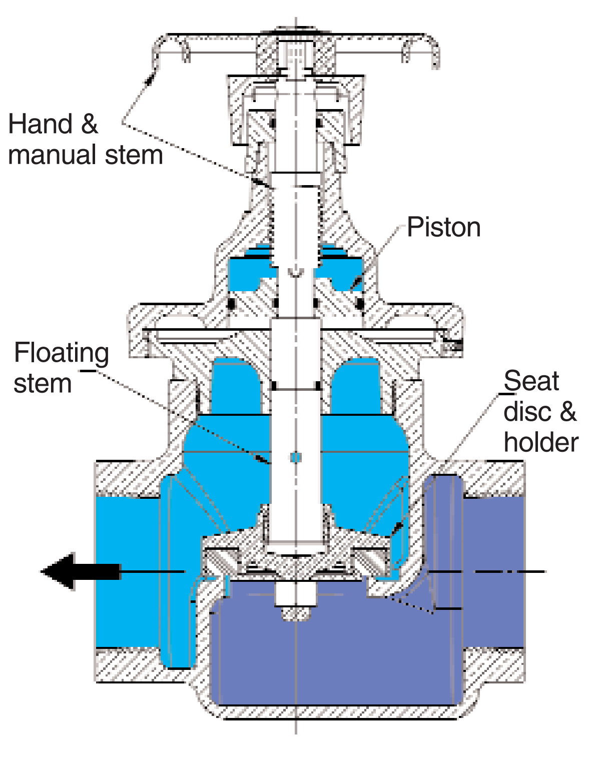
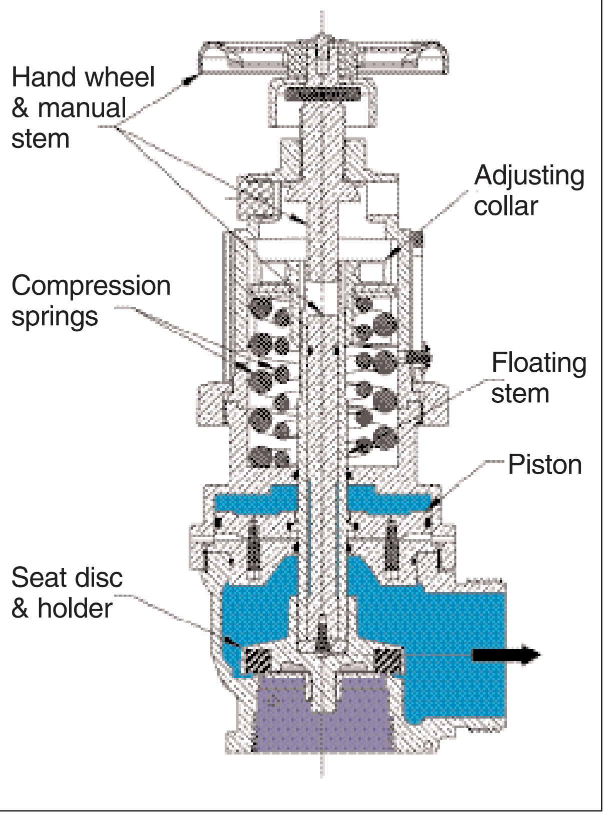


Figure 2

Adjustable Pressure-Reducing Valve



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compression springs acts on the floating stem and seat in the opposite direction as the hydraulic load produced by the piston. Notice that the piston diameter is equal to that of the largest piston offered in the nonadjustable valve. If the adjustment collar is turned in the direction to reduce the compressed height of the springs, the spring load is increased, and the load produced by the piston is counteracted. The piston "diameter" is effectively reduced, and the valve pressure reduction ratio is decreased. The opposite effect is achieved by turning the adjustment collar to increase the spring height. The specific design depicted in Figure 2 has the advantage of a unique hollow floating stem that eliminates friction produced by high spring force on the manual control components. The valve can be manually opened and closed with much less operating torque on the hand wheel than is required in previous adjustable PRV designs.

Selecting & Adjusting PRVs

Manufacturers of PRVs must provide complete selection and/or adjustment information for a given valve model. This information shall include reference to the inlet pressure range, outlet pressure range, flow range or conditions, and performance characteristics when the inlet pressure is below the intended valve outlet pressure referenced in the manufacturer's instructions.

A typical valve performance and selection chart for a non-adjustable PRV is shown in Figure 3. This chart represents the valve performance for flow rates up to 400 gpm, with the vertical axis labeled residual inlet pressure, and the horizontal axis indicating residual outlet pressure. The diagonal "curves" provide the performance for each of nine different valve "types." Each valve type signifies a specific piston diameter. To make a valve selection, first locate the intersection of the system demand pressure (desired valve outlet pressure), and the residual inlet pressure on the riser at that floor level. Choose the type curve closest to the intersection point. After making the valve selection based on flowing pressures, a similar chart for static performance must be referred to in order to ensure that the maximum allowable static pressure is not exceeded.

The process for determining the correct setting for adjustable PRVs is conducted in a similar manner. Figure 4 shows performance curves for such a valve. Again, the vertical axis represents valve residual inlet pressure and the horizontal axis gives residual outlet pressure. Locate the intersection of the desired valve outlet pressure and inlet residual pressure. Choose the setting curve closest to this intersection. Next, check the valve static pressure performance for the chosen adjustment setting to be sure that maximum allowable static outlet pressure is not exceeded. If it is, the next adjustment curve to the left must be used. Follow the manufacturer's instructions to adjust the valve to the chosen curve.

Figure 3

2.5 Pressure-Matic Valve Performance & Selection Chart Model UR-20 & 25

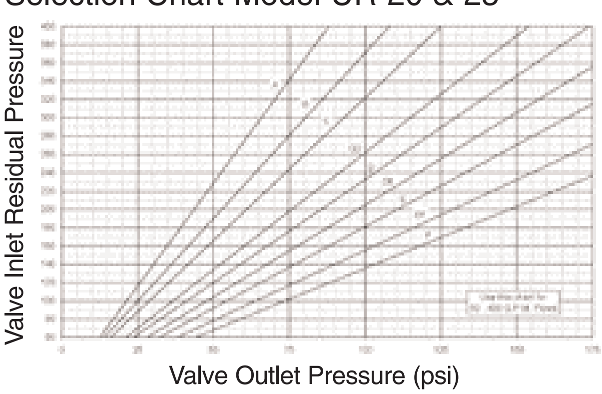
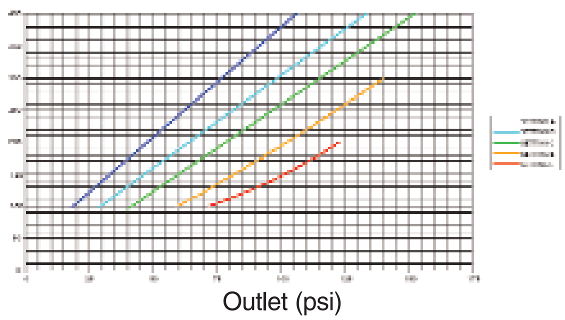


Figure 4

URFA-20-2.5 URFA-25 (250 gpm)



Inspection & Testing

Regular inspection and testing of fire protection systems and their components, including pressure-reducing valves is necessary to ensure long-term reliability. The required inspections and tests as well as the frequencies are specified in NFPA 25, Inspection, Testing and Maintenance of Water Based Fire Protection Systems. A quarterly inspection is required to verify that valve is in correct open or closed position, inlet and outlet pressures are acceptable, hand wheels are in place, hose threads are in good condition, and hose caps and adapters are in place. An annual partial flow test is required with the intent being to move the valve seat from the closed position.

At 5-year intervals, all PRVs must be subjected to a full flow test. This testing can be accomplished using sprinkler system drain valves, or hose lines connected to a drain riser. Flow meters should be used to confirm that the system demand is being flowed, and test results, including inlet and outlet pressures under flow and static conditions should be compared to design specifications. Valves that do not meet specifications should be readjusted or replaced. ■

About the Author

Jim Trapp *is chief engineer for Elkhart Brass Mfg. Co., Elkhart, IA. He is a licensed professional mechanical and fire protection engineer. Trapp earned a degrees from Michigan State University and University of Maryland in Mechanical Engineering and Fire Protection Engineering, respectively. He also holds numerous patents on firefighting and fire protection equipment designs. Trapp served many years on NFPA Standpipe Committee and also has served on NFPA 13 working group. In addition, he is a member of the Society of Fire Protection Engineers.*