Gas-Solids Fluidization

A PRACTICAL PRIMER

Process Lead Responsibilities In Design Projects

Waterhammer In Condensate Return Lines

Facts at Your Fingertips: Heat-transfer Expansion Tank Design

Achema 2012 Takes a Forward View

Focus on Temperature Measurement & Control

Focus on Pipes and Fittings

Seals and Gaskets: Small but Mighty
Globe-style control valves are in virtually every chemical processing line where pressure and flow must be controlled. And for the most part, they perform as required, day in and day out, requiring little to no thought or attention. In short, control valves are not an everyday topic of discussion.

In fact, the globe valve provides a direct contrast to today’s consumer electronics where major changes seemingly are announced and touted every year. While these valves represent an evolution of gradual change, significant improvements in control capability, reliability and breadth of application have been made in recent years.

Until about 45 years ago, globe valves with their massive body castings and rugged stem-guided valve plugs prevailed across the chemical process industries (CPI). Yet despite their wide usage and decades of service, the valves of that era were quickly replaced by a new, efficient-in-design globe-valve body that utilized interchangeable, drop-in trim packages to meet a wide range of control needs. This article answers the “what” and “why” questions about the changes in control valve design, and in doing so, offers readers a better understanding of what valve features are available and how they may apply to particular application needs.

**Background**

A historic disruptive innovation was brought to market in the mid-1960s with the introduction of cage-style trim. Prior to that time, the control valve shown in cross-section in Figure 1 was typical of the globe design offered by valve manufacturers. It featured a heavy, thick-walled body casting with two internal ports and a top-and-bottom guided closure member, or valve plug. Single-port valves were offered as well, and their body castings mirrored that of the large, double-port design. For decades these valves provided adequate service in a wide variety of applications. So why the dramatic 1960s change in body shape, mass and trim design?

The answer, quite simply, is economics. That double-ported valve required a great number of machining operations. Both the bonnet and bottom flanges were drilled and tapped. The internal webs were also bored and threaded in order to accommodate screwed-in seat rings. Assembling the dual-port valve body required extra effort to ensure that when the valve plug moved to the closed position, its seating surfaces contacted the seat rings simultaneously. All of these machining and assembly procedures required time and effort that built cost into the final valve product.

The 1960s-design globe valve with its cage-style, drop-into-place internals avoided many of these cost creators. Its body casting minimized material use while still complying with all design codes and requirements. It eliminated the machining and assembly of the previous design’s bottom flange and internal seat-ring ports. And since the new trim style relied upon the flow cage to control valve-plug movement, the potential for misaligned valve-plug guides was gone (Figure 2).

**Benefits for the user**

While the valve manufacturers realized a cost reduction in the new versus old design, so did the valve user. Tight shutoff reduces lost product. Improved reliability meant reduced maintenance costs and increased plant efficiencies. Double ported valves offered ANSI/FCI Class II shutoff, while the cage-designed valve provided a huge step change to ANSI/FCI Class VI shutoff capability. Recapturing this lost process equated to money back in the user’s pocket. Maintenance became less of an issue with cage-style trim. For the most part, a changeout of trim components required pulling out the old and dropping in the new — a relatively simple procedure.

**Protecting your investment with anti-cavitation trim.** Prior to the cage-style valve, answers to specific control problems, such as cavitation...
and operating noise extremes, involved use of expensive and often less-than-successful solutions. With simple trim changes, these problems could now be solved with cost-effective and reliable solutions.

Staging the pressure drop so that the pressure remains above the liquid's vapor pressure can prove effective in avoiding cavitation. With the pre-1960s valve, staging often involved the use of an orifice plate downstream of the main valve or the use of two valves in series. However, these techniques typically displaced cavitation from the main valve to the downstream restriction and did not effectively control the cavitation in the system. They also increased valve size, as less pressure drop was available to process the same amount of flow. Cavitation control was often less than successful, and the continual need to replace damaged piping components proved costly.

The cage-style valve delivered an answer to this cavitation dilemma with its specialized cages. For example, one cage design contains a multitude of highly engineered, shaped holes that improves the flow performance. The holes are radially aligned to flow cavitating jets of liquid to collide in the center of the flow stream, thereby avoiding damage to valve and pipe surfaces (Figure 3).

A more-extreme pressure-drop cage trim is designed specifically for liquid applications where pressure drops are above 207 bars (3,000 psi) and cavitation is a serious problem. It stages the pressure drop across successively larger flow areas, such that more than 90% of the overall pressure drop is taken in the first stages where there is little danger of bubble formation. Cavitation is completely avoided, thus protecting the valve, and providing an answer to the high cost of valve trim replacement.

The evolution of the specialty, anti-cavitation trims has extended to services where the fluid may have entrained particulate matter that could plug trim passages or cause erosion damage to conventional anti-cavitation trims. Used frequently in high pressure-drop applications up to 4,200 psid, this trim design employs a combined axial and radial flow path with large openings that allow particulate matter up to ¾ in. in diameter to pass through the valve. Due to the need for tight shutoff in many applications, its multi-stage design features a protected seat where the shutoff function of the valve is separate from the throttling areas of the trim. All significant pressure drops are taken downstream of the seating surface, and the seating surfaces are not worn away by throttling control action. The result, once again, is that replacement trim costs are avoided.

Continued product evolution of that mid-60s valve innovation created answers to other long-standing control valve problems.

The prevalent noise source of aerodynamic flow is fluid turbulence within the control valve body. Before cage-style trim, noise control techniques did not consider the reduction of flow turbulence as an answer. Instead, they centered on the use of acoustic wrap on the valve and adjacent piping, which served only to mask the noise. While this approach may have been adequate in protecting personnel who were working close to the valve, the noise would reappear downstream relatively unabated.

In the late 1960s and early 1970s, studies focusing on the mechanisms and abatement of control valve noise led to the development of different strategies to control fluid-generated noise. Today, putting these strategies to work are cage-style trims that utilize unique flow-passage shapes and multi-stage pressure reduction — capabilities not possible with previous generation valve designs.

A principle noise-reduction strategy is to break the aerodynamic flow stream into many small, parallel flow passages that ensure exit jet independence as flow exits the cage. This technique reduces the power of the noise source as it shifts the frequencies to a higher, more easily dissipated range. Up to 18 dB(A) of attenuation is typical.

Yet another cage architecture utilizes drilled hole technology to deliver...
excellent noise reduction for a wide range of vapor, gas and steam applications. Providing up to 30 dB(A) of attenuation, these cages also employ jet independence and frequency shifting. The design of this style flow cage gives the added benefits of flexibility of size, pressure class, materials of construction, rangeability and attenuation.

At the top of the noise attenuation hierarchy is the laser-cut, stacked-disk cage assembly (Figure 4) that provides up to 40 dB(A) attenuation in even the most severe applications. It employs unique passage shapes that stage pressure reduction to reduce acoustic efficiency and turbulence. Utilizing the expanding area principle to compensate for volumetric expansion of depressurizing gas, the velocity is managed through the valve. The parallel flow passages ensure exit jet independence, avoiding jet recombination and providing efficient coupling into the valve body. This stacked-disk cage design actually shifts the frequency spectrum, which reduces the audible acoustic energy and strain energy in piping. Combined with the complementary body design of the control valve, the solution prevents impingement on the body wall and offers enough cavity size and shape to control secondary noise sources.

Cavitation and noise control trims are but two examples of how control valve capabilities have evolved since the 1960s globe-valve revolution.

Environmental challenges

Continued studies into the mechanisms of fluid flow brought answers to other tough applications, such as extreme high-pressure control and related clearance flow problems. Cryogenic liquefied natural gas (LNG) services needed answers on how to ensure continued valve operation and survival at temperatures down to −321°F (−196°C), and valve metalurgists helped provide those answers. Environmental mandates required answers to valve-related fugitive emissions. Extended studies and evaluation programs led to packing systems that not only perform beyond minimum requirements, but also ensure smooth and continued valve operation.

While control valves have always been essential to the CPI, today the demands are different thanks to global competition and continued pressure to boost plant performance and improve process reliability. As never before, the control valve has a direct impact on a facility’s operational excellence — a combination of profitability, plant efficiency, quality and safety — putting it at the top of the process engineer’s list of critical control equipment.

Looking ahead, will there be another control-valve design revolution to match that of the 1960s? The basic concept of a globe valve with drop-in, cage-style trim continues to provide dependable process control over an extreme range of applications. However, while change and development of the globe-style control valve march ahead at a slow and measured pace, that’s not the situation with valve-related instruments.

The digital valve controller

The introduction of the digital valve controller some 15 years ago marked a step-change in control valve operation and maintenance by enabling functionality that goes far beyond that of the traditional analog or pneumatic positioner.

Today, the role of the digital valve controller is to ensure control valve performance and reliability, first by accurately establishing and maintaining a control valve’s operating position to reduce process variability, and second by diagnosing the operating health of the assembly to allow predictive and effective control-valve maintenance.

For example, the digital valve controller — when interfaced with advanced asset-management applications — provides a way to increase plant reliability and productivity while reducing costs. Diagnostic software utilized with the controller serves as a configuration, calibration and diagnostic tool. Of particular importance is that the software provides feedback regarding control valve operation, resulting in the identification of poorly functioning valves that are impacting process efficiency.

As an example, in one of many such instances when valve diagnostic software was utilized to evaluate 188 valves at a major chemical plant in Texas, only 14 of those valves actually needed service. By evaluating, diagnosing and prioritizing control valves for maintenance prior to a plant turnaround, the user realized substantial cost savings.

This ability to analyze a control valve’s operating condition, aptly called performance diagnostics, enables performance monitoring of the entire valve assembly (not just the digital valve controller) while the valve is actively controlling the process. Examples of identifiable issues include the following:

- Low air supply or pressure drop
- Incorrect regulator setting
- Dirty air supply
- External air leak (actuator diaphragm or tubing)
- Calibration shift
- Valve stuck
- Piston actuator O-ring failure
- Excessive valve-assembly friction
- Excessive valve-assembly deadband
- Elastomer failure
- Broken actuator spring

Performance diagnostics continuously analyze the valve assembly and passively gather data without disturbing or interrupting the control valve while it is in the process. These diagnostics may be used to help detect problems; and when identified, the diagnostic provides a description and severity of the problem, a probable cause and a recommended course (or courses) of action.

Dynamic performance diagnostics are run optimally as part of a plant shutdown. These full-stroke tests vary the digital valve-controller setpoint and plot valve operation to provide insight into the dynamic performance of the valve/actuator assembly. Performed while the valve is isolated from the process, the tests include valve signature, dynamic error band, step response and stroke check.
Since a process control plant, regardless of industry, makes money based on its ability to minimize variability and maximize availability, the digital valve controller becomes an essential control valve component thanks to its ability to maintain control valve position, provide assembly diagnoses and enable predictive maintenance.

The digitally integrated valve

While keeping up with the latest revision of our consumer electronics, our culture has grown accustomed to products that are intuitive. These products allow us to do our jobs faster, more efficiently and most often with fewer resources. A recent innovation was the design of the digitally integrated control valve (Figure 5). The valve, actuator and digital valve controller were designed together, providing optimized performance and using the theoretical minimum of parts needed. Alloy constructions became much more affordable to the CPI user than previous valve designs, including the 1960s cage-style design. Reliability and maintenance were improved and, of course, the cost to the user reduced yet again.

This concept offered a tidy and compact solution, having eliminated external tubing and reducing the overall envelope dimensions. Now the digital valve controller could sense the valve stem position without using mechanical linkages inherently prone to wear. A magnet array connected to the valve stem slides through a Hall-effect sensor in the digital valve controller to detect valve travel. The digital valve controller paired with this control valve provides a local pushbutton for calibration. This feature brings the control valve into a new realm of intuitive use for instrument and control technicians.

The decision to design this product may have been driven by economics, but it was made possible by means of modern tools and processes previously not available. Tools — such as computer aided design (CAD) software — improved the ability for foundries to make consistent patterns to capture the design intent. Today, patterns are made directly from 3D models to ensure accuracy. Finite element analysis (FEA) is used to calculate stresses to optimize casting weight. Fluid dynamic modeling is used to analyze flow geometry for an optimal performing design. Manufacturing processes also evolved to a new level of efficiency. Not only are the tools carefully defined for each step of assembly, but also the process in which the product is tested throughout assembly, both improve the overall quality. Another level of precision and quality is achieved by using the lost wax-casting process to achieve design goals. These modern processes finally provided the means to execute the ideal control valve design for CPI users — smaller, lighter and less expensive.

Wireless valve control

Wireless technology in process control is becoming a game-changer. It lowers implementation costs, creates new approaches to valve monitoring and control strategy, and expands access to areas within the plant that were previously out of reasonable reach.

While the simplicity and economic advantages of wireless are changing new-project and new-installation wiring practices, the largest target of opportunity lies with valves that are already installed. Plants that implement wireless feedback gain the competitive advantages of reduced operating costs, improved product quality, greater product throughput and increased levels of worker safety.

Available today are smart wireless adapters for use on digital valve controllers that utilize the HART communications protocol. The adapter provides an easy way to access otherwise “stranded” valve diagnostics. The wireless adapter also can be used to pass along important valve operating and maintenance information, including valve friction, pneumatic leaks (air mass-flow test), and instrument problems (I/P [going from an electric signal to a pneumatic signal] and relay integrity test), that can be viewed and analyzed to improve process performance.

Wireless valve monitoring is available today. Wireless valve control is not. Yet many plant operations are embracing today’s position monitoring and looking toward wireless valve automation and control in the near future. Designers of control strategies will take increasing advantage of wireless instrumentation to expand the reach of automated valve control as well as gain increased valve-health awareness. The digital communications link with globe valves has decreased the cost of commissioning thanks to auto-tune and auto-calibrate features.

The possibility of wireless control will greatly reduce commissioning cost. Performance diagnostics improve the reliability of globe valves by communicating impending problems so that repair can be planned and executed prior to an unplanned outage. Once again, the driving force of globe valve evolution is economics, reducing the total cost of ownership. This, in all likelihood, is the next control valve revolution.

Edited by Dorothy Lozowski

Emily Hoop is the marketing manager for sliding stem control valves with Emerson Process Management, Fisher Business Unit (301 South 1st Ave., Marshalltown, IA, 50158; Email: Emily.hoop@emerson.com; Phone: 641-754-3750). She has been with Emerson for 9 years. Hoop started her career in sales engineering and worked in both the chemical and refining industries. She received a B.S. in mechanical engineering from Iowa State University of Science and Technology.