WHITE PAPER

Advances in Compressor Anti-Surge Valve Design Enhance Reliability and Performance

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Advances in compressor anti-surge valve design enhance reliability and performance

Centrifugal and axial compressors are some of the most critical components used within a process plant to handle gases. These machines impart energy to the process fluid, helping to create optimum process conditions while also allowing the transfer of fluid. They typically comprise a major portion of the equipment cost on a project and thus generally do not have a spare or stand-by equipment. Proper operation of these machines is imperative to the ensure the plant runs safely and reliably.

However, these compressors can be exposed to surge events, which tend to have adverse effects on a compressor's lifetime productivity. In some cases, the surge event can also be disastrous to the compressor, leading to extended periods of lost productivity.

Compressors are designed to take in energy from an external source (compressor driver) and transfer it to the process fluid to maintain a continuous and reliable flow rate. But if the flow rate changes suddenly — due to an upset condition elsewhere in the system — the compressor's energy balance is disrupted, causing a reversal of gas flow as well as higher temperatures and increased vibration inside the compressor. When this happens, the blade stalls, causing the thrust and flow across the blade to stop. The cyclic reverse and normal flow inside the compressor result in forces hammering the bearings of the compressor. This occurrence is referred to as a *surge event*. Together, these conditions can lead to catastrophic compressor failure. This process can happen in seconds, making it difficult to react to — which puts not just the compressor, but the entire operation at risk. The latter scenario faces a high potential of resultant downtime and production losses. Operators must employ methods to protect the system from the dangers of surge.

A standard method to mitigate these risks is using an anti-surge control system that controls the performance of the compressor through an anti-surge valve (ASV).

How anti-surge valves work

Anti-surge valves recycle media from the compressor's discharge end back into the inlet when surge conditions are detected. By temporarily increasing the amount of material into the compressor, the pressures equalize and a blade stall is avoided. Once the feed rate stabilizes, the anti-surge valve closes and the compressor returns to normal.

Anti-surge valves must be able to adjust the flow rate quickly and precisely before the compressor crosses the surge line. While anti-surge valve designs vary by manufacturer, they all must meet certain critical aspects, including:

- Valves must be able to provide precision control and stroke quickly and accurately.
- They must be simple to set up, tune and maintain.
- Each valve's capacity must be sufficient to prevent a surge event.
- Valves must be able to attenuate noise to acceptable levels in high-pressure drop and high-flow conditions.
- The valve and actuator design must be robust enough to prevent it from damaging itself during fast stroke events.

Anti-surge valves are a very important part of a compressor system, but every valve does not contain the same internal components, so it's important to understand what these components do and whether they are required for your particular application.

Positioner feedback mechanisms enable precise controllability

Operators must be able to precisely control an anti-surge valve's stroke position to account for frequent small upsets. This gives operators the ability to make minor adjustments when running close to the surge line, allowing for enhanced productivity.

To ensure proper control, the positioner needs to receive accurate feedback to determine the current valve stroke position. A typical positioner has a feedback shaft that rotates as the valve strokes. The starting rotation angle of the positioner feedback shaft indicates the valve is closed, and the ending angle indicates the valve is open. Any angle between the starting and ending angles represents a certain percentage of the total valve stroke.

The mechanical linkage between the linear motion of the valve stem and the rotary motion of the positioner feedback shaft commonly consists of a take-off arm with a pin that rides in a slot. For control valves with strokes 305 mm (12 in) or longer, the typical positioner take-off arm is long, awkward, cumbersome and sensitive to vibration. Over time, excess vibration can cause the positioner to fall out of alignment, preventing its ability to accurately calibrate the precise valve stroke position.

For long stroke lengths, a more reliable configuration couples the rotary motion of the positioner feedback shaft to a tube with a helical slot mounted between two bearings. The axis of the tube is parallel to the valve stem. A take-off arm with a pin is mounted to the plug stem. As the valve stem moves, the pin rotates the tube, providing plug stem feedback to the positioner.

Valve design determines flow capacity

While the compressor is slowing down during an emergency event, the anti-surge valve opens, providing gas to the compressor inlet that maintains high flow rates in the compressor, preventing surges during the shutdown. In this case, the valve needs to deliver very high flows to the compressor very quickly. The ability of the valve to successfully deliver such high flow rates depends on its design. For example, an angle body valve with a large-volume capacity gallery is capable of providing more flow capacity than other valve designs. The design of the valve also determines the ability of accommodating severe service trims, which can help in reducing noise and vibration in the most rigorous applications. Precision control means a more accurate production process, less waste, fewer upsets and more revenue.

Actuators determine stroke speed

During emergency situations, when the feedstock to the compressor has been interrupted, operators must be able to open the anti-surge valve quickly. Many oil and gas companies require anti-surge valves to fully open within one second, activated by solenoid. This fast stroke speed is critical to ensuring operators have enough time to shut the compressor down and investigate the cause of the upset.

Actuators and control systems in an anti-surge valve determine how quickly the valve can open and close. Since diaphragm actuators cannot provide the thrust and speed required, pneumatic piston actuators are necessary. Pneumatic piston actuators have positioners that supply air to both sides of the piston. This four-way control design is integral to produce the amount of speed and thrust required to quickly stroke the valve.

The control systems used on an actuator vary from banks of traditional three-way flow boosters to complicated systems where a computer, some type of electronic position feedback, and a large spool and block are joined together to make a positioner.

Air cushions prevent damage to actuator and valve assembly

While anti-surge valves must be able to stroke quickly, over time, this ability can cause damage to the actuator and valve assembly. For actuators with long strokes and fast stroking times, there is a need to decelerate and diffuse high-impact energies at the end of the stroke to avoid impact and potential damage to the actuator and valve assembly. For anti-surge applications, large valves that have fast stroke speeds and long stroke lengths use air cushions on the top of the cylinder to protect them from impact in the open direction. Air cushions are also available in "stroke to open," "stroke to closed" or both directions whenever needed.

The air cushion consists of a manifold assembled between the top of the cylinder and the end cap (if deceleration is desired in the "stroke open" direction) or between the yoke and the bottom of the cylinder (if deceleration is required in the "stroke close" direction).

Air cushions work by restricting the exit of air from the actuator at the end of the actuator stroke. This happens when the cushion spear engages into the cushion seal. The trapped air is compressed by the inertia of the load; the rate at which it exhausts is controlled by the actuator's cushion needle. By limiting the exhaust, the pressure in the top of the cylinder increases and slowly decelerates the piston.

Evaluating air cushion requirements

Air cushions are not always needed. For large valves (8 NPS and larger), to estimate air cushion requirements based on velocity at impact, use the following formula:

$$V_i = 3\,\frac{\text{Stroke}}{\text{Time}_s}$$

Where:

V_i = Velocity at impact (centimeters or inches per second)

Stroke = Valve stroke (in centimeters or inches)

Time_s = Required stroke time (in seconds)

The factor of 3 in the equation is to take into account the time to accelerate from being at rest.

This guideline suggests an air cushion **should be considered** when using an actuator with a velocity at impact of 60.96 cm (24 in) per second and is **strongly recommended** when the velocity at impact is 91.44 cm (36 in) per second.

Additional considerations

There are a variety of anti-surge valves on the market today. Aside from considering the previously mentioned capabilities, which have a direct impact on an anti-surge valve's reliability and performance, pay attention to the following abilities, which deliver additional advantages:

Ease of set-up, tuning and maintenance

In addition to being durable, anti-surge valves should be easy to maintain. Consider valves and actuator systems that can be easily disassembled and reassembled in the field. On-site technicians' abilities to repair and tune the valve without relying on factory experts lowers operating costs, reduces critical downtime, and minimizes maintenance workloads.

Noise and vibration control

Over time, excess noise and vibration loosen system components, resulting in additional maintenance labor and costs. Consider valves that operate within the 85 to 95 dBa range. Certain anti-surge valves use control valve trims to reduce noise (and vibration) by up to 30 dBa through staging, frequency shifting, attenuation and velocity control.

Extensive OEM testing

Consider valves that have undergone extensive OEM testing and evaluation. OEMs who use testing methods such as computational fluid dynamics (CFD) analysis can ensure valves are going to perform as expected under a variety of conditions. CFD is used to analyze, optimize and verify the performance of valves to confirm they will perform as initially designed.

Conclusion

Anti-surge valves play a vital role in compressor safety and plant performance. By installing anti-surge valves, facilities can run compressors up to the surge line, increasing productivity without worrying about surge events. While there are a variety of different anti-surge valve designs available, specific features — such as four-way actuation, air cushions and positioner feedback mechanisms — make for a more reliable and efficient valve.

Flowserve can help

Do you want to learn more about enhancing your operational reliability and performance with an anti-surge valve? Please contact your local Flowserve sales representative to learn about our selection. Contact details can be found on Flowserve.com.

About the authors

Bradford Haines

Brad has more than 25 years of experience with Valtek® and Flowserve, contributing and leading as an application engineer, project manager and product manager. He excels in finding solutions to difficult applications. As a project manager, Brad regularly has delivered technically complex, multimillion-dollar projects. Over his career, he has successfully envisioned, led and delivered a multitude of new products and critical product enhancements. Some of these include: the Survivor™ anti-erosion control valve; the VL-ES pneumatic actuator product suite; Mark 100 high-capacity control valves; an extensive MegaStream™ product update that provides significantly lower noise levels; and the DiamondBack™ and SideWinder™ suite of anti-cavitation control valves.

Brad holds numerous patents in the areas of control valve construction, anti-noise designs for control valves, and anti-cavitation designs for control valves.

Brad earned a bachelor's degree in mechanical engineering from Brigham Young University.

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Michael P. Nelson is principal R&D engineer at the Flow Control Division of Flowserve Corporation. He has more than 30 years of diverse mechanical design and manufacturing experience with over 22 years in the process control valve industry. He has dedicated a considerable portion of his career to designing process control valves, actuators, positioners and various styles of low-noise valve trim.

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VAWP000194 (EN/AQ) June 2020