

Control ball valves for severe services

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Control valves are primarily classified according to the type of their obturator motion which can be linear or rotary. Among linear, the globe valve has reached a leadership in the oil & gas and power markets thanks to the optimal control performances shown in several applications. Actually the globe valve is the most popular product among control valves. Rotary control valves use has grown in the last 30 years thanks to a series of advantages specific of their design. Butterfly and control ball valves started progressively to increase their presence in the market and today the process engineer can choose among several products. The experience has taught that butterfly and control ball valves can be valid competitors of the globe valves for most of not critical applications but also that they have to give up for severe services. In this article is introduced the 4-4009 series Limiphon Control ball valve, developed by Parcol S.p.A.. Its design is meant to combine globe valve strengths for severe application and rotary control ball valve advantages. It wants to represent an alternative to the most popular high performances globe valves also for severe service.

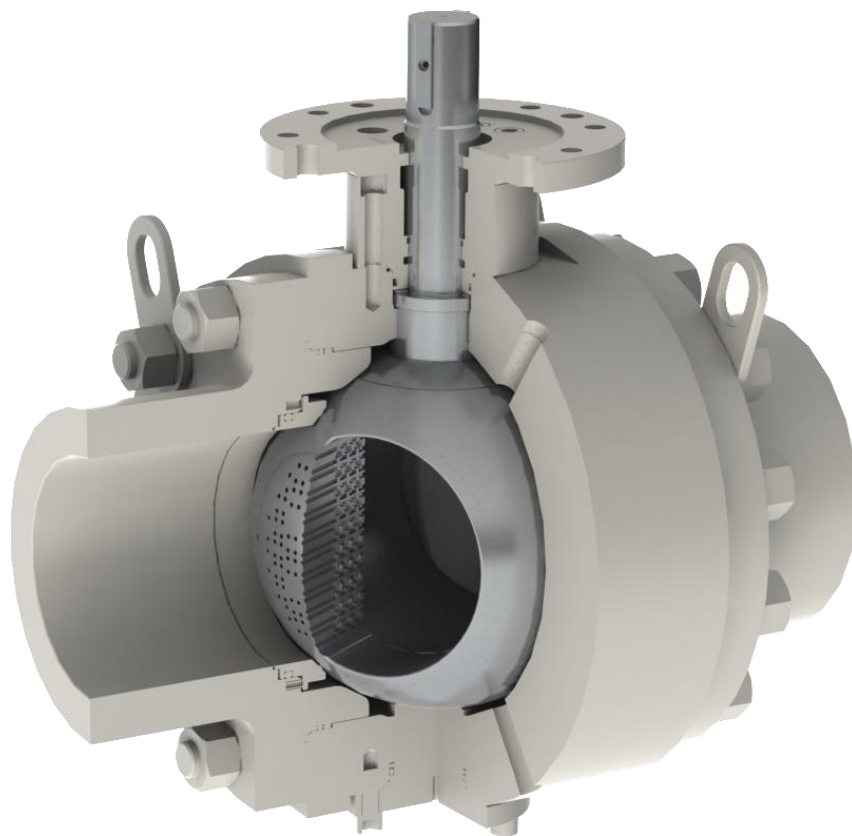


Figure 1

Multi-stage ball valve vs. double cage globe valve

In the first part of the paper all the advantages and disadvantages of a control ball valve, compared to a globe type, are summarized. A typical control ball valve equipped with drilled plates, as the Parcol 4-4005 series Perforated Plates valve, and Parcol VeGA 1-6943 series double cage globe valve are compared (figure 2). Since for both valves the working principle is based on the multi-stage + multi-path concept, from the fluid-dynamic point of view they can be considered as competitors. Thanks to the trim geometry, the velocity in vena contracta is controlled, the risk of cavitation with liquid flow is minimized and SPL (Sound Pressure Level) produced with gas flow reduced. These control valves do not represent the top of the range as are suited for medium-severe services.

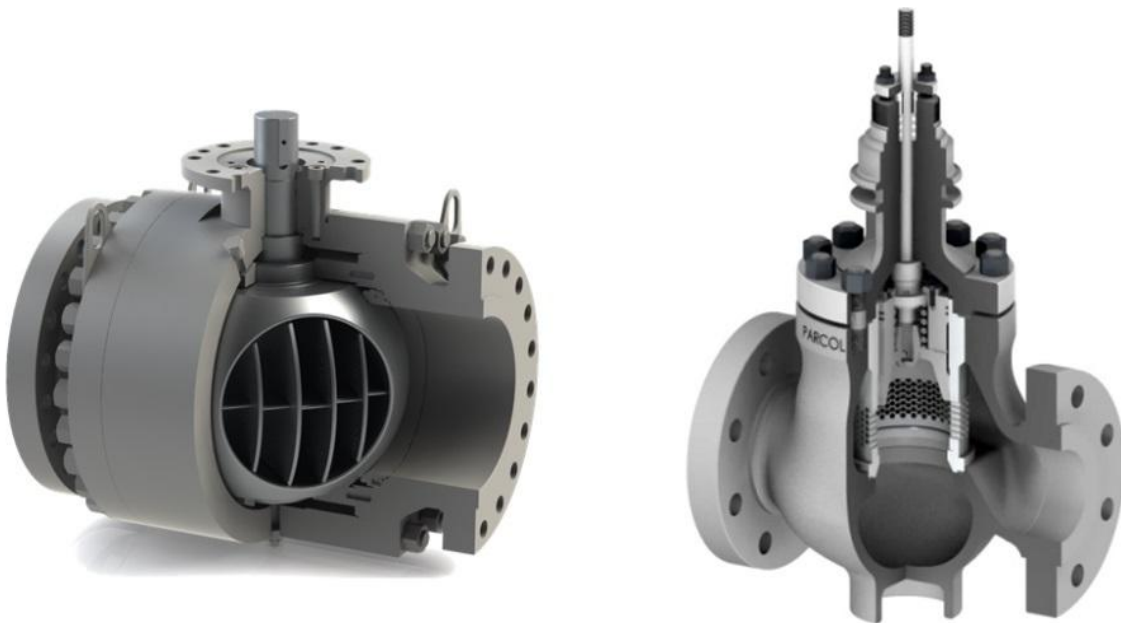


Figure 2

More in detail, the main advantages of a control ball valve compared to a globe valve are:

- lower weight of bigger valve sizes,
- higher rated capacities,

- higher seat sealing properties.



Figure 3

The curve of the weight of the two products with respect to NPS shows that after NPS 12 (figure 3) a control ball valve is lighter than any globe valve of the same size. This advantage reflects on raw materials costs and makes control ball valve a cheaper solution.

It is also possible to compare the two valves at the same rated capacity. Most of the control ball valve models take advantage of the rotary motion to create obstacles at intermediate valve openings minimizing the resistance at fully open position. Valves with drilled plates inside the ball like Parcol 4-4005 series are the most common example of this design. Due to the true axial flow, turbulences and pressure drop are minimized when the valve is fully open, giving very high rated capacity (figure 4). For this reason usually a caged ball valve of one or more size smaller is the direct competitor of a caged globe. Figure 5 shows the rated capacity with respect to NPS for Parcol 4-4005 control ball valve and VeGA 1-6943 double cage control globe valve. This is a preliminary analysis that doesn't account for other fluid-dynamics performances but that easily shows how a control ball valve results to be cheaper every time higher capacities are required.

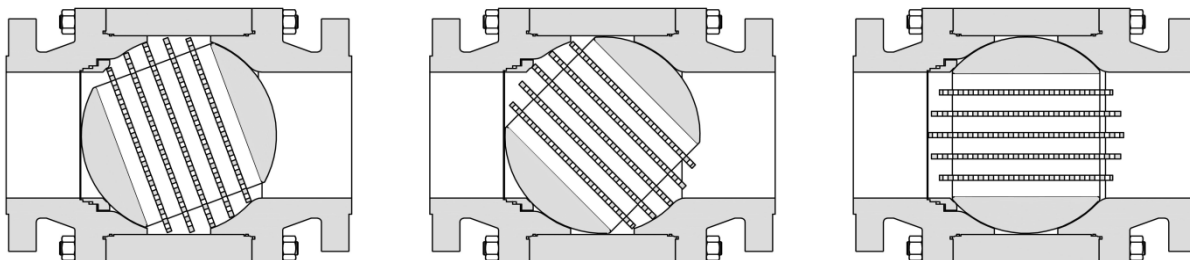


Figure 4

The third advantage of the ball valve compared to the globe type is the better seat tightness: every time is required a double function of controlling and blocking the flow, control ball valve is the most reliable solution. No direct flow impingement on the seating area ensures the nominal leakage during all valve life against wear and erosion.

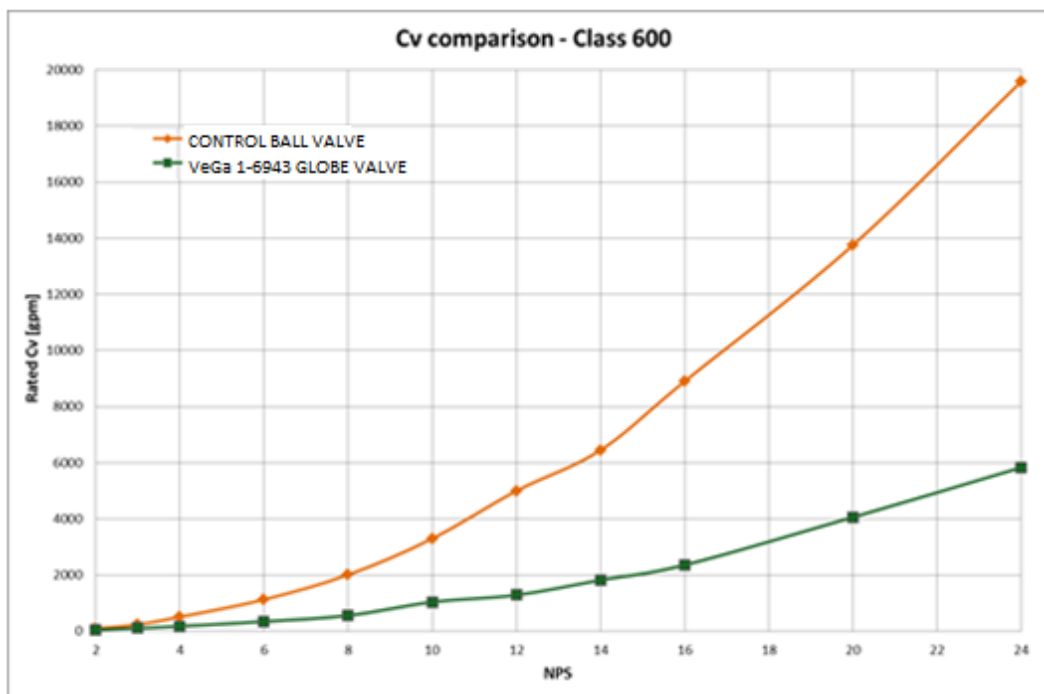


Figure 5

As previously mentioned there are also disadvantages of the rotary motion Parcol 4-4005 control ball valve compared to double cage globe valve such as the Parcol VeGA 1-6943, all related with the better fluid-dynamic performances of the latter one:

- higher values of F_L and x_T coefficients which remain constant over the whole range of valve opening;
- independent fluid channels in the trim, with better control of velocity and more accurate prediction of the produced SPL.

Taking into account the comparison between F_L and x_T coefficients, the Parcol 4-4005 control ball valve ensures the best fluid-dynamic performances only up to the intermediate travels where most of the stages are involved. On opening, the number of effective stages decreases together with the recovery factor F_L and the limit pressure ratio x_T . When the valve is fully open, the drilled plates become less effective on limiting noise and cavitation. Even at the very first opening degrees the trim is not completely efficient, because the drilled plates inside the valve are still not able to work properly resulting in less favorable fluid-dynamic performances. As a matter of fact control ball valves with cage trim usually are not usually recommended for services with high Delta-P and low flow rate. Conversely the VeGA 1-6943 globe valve can guarantee the same performances throughout the whole travel: during its lift the plug uncovers several rows of holes in the drilled cage, allowing stream in a completely independent and controlled way. Every row of holes of the cage is separated from the others and represents an independent flow path. All the flow that crosses a line of holes in the internal cage is forced in a controlled manner towards the corresponding line of holes on the second cage (figure 6). This behavior is the same all over the entire stroke of the valve, thus ensuring changeless fluid-dynamic performances at different working positions of the valve. Also at small openings with high Delta-P the valve is very efficient limiting damages due to cavitation or erosion. The figures 7 and 8 show a comparison of the two valve types.

In conclusion, if a minimum F_L or x_T is required at a wide range of capacities, Parcol 4-4005 series control ball valve may not be suited (very small flows with high Delta-P) or has to be oversized to work in the efficient range (intermediate Delta-P at very high flow). This phenomenon contrasts the advantage shown at figure 5 reducing the gap between interchangeable

globe and ball valves to one or two sizes. Figure 9 summarizes this concept: valve weights instead to be plotted at the rated capacity are compared at the values where the cages are still efficient; it means that for the globe valve the Cv value is the rated one, for the caged control ball valve is an intermediate Cv where a sufficient level of fluid-dynamic performances is ensured.

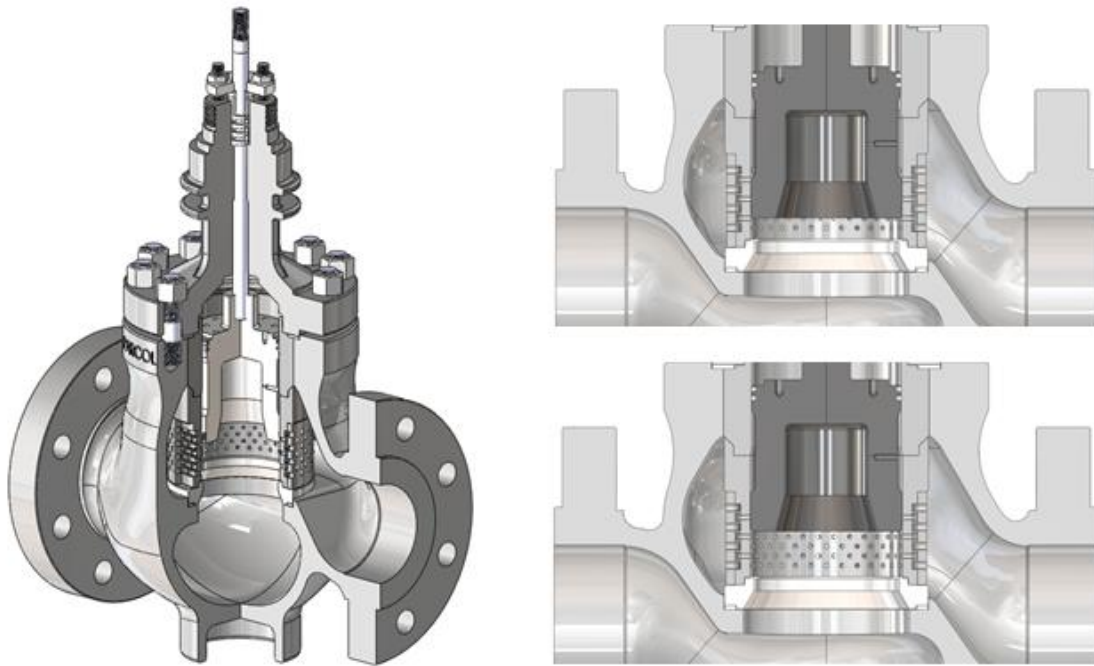


Figure 6

The second advantage of the caged globe valve over the caged ball is the better control of the performances which is possible only with the typical design of the globe valve trim: this is a real multi-stage + multi-path trim, because the fluid paths are really independent and the change of the passage area along the path (the “expansion ratio”) is strictly controlled.

The caged ball is inspired by the same concept, but the multi-stage + multi-path is provided only in an average vision, because the fluid channel are not truly independent, and the expansion ratio is not uniquely determined. When the flow enters into the ball and impacts the internal stages, velocity's intensity and direction is different along a drilled stage. The effect is to have slightly different performances along its surface. Moreover the same internal stage has to work with several ball inlet areas due to the dependence of the ball inlet area to the valve opening (figure 4).

This fact limits the efficiency of the stages to a narrow range of valve openings (figures 7 and 8). This ensures a better control of velocity for the globe valve and more accurate prediction of the produced sound pressure level.

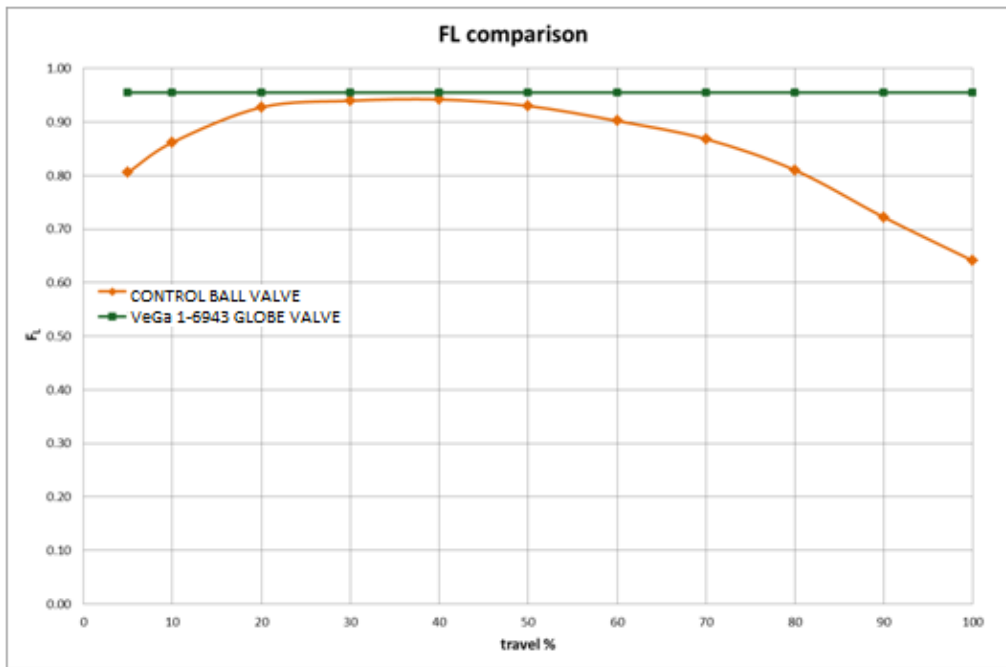


Figure 7

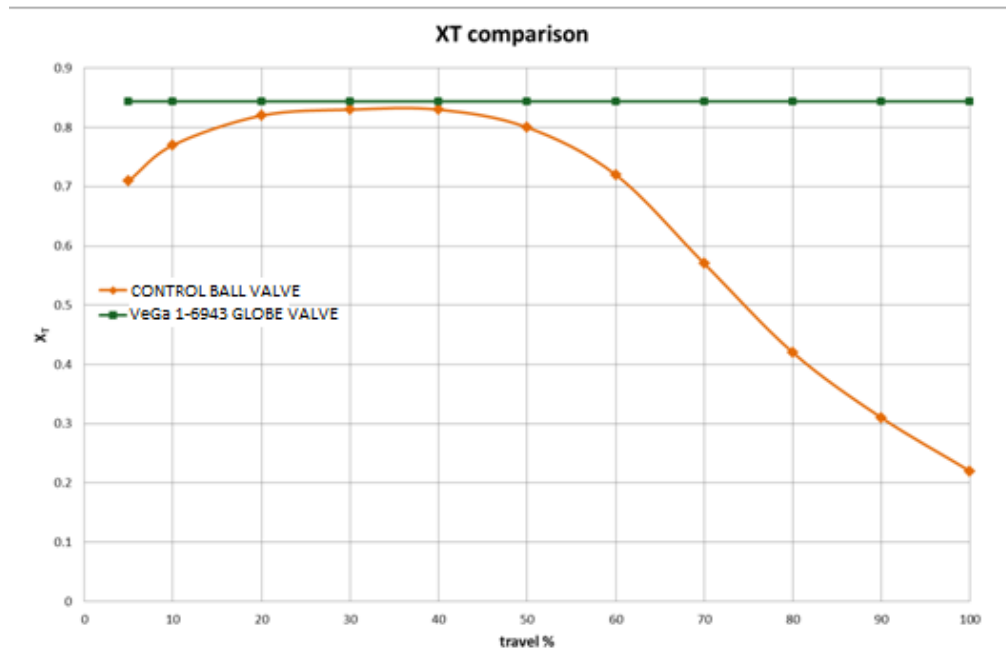


Figure 8



Figure 9

In conclusion from the comparison between Parcol 4-4005 series control ball valve and VeGA 1-6943 series globe valve it can be stated that the globe valve ensures better and constant fluid-dynamic performances, while the ball valve has an advantage in terms of weight at the same capacity and from seat sealing properties point of view, with an optimization based on a tradeoff between maximum capacity and fluid-dynamic performances in a limited range of valve openings.

Control globe valves for severe services

Fluid-dynamic performances of globe valves trim has been improved by Parcol since the 70's. Starting from the concept of multi-stage + multi-path, a trim with labyrinth channels has been developed. It is the so called Limiphon trim that ensures the best regulation performances for very severe applications, having at its disposal a wide range of geometric solutions in terms of number of stages and expansion ratios (figure 10). With Limiphon technology the best anti-noise and anti-cavitation behaviors can be achieved.

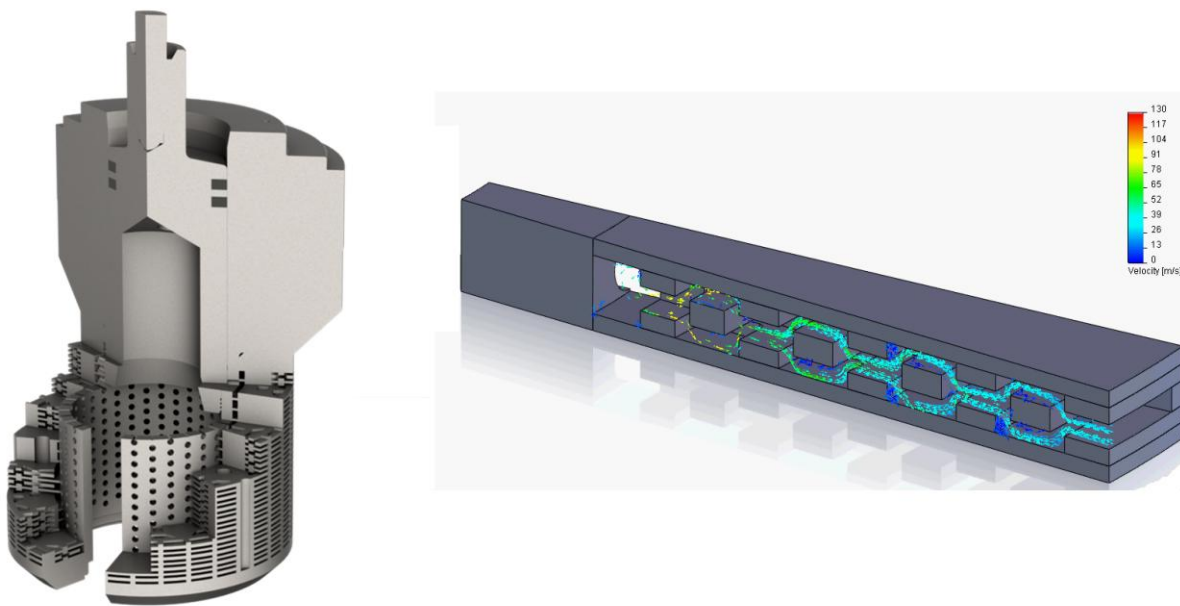


Figure 10

The multi-stage + multi-path trim splits the pressure drop in a suitable number of stages to reduce the generated acoustic power by limiting the flow regime of each single stage to subsonic one (lower acoustic efficiency, figure 11). At the same time the flow is split in a large number of passages to increase the frequencies of the produced noise maximizing the TL through the pipe wall (figure 12). With this geometry the velocity in the valve is perfectly controlled with the advantage of a better prediction of the produced sound pressure level and of the damages created by erosion.

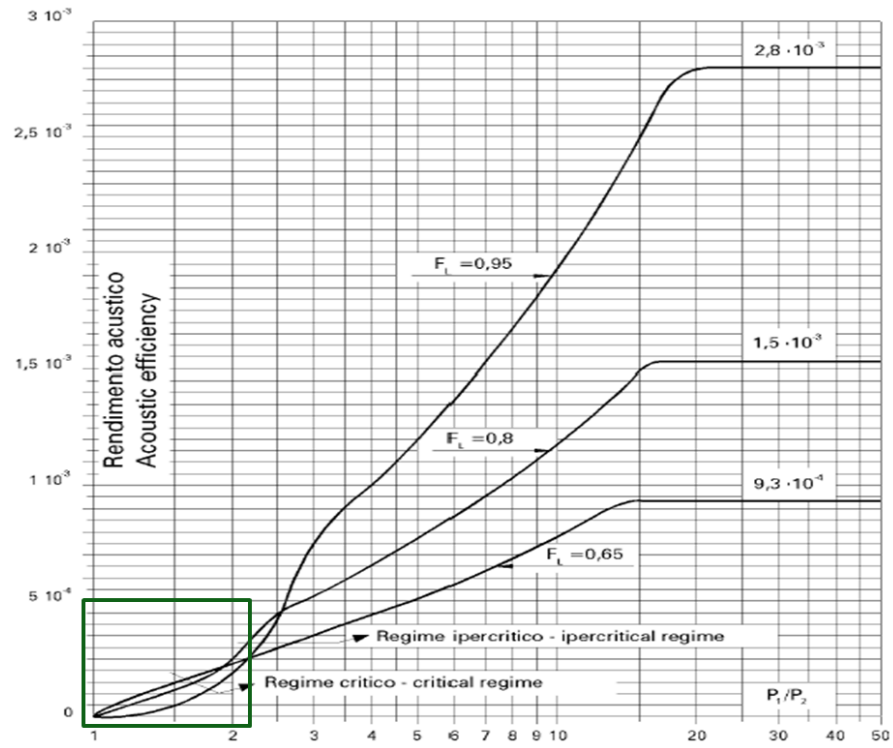


Figure 11

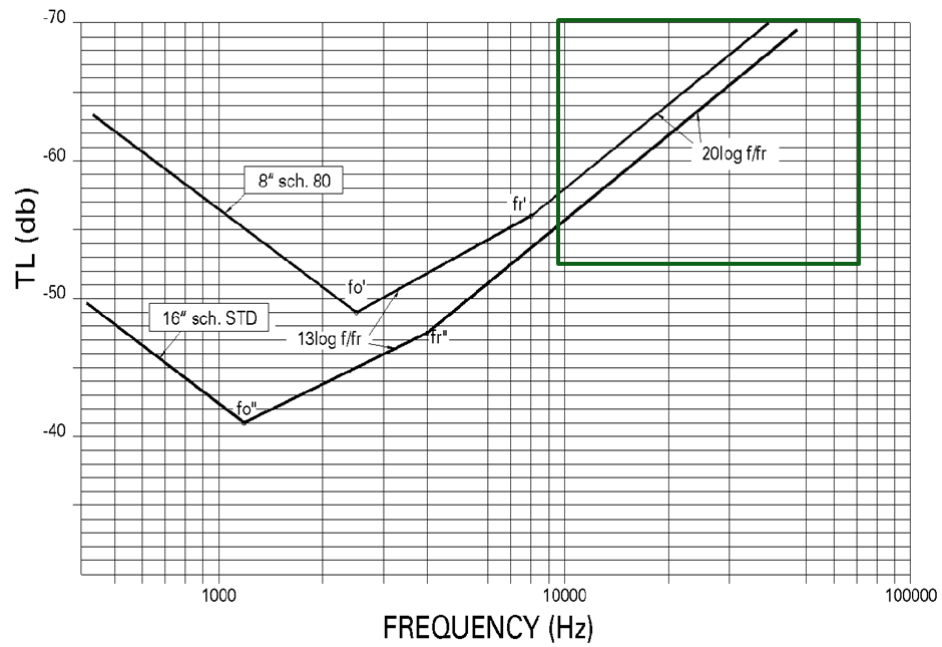


Figure 12

The Parcol 1-6962 series Varistep globe valve, a combination of Limiphon and of single cage trim along the valve stroke, increases valve performances and rangeability, positioning this valve at the top of the globe valve product range (figure 13). A first cage feeds, in a completely uncoupled manner, every single labyrinth located behind it. The pressure drop is created by maintaining the velocity in every flow section under control. The flow field of each labyrinth of the same row is just alike: the result is the best possible control of the fluid-dynamic performances. F_L and x_T up 0.999 can be achieved. The design of the labyrinths changes from the very first opening to the fully open position where the internal cage is the only active trim stage. This characterization is designed to suit the typical process requirements, ensuring the best fluid-dynamic behavior at each valve stroke, and is the key to increase the valve rangeability.

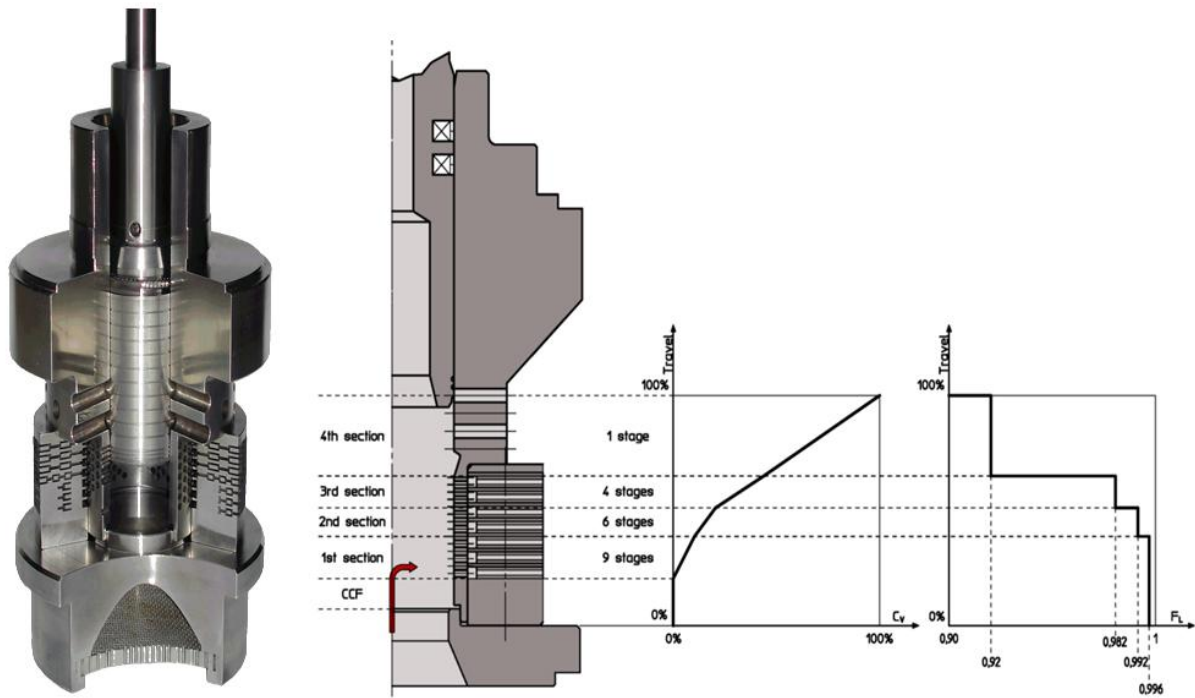


Figure 13

4-4009 series Limiphon: the control ball valve for severe services

A product with the same performances among control ball valves is really uncommon. 4-4009 series Limiphon control ball valve want to fill this gap. *What* has been done? The performances of the Limiphon trim for globe valve have been exported to a control ball valve.

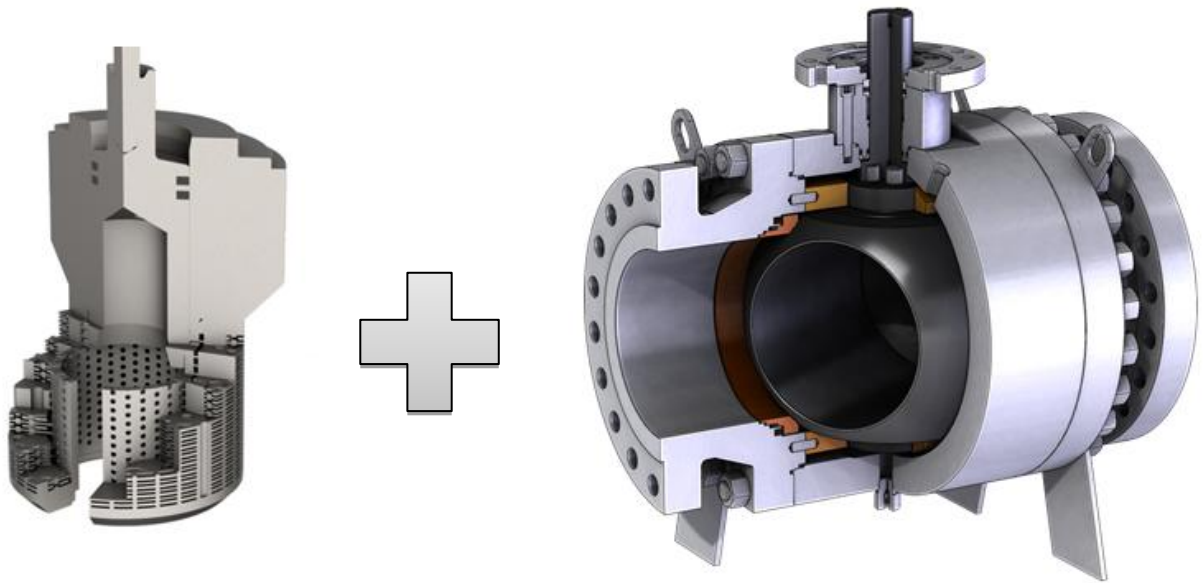


Figure 14

But other two questions automatically arise: the first is *why*. Typical problems of controlling the fluid-dynamic performances inside a ball valve have been already explained together with the natural tendency of a globe valve to be designed also for severe applications. The idea is to take advantage of the lower weight of a control ball valve at bigger sizes to offer a cheaper solution with equivalent efficiency on the entire stroke range of a globe valve designed for severe service, saving the better sealing of control ball valves that is a great pro especially when also a block action is required.

The second question is *how*: to achieve the same result is important to obtain the full control of the performances inside the trim. Starting from Parcol experience, a new labyrinth suitable for the ball construction technology has been studied. Every labyrinth develop along the bore axis and is

individually fed at ball inlet (figure 15). This feature ensures the full control of the fluid-dynamic performances with the same principle of a globe valve equipped with Limiphon trim. At every valve opening only a set of labyrinths is active and the flow is split among them. The higher the number of labyrinths, the higher is the noise peak frequency and the TL. Very high pressure drops can be managed with both liquid and gas flows thanks to the multi-stage technology. Cavitation is avoided on liquid flows, while the aerodynamic noise can be reduced and maintained under a given limit with gas. The use of a Limiphon inside the bore gives the possibility to split the regulation function of the valve with the sealing function, thus avoiding damage and erosion phenomena at the sealing surfaces, ensuring a long lasting excellent tightness.

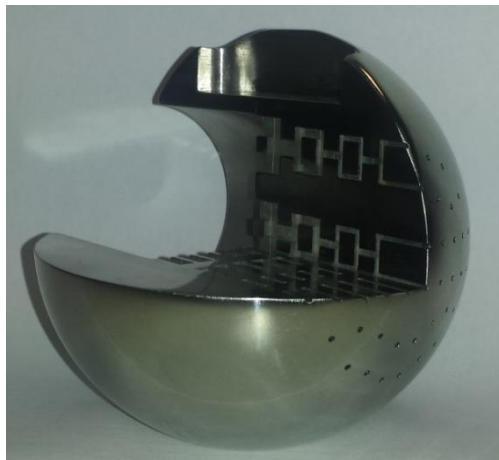


Figure 15



Figure 16

This solution ensures very high flexibility so the 4-4009 series Limiphon control ball valve can be customized to meet various requirements such as:

- *flow capacity characterization*
- *rangeability*
- *modulating precision*
- *fluid-dynamic performances*

The *flow capacity characterization* is achieved varying the extension of the Limiphon trim within the bore (the frontal area filled by the Limiphon insert, also called the Limiphon portion, Figure 16) and the type of labyrinths discovered at a specific valve opening, with an approach similar to that used for the 1-6962 series Varistep globe valve. In this way the characteristic curve of the valve can be customized on the specific application (figure 17).

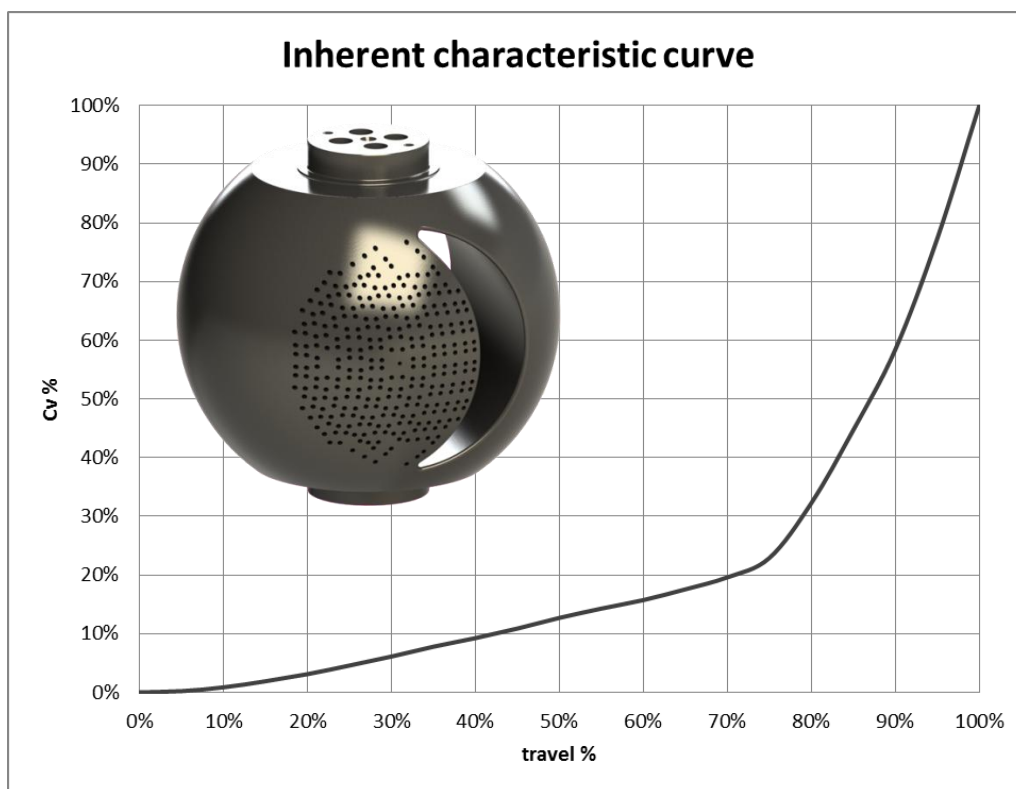


Figure 17

The valve *rangeability* can be increased up to 1000 to 1 values and over by modifying the dimensions of the channels working at the first openings degrees, and the extension of the Limiphon trim within the bore.

The *modulating precision* is very high in the working range of the Limiphon portion of the trim, thanks to a perfect multi-stage + multi-path concept, in which a fixed number of new channels are fed for a certain increase of valve opening.

The *fluid-dynamic performances*, in the Limiphon portion of the trim, are the best achievable by a control valve thanks to a trim design customized on the basis of the process data. The customized trim is obtained varying:

- *the number of openings* in the Limiphon portion

and for each channel:

- *the number of stages*
- *the expansion ratio*
- *the shape of the expansion.*

The number of openings of the fluid channels, as well as their dimensions, can vary as required, with the aim to saturate the trim with the highest number of channel, to obtain the highest possible Cv for the Limiphon portion of the trim. Enlarged openings combined with the increasing section areas along the labyrinths, provide the trim with a self-cleaning feature and make it suitable for dirty services with slurry or solid particulates. Moreover the dimensions of the channels allow an effective penetration of some types of hard facing, whenever requested.

The number of stages, the expansion ratio and the shape of the expansion (that is the law of growth of the areas) can be completely customized. Varying these features the velocity can be controlled, keeping it constant along the channels. For gas services, with high pressure drop, the use of an increased number of stages and of a higher expansion ratio, limits the sound pressure level produced, while for liquid application the use of less stages and expansion can keep under control cavitation and erosion phenomena due to high velocity.

DIMENSIONAMENTO VALVOLA LIMIPHON

Riferimento: Esempio compressibile

Espansione ultima lunetta: R= <u>4</u>		$\alpha = 0.04015$	$Q_m = 142$ kg/h	Portata massima:
Numero lunette: N= <u>4</u>		$r = 0.67$	$p_1 = 75.00$ bar	56 122 kg/h
Spessore disco lamiera: <u>2.0</u>		Cv modulo= <u>0.21</u>	$p_1 = 20.96$ kg/mo	
interno: <u>1.50</u>		Esponente di R= <u>0.223</u>	$p_2 = 6.50$ bar	
esterno: <u>1.50</u>		Lunetta 2/5 ed = <u>1.49</u>	$\alpha = 0.04015$	$p_2 \text{ per } 0.00$

Lunetta numero	Numero passaggi	Spessore monte lunetta [mm]	Sez. 10d & valle [mm]	Sezione assiale [mm]	Rapporto espans. radiale	Rapporto espans. lunetta	1/R/p	p monte	p valle	p sez.	v sez.	ro v ^{0.73}
Barra			8	3.5				75.0	66.5	59.77	209	1.0E+09
Barra			9	3.5				66.5	58.0	52.02	207	2.0E+08
1	1	1.5	3.00	6.7	1.00	9.0	1.00	58.0	43.0	35.54	591	1.5E+09
2	1	2.0	3.33	17.0	2.55	10.0	1.11	41.0	24.6	6.89	336	2.6E+08
3	2	1.5	5.67	24.0	3.60	17.0	1.89	24.6	15.1	4.21	389	2.5E+08
4	1	2.0	12.00	39.6	5.94	36.0	4.00	15.1	11.9	3.33	288	8.8E+07

ANDAMENTO

Sezione	passaggi	spessore	sezione
2	1.5	39.6	

Esponente di espansione: 1.0

Diametro sede [mm]: 87

Diametro interno [mm]: 108

Diametro esterno [mm]: 156

Numero moduli per term: 24

Cv term: 5.0

Numero term: 19

Cv pecco: 95.5

Spessa. disco separatore: 1.50

Cv gabbia: 180.71

Cv sede: 416.13

Area uscita [mm²]: 16.416

Area ingresso [mm²]: 2.736

Numero spine per pecco: 12

Corsa massima: 122

Cv totale: **82.931**

PARCOL

● Fluid velocity
— Speed of sound

Figure 19

The 4-4009 series Limiphon control ball valve has therefore its own collocation in the range of the control valves for severe service, combining the advantages of a control ball valve with the performances and accuracy in terms of regulation of a globe valve. The advantages obtained with this new trim are only partially limited by a geometrical consideration: while in a globe valve the capacity of the Limiphon trim, achieved by exploiting a cylindrical surface, can be increased varying the stroke of the valve, in a ball valve the available frontal section area is necessarily determined by the NPS and rating of the valve. This geometrical limit imposes the designer to find a tradeoff between the total capacity of the trim and the capacity of the Limiphon portion.

For all the consideration explained the 4-4009 series Limiphon control ball valve finds its most suitable applications, in gas and liquid fluids, for the severe services, where:

- a higher total valve capacity is required along with higher control performances only at small openings
- higher control performances are needed all over the valve stroke with limited capacity requirements but with an excellent and reliable tightness

Examples of these applications are given below:

APPLICATION	FLUID	NPS – RATING	P _{INLET} P _{OUTLET} [bar A]	T _{DESIGN} [°C]	C _v [gpm]	Tightness class	
Slurry pump recirculation Focus: anti- cavitation, high temperatures, erosion	Liquid with particles	6” ANSI 600	13.5 3.3	397	121	FCI 70-2 Cl. V	
Vent Focus: acoustic performances, erosion	Gas	2” ANSI 1500	233 1	93	1.5	FCI 70-2 Cl. V	
Blow down Focus: tightness and velocity control at first valve openings.	Gas	4”, 6”, 8” ANSI 600	68.7 - 1	60	362 737 1655	ISO 5208 Rate B	