CONTROL VALVE EVOLUTION

INTRODUCTION TO THE PUMPS, VALVES AND SEALS REVIEW

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Since the early stages of downstream installations, the need for controlling flows and pressures, often under severe conditions and involving aggressive fluids, has been a specific prerogative of the industry. Today, even more so, control valve technology continues to play a critical role within downstream plants, as well in other process industries (energy, chemical, etc).

The oil and gas processing industry, with its gigantic dimensions and high degree of technological sophistication, uses a large number of control valves, installed in new as well as pre-existing plants. In most cases, control valves are assigned to critical or vital tasks for process performances, as well machinery control and protection.

In particular, special control valves for compression and pumping applications, but also for other services such as process fluid supply/circulation and product transfer, significantly contribute to determining the overall robustness of the plant, with a consequent impact on production rates, operational costs and, finally, on overall plant profitability. Today, the control valve market covers several applications in the downstream sector, with a wide range of sizes and types (from 0.5 - 20 in. and 0.001 - 5000 flow coefficient [CV]).

Being present in almost all plant process loops, a control valve can essentially be seen as an interface between a low energy level (the regulator) and a high energy level (process). The control valve's main task consists of varying the flow rate and the pressures of the fluid, accommodating process needs and requirements.

Fundamentally, the control valve is a modulating component slaved to a control signal. Some of its specific requirements are:

- Internal flow patterns and regulating areas must guarantee a correspondence between the stroke commands and flow output (CV curves, inherent and installed characteristics).
- Material should be adequate for the service conditions and operative fluid.

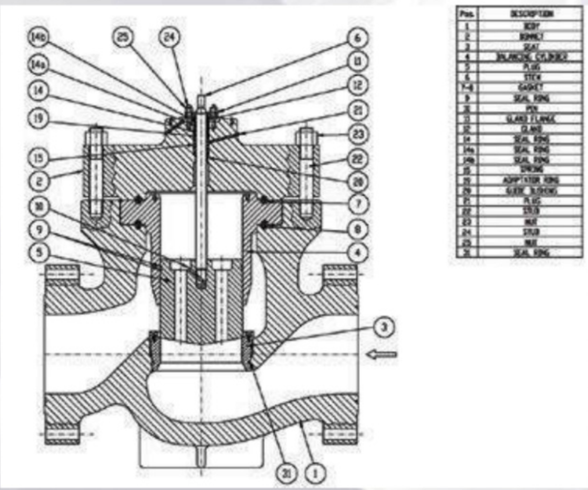

Figure 1. Sectional drawing.

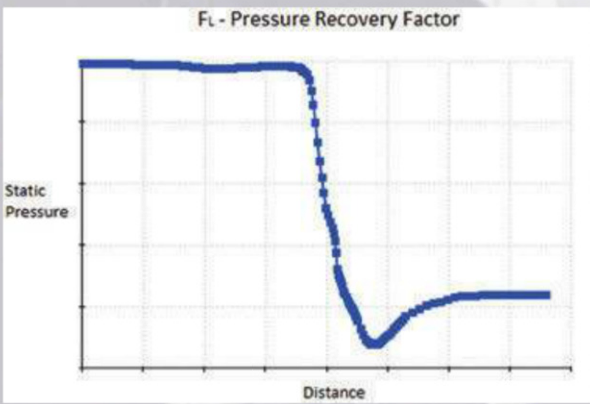

Figure 2. Pressure recovery factor.

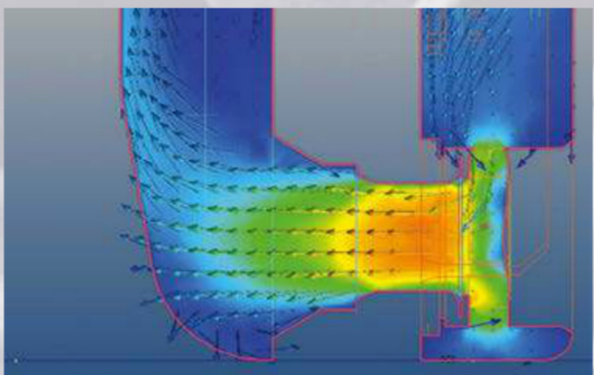

Figure 3. Velocity vectors.

- Pressure drops should be controlled so as to avoid flashing and cavitation phenomena.
- The valve should be operated by an actuator of modulating type, which produces a finite stroke for a corresponding finite variation of signal.
- The valves should be free from friction or other significant obstacles during the working range (stroke).
- Temperatures and pressures should be supported without producing excessive friction on the packaging than is necessary, providing an adequate design of the bonnet.
- The valve response velocity should be adequate to the requirements of the specific application. In some special services (e.g., anti-surge valves), valve opening times must be very quick (a maximum of 1 - 2 seconds from closed to fully open).

A typical control valve includes several components, each one with its own specific peculiarities and characteristics. Figure 1 shows a typical control valve sectional drawing with its main components.

Control valve technology advancements

Right from the beginning, the globe control valve industry existed in a state of continuous improvement, both from a design point of view and from a performance one. Due to the importance of this device, and the direct impact on overall plant performance, over the last few decades, plant managers have pushed control valve original equipment manufacturers (OEMs) towards continuous technological developments, with a goal of final market competitiveness.

Control valve technology has developed in terms of increased performance requirements (the capability to manage the most severe plant conditions), and in the reduction of overall manufacturing and operational costs. The following sections will provide a brief overview of some of these technology improvements.

Material selection

The selection of control valve materials has always been one of the most difficult design tasks. In fact, the designer has to consider both the process fluid characteristic and the environmental boundary conditions; sometimes these two requirements are at odds with each other, leading the designer to find an acceptable compromise. Great strides have been made since the time when manufacturers simply used stainless steel for the majority of valve services.

In some special services, where the valve typically stays closed (e.g., vent applications), the presence of very high differential pressures may generate leakage flows with very high velocities, which produce intense erosion effects. In such conditions, the technology trend has moved towards the adoption of very hard surfaces obtained with tungsten carbide coatings. These solutions require the execution of an extremely accurate and controlled welding process, with the aim of achieving the intimate melting of the coating material onto the base one. Furthermore, when working on absolute high pressures, the geometry of the trim becomes critical: in these conditions it is important to avoid triggering torsional vibration modes, which may be caused from the action of non-optimal flow distributions, and create destructive phenomena.

For these types of applications, an accurate and adequate choice of the material, and the implementation of a state of the art technological process, are key for a successful valve service lifetime.

The compatibility between fluids and materials, with regard to special phenomena such as erosion and

Figure 4. Wrong plug material selection.

Table 1. ISA trim outlet kinetic energy criteria

Service conditions	Kinetic energy criteria		Equivalent water velocity	
	psi	kPa	ft/s	m/s
Continuous service, single phase fluids	70	480	100	30
Cavitating and multi-phase fluid outlet	40	275	75	23
Vibration-sensitive system	11	75	40	12

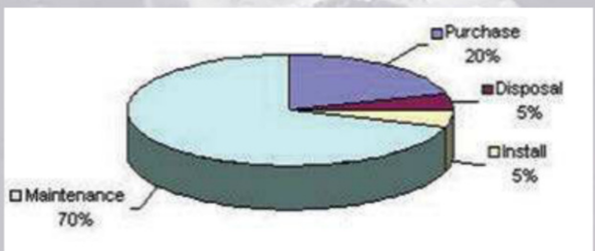

Figure 5. Control valve lifecycle costs.

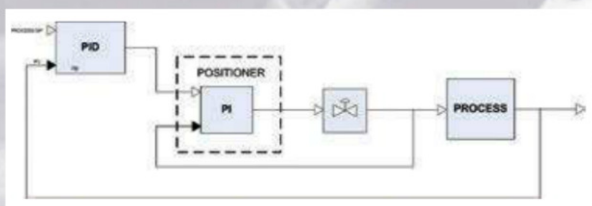

Figure 6. Typical process loop.

corrosion, is often indicated by the manufacturer guidelines.

In high temperature steam applications, for example, the use of martensitic stainless steel is very common, due to its good mechanical properties at elevated temperatures, low thermal expansion and an acceptable corrosion behaviour. For applications with erosion/wear, Co-Cr alloy is widely used (e.g., Stellite®), as its particular intermolecular pattern provides a very high opposition to the erosion, meaning that it is particularly suited for processes with dirty fluids, or with very high velocities inside the valve.

Computer aided engineering

Today, the increased adoption of computer aided design practises (finite element method [FEM] and computational fluid dynamic [CFD] simulations) allow operators to thoroughly investigate and understand the actual stress distribution and flow patterns inside a valve. These developments have provided manufacturers with reliable engineering procedures, aimed to address design decisions and achieve optimal solutions.

Nevertheless, the best solution is not always univocal, and is not always the one that simply increases the valve service life: trying to achieve a 20% lifetime extension may require the operator to double trim costs, which may not always be a desired choice. Consequently, the problem becomes a search of optimisation and trade-off between the advantages (lifetime extension) and disadvantages (manufacturing costs).

OEM technical guidelines have also played an important role. Provided by different manufacturers, these guidelines provide a useful tool for valve selection and application. However, it is interesting to note that these guidelines sometimes conflict, depending upon the individual OEM experience.

The introduction of CFD also influenced the development of the control valve industry. The increasing computational power, and the availability of reliable codes, allowed for consistent improvements to the valve design process, and the integration of the OEM experience with reliable simulation predictions. Software capabilities, therefore, are a valuable tool for the designer, but the overall design loop must be closed for final device physical testing. Globally, the implementation of CFD methods results in better designs in shorter turnaround times, and in lower project costs.

Considerable steps have been carried out with regard to the investigation of cavitation and flashing, which were, at the beginning, not fully understood and approached mainly on an empirical basis. Nowadays, these phenomena have been, and continue to be, intensely studied, since most plant issues are related to them. Even though no known material is totally immune from damage caused by cavitation, simulations carried out using CFD provide the designer with the ability to evaluate actual critical flow levels, possible damages and sensible internal areas. Figures 2 and 3 show some examples of CFD and FEM valve analysis developed by IPC.

In some specific applications with high pressure drops, it is well known that the pressure in the vena contracta may go beyond the level of the vapour pressure at the operating temperature, resulting in the onset of cavitation and flashing. For such cases, some OEMs used the multiple pressure drop technique, which involves dividing the overall differential pressure across the valve within a number of smaller pressure drops in series (multiple pressure drop trim). Several designs have been proposed over the last few decades, with good results.

Kinetic energy and wear correlation

The correlation between flow velocity and valve trim wear/damage has always been taken into account by valve manufacturers. Many of them have also published 'rules of thumb' concerning suggested velocity limits for both liquid and gas applications, depending on the valve size and selected materials. At first glance, this approach could seem accurate enough for valve sizing purposes. Indeed, velocities are undoubtedly important, but the type of fluid and its properties must also be taken into account to achieve an accurate approach to the problem. To do this, a more general criterion has been developed, based on jet energy at the vena contracta outlet. Despite the fact that the expression of kinetic energy, of a fluid flowing in a pipe, can be traced back to the beginning of the last century, even today it is not well diffused among all manufacturers – most likely because it is not yet endorsed by main control valve standards. Nevertheless, large impacts and benefits can be forecasted using this approach, and, for this reason, the design department at Bellino S.r.l. uses the kinetic energy sizing approach to identify advantages on trim wear and valve vibrations, especially in severe service applications.

Maintenance programmes

Figure 5 illustrates the importance of maintaining globe control valves, with regard to lifetime costs. Sometimes, the only discriminating factor between manufacturers is the purchase cost, but it is interesting to note that the purchase represents only a fifth of the overall valve lifetime cost (from design to end of service), while the remaining 70% is attributable to maintenance activities.

In contrast to minor devices in the control loop, which, sometimes, may be fixed or adjusted without the need for a plant shutdown, for control valves, in many cases, maintenance and repair activities may require a section of the plant to shut down. For this reason, proper and timely valve maintenance is fundamental.

In the past, the more common solution was 'fix only after the valve fails' (a reactive approach); however, nowadays, a new approach is currently used, involving the adoption of preventive methods and periodical scheduling of maintenance works.

Furthermore, great results have been achieved over the last few years through the use of a predictive approach base on specialty analysis (such as vibration, and noise and leakage detection), used for premonitory symptoms of incoming failures.

In order to support better maintenance decisions through valve diagnostics, special solutions have been studied and applied by OEMs. For some critical valves, special systems with double packing and leakage detectors have been used. In these cases, damage to the primary packing is detected through a measurement of the pressure drop within the packing chamber, or through the installation of external flow switches for leak detection, or both.

On other occasions, the availability of the actual stem position signal allowed a continuous monitoring of the difference between the latter and the request position signal coming from the upper level control system. The detection of an excessive difference among these two signals has been used as indicator of valve mechanical failure.

Control systems and valve accessories

Furthemore, the valve control loop has undergone continuous improvements over the last few years. Due to the availability in the market of more sophisticated positioning systems, considerable advantages have become accessible to valve users.

The valve control technology offering now includes advanced systems for valve auto-calibration (highway addressable remote transducer [HART] protocol) that allow users to avoid possible errors, decrease valve setup time, and reduce installation costs. Such systems allow users to check the valve calibration remotely, as well – when specific process conditions allow.

Often, boosters are used in order to increase the pneumatic power of the positioner when higher actuating speeds are requested. This is the case for applications in rotating machinery protection, such as anti-surge valves.

IPC, as Bellino's advanced engineering partner, develops many special solutions for centrifugal compressor anti-surge valves. In these cases, very short periods are permitted from closed to 100% open state, and special analyses are developed in order to verify the effective valve dynamics and capability to satisfy the requested machinery protection requirements.

Conclusion

Globe control valve research and development is a non-stop process, and the market has experienced exponential growth during the last few decades. The diffusion of powerful and demanding simulation software, and the parallel availability of suitable computers, has allowed control valve OEMs to access the computing power necessary for the execution of accurate FEM and CFD analysis, gaining considerable advancements from the design stage.

Furthermore, the integration of control valves within more sophisticated control systems has been a common path for control valve installation in downstream projects, allowing for a better valve enslavement to process requirements, along with more precise diagnostic indications for the reduction of operational and maintenance costs.

Together with the above mentioned features, new maintenance approaches and careful scheduling offer customers increased performance and reliable decrement of device downtime periods, with all consequent potential production benefits and cost reductions.

Within this industry trend, the Bellino design department has always focused its attention and resources on control valve design improvements, especially for severe service globe control valves.

IPC is now also investing in the development of control valve technology improvements, for example, with a new type of control valve (Digiflux, patented) with digital flow regulation, for applications within line compact mounting, high flexibility (electronically configurable CV characteristic), high rangeability and fault tolerance. HE