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Pilot-operated safety relief valves: A simple, effective plant upgrade

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Replacing spring-loaded valves can help increase efficiency and output

Keywords:

A never-ending quest for plant operators is how to wring more output from the existing infrastructure and budget without compromising safety or product quality. The challenge is daunting, but a relatively simple upgrade can help plant operators take a big step toward meeting it.

The replacement of direct spring-operated pressure relief valves (PRVs) with pilot-operated safety relief valves (POSRVs) can help plant operators streamline maintenance processes, reduce maintenance costs, address common valve performance issues, maintain safety and potentially increase output.

This article explains how valve replacement can be beneficial. It also clarifies some common misconceptions about POSRVs and identifies factors that should be considered when specifying pilot-operated safety relief valves.

GREATER EFFICIENCY AND INCREASED THROUGHPUT

A POSRV relieves an overpressure situation by actuating a pilot valve that is plumbed to a main valve. The pilot valve opens and closes the main valve in response to system pressure, and all of the relieving capacity flows through the main valve.

The pilot valve receives vessel pressure through a sensing line attached at a point below the seating surface of the main valve or at a point directly on the vessel. The pressure travels through the pilot and pressurizes the dome. The surface area of the dome is greater than the seating surface, which is the area under the disc. Since Force = Pressure 3 Area (F = P 3 A), the force pushing down on the main disc is greater than the force pushing up. With a POSRV, as system pressure increases, seat tightness also increases. By contrast, the seating forces of a direct spring-operated valve are essentially a simple force to close (spring) against a force to open (system pressure). This difference means that the pilot valve has greater seat tightness at higher system operating pressures.

Since the pilot and main valves work together to protect the system, the system operating pressure can be closer to the valve's set pressure than what is possible with a spring-loaded valve; 98% of set pressure is possible while staying within American Society of Mechanical Engineers (ASME) guidelines, vs. 90% of set pressure with a spring-loaded valve. Operating closer to set pressure allows plant personnel to maximize system efficiency while maintaining safety and reducing loss of product through seat leakage. As shown in Table 1, a POSRV's set pressure can be higher than that of a comparable spring-loaded valve, helping increase throughput.

TABLE 1. Set pressure comparison: POSRVs vs. spring-loaded safety relief valves

Valve size, in. (cm)	Nominal orifice area, in.^{2} (cm^2)	Set pressure, psig (barg) Spring-loaded safety relief valve	POSRV
3K4 (8K10)	1.838 (11.8)	2,220 (153)	6,250 (431)
4P6 (10P15)	6.38 (41.2)	1,000 (69)	3,750 (259)
6R8 (15R20)	16.00 (103)	300 (21)	1,500 (103)
8T10 (20T25)	26.00 (168)	300 (21)	1,500 (103)
8FB10 (20FB25)	38.96 (251)	N/A	1,500 (103)

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VERSATILE PROBLEM-SOLVERS

POSRVs are powerful problem-solvers and can help system designers overcome a variety of challenges commonly faced in hydrocarbon processing facilities. They are particularly appropriate choices for applications that include the following attributes.

Involvement of costly fluids. These fluids could include liquid natural gas (LNG), gasoline or another end product; or lubricants, cleansers or other additives used in the production process. The greater seat tightness delivered by POSRVs reduces the potential for these valuable fluids to be lost to leakage.

Presence of dangerous fluids. Such fluids create a potential breathing or explosion hazard. Again, seat tightness is the key. By reducing the potential for leaks, POSRVs help ensure safety by preventing these fluids from being released into the atmosphere.

Concern over fugitive emissions. Increasingly strict regulatory guidelines have made controlling fugitive emissions a major focus for plant operators. Leaking valves are one of the leading causes of fugitive emissions.

Direct spring-operated valves operate at something akin to a low boil. As system pressure begins to approach the valve's set point, the valve will start to simmer as the disc gently rides on top of the valve seat. Although this is how the valve is intended to operate, the fugitive emissions caused by this slight leakage may not be acceptable in some applications. A POSRV's tighter seal eliminates the simmering.

Existence of significant back pressure. It is, of course, common in hydrocarbon processing facilities for a PRV to exit into a header system where multiple valves are piped together. A prime example of this setup is a valve that is vented to a flare. This configuration will create superimposed variable back pressure when a valve relieves and generates pressure in the shared outlet pipe. Typically, the solution has been to use a direct spring-operated bellows valve.

POSRVs are an ideal alternative to direct spring-operated bellows valves since a POSRV's set pressure does not increase with the addition of back pressure (provided that the pilot is balanced against the effects of back pressure). Valve stability is greater with a POSRV because the back pressure cannot act on the back side of the disc to hold the valve closed. As a result, POSRVs are suitable for use in applications with 60–65% variable back pressure. In some applications, POSRVs may be used with back pressures up to or exceeding 80%.

A POSRV can also be a more cost-effective choice in these applications. Although the up-front cost of a spring-loaded valve may be lower, bellows are relatively fragile and are generally costly to replace when damaged, potentially creating lead-time issues during shutdowns and resulting in higher life-cycle costs.

High pressure drop exists. A variety of maintenance and construction considerations can lead plant designers to create facilities that have piping with multiple bends, narrow pipes or long runs of piping. High inlet pressure drops can result, causing a direct spring-operated valve to chatter or flutter and leaving the system at risk. However, a POSRV with remote sensing will protect the system without the need to re-pipe. Placing the sensing line in an area of the vessel that is unaffected by pressure drop allows accurate operation of the main valve (Figs. 1 and 2). The American Petroleum Institute (API) and ASME Section VIII Appendix M recommend a maximum inlet pressure drop of 3% of set pressure.

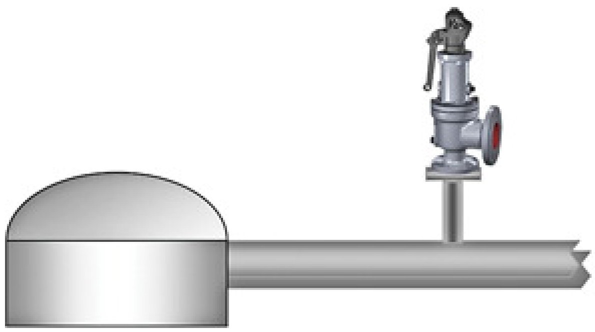

Fig. 1. This piping configuration has a pressure drop, potentially greater than 3%. Note: Valve piping and vessel not to scale.

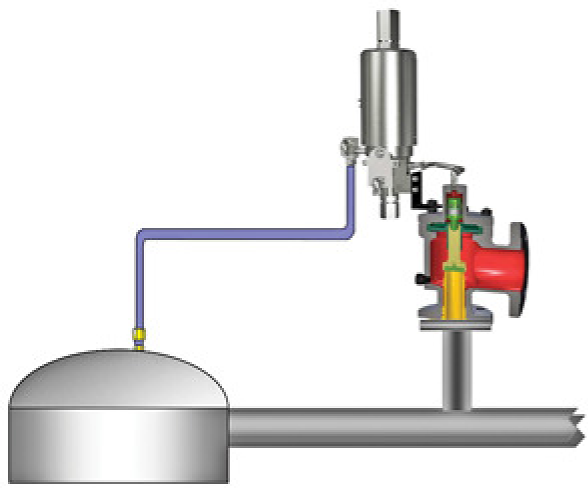

Fig. 2. The POSRV shown here senses pressure at the vessel rather than at the valve inlet piping. Note: Valve piping and vessel not to scale.

One application in which these high pressure fluctuations are commonly found is a reciprocating compressor in a refinery. When operating at high capacity, these compressors have a tendency to surge, creating pressure variations that can cause a direct spring-operated PRV to chatter. A POSRV, on the other hand, will not chatter under these conditions.

Size and weight are major considerations. POSRVs are much more compact than their spring-loaded equivalents, allowing them to be used in tighter quarters and making installation and maintenance more convenient. POSRVs also weigh considerably less than direct spring-operated valves, reducing the number of piping supports required and making installation and maintenance easier. Consider, for example, the weight savings that can be achieved by replacing the following common spring-loaded valves with POSRVs:

- 3-in. inlet and 4-in. outlet: up to 42%
- 2-in. inlet and 3-in. outlet: up to 33%
- 1.5-in. inlet and 2-in. outlet: up to 36%.

COMMON MISCONCEPTIONS ABOUT POSRVs

Regardless of POSRVs' problem-solving abilities and attractive characteristics, several common misconceptions lead some plant operators to shy away from specifying POSRVs. Some of these misconceptions are based on simple misunderstandings, and others are based on operators' experiences using traditionally accepted POSRV technology.

Misconception 1: Pilots cost more.

It is true that the sticker price of a POSRV is typically higher than that of a comparable direct spring-operated valve. POSRVs can, however, help plant operators reduce their overall investment in PRVs and increase plant uptime, for the following reasons:

• **Fewer valves may be required.** A hydrocarbon processing facility may experience a variety of overpressure scenarios. Multiple direct spring-operated valves, each with a different relieving capacity, would be required to accommodate all of these situations. A single proportional lift-modulating POSRV, on the other hand, will adjust to and accommodate all overpressure situations, eliminating the need to install and maintain multiple valves.

• **POSRVs are easier to maintain** than direct spring-operated valves, resulting in a lower life-cycle cost and increased plant uptime. Maintaining a direct spring-operated valve is an extremely labor-intensive and time-consuming process that involves pulling the valve from service, lapping and polishing the seat, re-machining the nozzle and sometimes replacing the disc. This process can span several hours for a single valve, multiplied by the high number of valves that are found in a typical hydrocarbon processing facility. In today's world of shortened and highly time-sensitive plant turnarounds, the time for extended valve maintenance does not exist.

Maintaining a POSRV is a far easier process. The valve is simply pulled from service, the O-rings and seals are replaced, and then the valve is brought back online. Eliminated are the hassles of measuring minimum machining dimensions and critical dimensions, completing a spring rating test and inspecting the spindle.

• **The interval between required maintenance activities is often longer with POSRVs** than with direct spring-operated valves. Once a valve begins to leak, the disc and nozzle can quickly become eroded to the point that the valve must be repaired, requiring a complete shutdown of the process. A POSRV's greater seat tightness means fewer leaks and, therefore, fewer costly and disruptive shutdowns.

Switchable dual-pilot actuators provide an additional opportunity to increase operational uptime and lengthen service intervals. One pilot actuator remains active while the other is removed for repair and setting in a workshop. Periodic changing of the O-rings in the main valve and checking of free movement allow the main valve to be removed from the line less frequently than direct spring-operated valves.

• **In-situ testing allows POSRVs to be tested without costly process downtime.** Valve manufacturers have developed equipment that keep the main valve closed during testing, eliminating the need to remove the valve from service and allowing production to continue safely while the test is completed.

Misconception 2: Pilots are more complex.

POSRVs are more complex than traditional spring-loaded valves, but that comparison is also a bit like comparing today's cars to a Model T. Yes, technology has progressed and POSRVs incorporate more advanced technology; however, just as today's auto mechanics are more skilled than those of a century ago, so are today's plant operators. A modest amount of hands-on, practical training is all that is required to ensure adherence to the manufacturer's recommended maintenance practices and techniques.

Misconception 3: Pilots are for "clean service" only.

When POSRVs were first introduced, their use was limited to "clean service" applications. Engineering technology has advanced considerably since that time, and today POSRVs can effectively be used in many "dirty service" applications.

The "non-flowing" design used in virtually all modern POSRVs protects the "brain" of the valve assembly—the pilot valve actuator—from potentially damaging process fluids. Early POSRVs had a "flowing" design wherein process fluid also flowed through the pilot actuator when the main valve was open, thereby exposing the actuator to the process fluid and making it

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vulnerable to erosion and contamination. The advent of non-flowing POSRVs removed this risk by ensuring that no process fluid moves through the pilot actuator when the main valve is open, thus eliminating contamination and possible erosion within the pilot actuator. It should be noted, however, that, despite these advances, precautions must be taken when applying POSRVs to dirty, viscous or paraffin-laden fluids.

Clean service connections can be installed to keep sand, grit and dirt from clogging a POSRV's sensing line and damaging other vital valve components. A closed chamber filled with an inert gas is positioned at the top of the pilot valve body and below the pilot valve bonnet. The process media pressure still controls the set pressure and blowdown of the POSRV, but crucial valve parts such as the modulator, dome assembly, vent and inlet seals never come into contact with the dirty system media.

Cover gases can also be used to protect the disc and sensing line from corrosive process fluids. A blanket of inert gas fills the spaces between the process gas and the relief valve, ensuring that the fluid does not come into contact with the disc or enter the sensing line.

Misconception 4: Re-piping will be required.

Many operators believe that converting from direct spring-operated valves to POSRVs will involve re-piping the system to make room for the main and pilot valves. In many cases, however, existing piping may be used since manufacturers now offer POSRVs that fit directly into the holes left by the spring-loaded valves they are replacing. These pilot valves have a main valve designed to API 526 rules for direct spring-operated valves and are ASME-certified POSRVs, according to the National Board of Boiler and Pressure Vessel Inspectors.

In one example, such a valve was used to replace two safety relief valves in a medium-pressure steam header application. The safety relief valves were prone to not closing properly and, as a result, required frequent maintenance. (The second valve had been installed so that one valve could remain in service while maintenance was completed on the other.) The valves also fluttered due to a high pressure drop created by a long run of piping between the valves and the system pressure flow. The safety relief valves were replaced with a single POSRV designed to API 526 face-to-face dimensions. The seating issues were resolved, and remote sensing eliminated the high pressure drop and the potential for flutter. Also, no new piping was required, likely saving the customer tens of thousands of dollars.

THE NEW GENERATION: TUBELESS POSRVs

A relatively new kind of POSRV, the tubeless POSRV, offers significant additional advantages. As the name implies, tubeless POSRVs operate under the same principles as other POSRVs, but the media is directed through internal passages rather than external tubes (Fig. 3). Eliminating the tube—the part most frequently in need of repair or replacement—gives the valve even greater flexibility, further streamlines maintenance practices and enhances safety.

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Fig. 3. In a tubeless POSRV, the media is directed through internal passages rather than external tubes.

Doing away with the tube eliminates the risk of tube failure—and ultimately valve failure—caused by human error, misuse, vibration or atmospheric conditions. Hydrocarbon processing facilities are inherently high-risk, making safety the highest priority. Tubeless POSRVs can help plant operators ensure that a valve will not be disabled if a worker inadvertently steps on and crimps the tube, if extreme vibration breaks the tube, or if freezing temperatures cause hydrates to form in the sensing line, plugging it. Furthermore, the absence of a tube in a POSRV lowers the potential for leakage and reduces the need for custom configuration.

CHOOSING THE RIGHT POSRV

There are several important factors and options to consider when specifying a POSRV:

• **Should the POSRV use internal or remote sensing?** Specifiers should examine where the valve will be installed and determine whether the POSRV should have internal or remote sensing. High pressure near the valve inlet can cause a valve with internal sensing to discharge unnecessarily because the valve is not correctly sensing the pressure. In these instances, system designers should opt for a POSRV with remote sensing that can be placed an adequate distance from the valve inlet.

• **Will there be condensable gases in the flow stream?** If the flow stream will contain condensable gases, a dual-phase POSRV that can accommodate both liquids and gases must be used. In most installations, the pilot valve discharges into the main valve outlet. If the flow stream contains condensable gases and the main valve experiences cooling, liquid condensate will form in the top of the main valve. If the POSRV is not designed to handle liquids, the main valve will not open and will not protect the system in the event of an overpressure situation.

• **What material should be used?** The valve material should conform to that used in the piping, as the piping will be compatible with the fluid. For example, if the fluid will already have been treated and cleaned, carbon steel with stainless steel trim will be acceptable. However, if the gas will be sour, exotic materials should be considered. NACE International offers a list of materials that can be used in environments that cause stress, corrosion and cracking, such as sulfur and hydrogen sulfide.

- **What are the code requirements?** POSRVs are governed by two primary regulating bodies. ASME establishes regulations for certifying valve capacity and the materials that can be used in constructing valves. The US Department of Transportation, with its responsibility for governing interstate and offshore pipelines, establishes requirements for valve testing.

As hydrocarbon processors strive to meet ever-higher expectations, replacing direct spring-operated pressure relief valves with pilot-operated safety relief valves is a relatively simple upgrade. Such replacements can pay significant dividends, from improved valve performance to streamlined maintenance processes, lower maintenance costs and, potentially, increased output. **HP**

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