

# Valve World

Volume 7, Issue 5, October 2002

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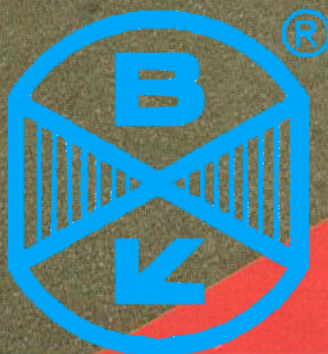
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12-14 November, Maastricht, the Netherlands

# Notes on advances in piston valve technologies

By Mr Raffaele Angelini, Cesare Bonetti SpA.

The enormous variety of process valves that exist in the marketplace is mainly due to the fact that each type of valve is only able to fulfil a part of plant operating conditions and design specifications. Since each type of valve can meet a very limited range of conditions, almost each application requires specific features and moreover an exactly suitable design can be hard to find, at least a reasonably inexpensive one. The manufacturer's first endeavour is to produce valves which meet the widest possible range of operating conditions, with a satisfactory performance and at a reasonable cost. Surprisingly enough, the type of valve which best fulfils this requirement, i.e. 'the piston valve', remains a matter reserved to connoisseurs, although invented nearly a century ago.

In fact, the piston valve offers far more advantages than it imposes limitations and could cover a really much wider range of applications than it actually does. This paper discusses recent fundamental technological improvements which could make the piston valve popular everywhere.

## The unbalanced piston valve

Let us go through its description and characteristics (see Figures 1 and 2). Externally, a piston valve resembles a single seated globe valve, where the body shows a ring shaped protuberance corresponding to the internal space designed in order to offer the process fluid a constant passage throughout the whole path across the valve, and to avoid passage sections less than the seating section, therefore preventing a higher velocity in any other part of the valve. The internals show a cylindrical seat ring (A: lower valve ring) which is either closed by a piston perfectly fitting its cylindrical shape, or open, offering a cylindrical and then radial path to fluid across a lantern bush, or cage (2.1), when the piston is shifted out of the ring itself. The piston does not rotate, it translates under the pushing or pulling of the spindle (2.2) which is free to rotate relatively to the piston.

Above the lantern an upper ring (B) interposed between piston and body ensures the outside shutoff with the piston in any position, as the piston remains in contact with the upper ring for its whole stroke. The total guiding of piston by upper ring in any degree of valve opening avoids the vibrations which the flow would cause.

The lower valve ring is kept in its position by the lantern, which is pressed by the upper ring, pressed in turn by the bonnet. These pieces are all steadily kept in place exclusively by the stud nuts and bolts connecting the bonnet with the body. No welding, no screws, nothing else but the thrust of bonnet and the perfect positioning of all parts. This

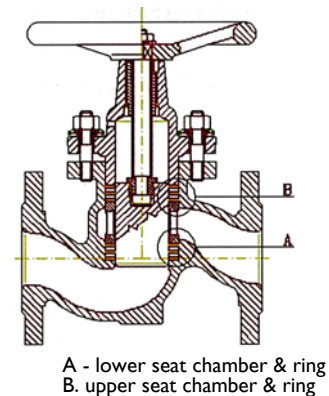


Fig. 1: Cross-section of a piston valve, unbalanced piston design

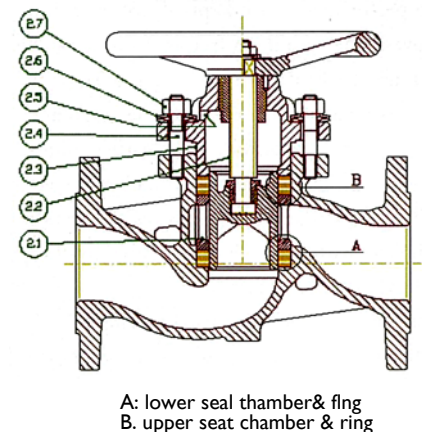


Fig. 2: Cross-section of a piston valve, unbalanced piston design

facilitates easy disassembly and re-assembly in those very infrequent cases where a repairs (replacement of rings) is needed.

Incidentally, it should be noted that the part termed the bonnet (2.3) is not a real bonnet since it does not contain the pressure. This part functions only indirectly as a pressure retaining part, having to keep in place piston and rings through the spindle (2.2) and bolting (2.4, 2.7).

On the other hand it can be seen that the

bonnet fully protects the piston surface in its open position from any external damage (dirt, chemical attack), but a possible pressurization (pumping effect) is prevented either by means of an opening around spindle or a side hole also positioned in the upper part of bonnet wail (2.5).

### The balanced piston type

In a large size piston valve, say above 2", the fluid pressure on the piston can make it difficult for the operator to turn the handwheel. Therefore, valves above 2" (particularly the cast steel valves, which are supposed to operate with a more than 16 bar cold pressure) are normally equipped with a pressure balanced piston, that is a piston with a passage (Figure 3) connecting the high pressure side to a pressure balancing chamber, inside the bonnet. There are quite a few differences with the basic design described up to now, basically the stuffing box (3.2) now necessary for stem tightness, since the balancing chamber is under pressure, thus making a real bonnet of part 3.1. However, the essential characteristics, therefore the performance, are kept, if not even improved: the spindle is free to form an angle and also to slant with the piston axis, as in the basic valve, but it is not free to rotate relatively to the piston. This feature eliminates the alignment problem and offers excellent environment tightness as the spindle is linked with the rest of the valve by the following three points:

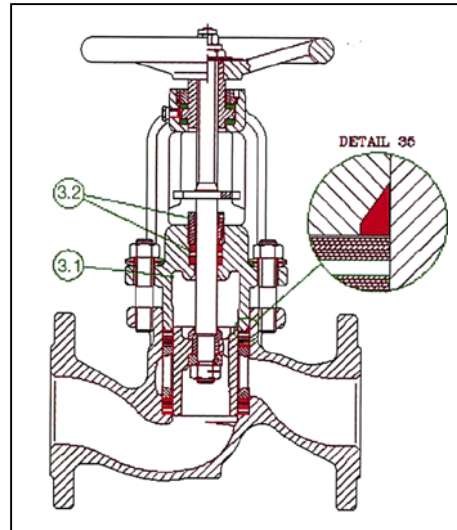
- piston (through the back seat ring)
- stuffing box (through the packing rings)
- yoke (through the roll bearing bushing).

As indicated, the connection with piston is such that the spindle may slightly shift and form a small angle with piston axis (can slant a little bit). Therefore the alignment points are only two, the piston is "independent" from spindle, the spindle is self-aligning with its packing rings, and since it also does not rotate, the stuffing box tightness is excellent and long lasting. Moreover the non-rotation of spindle plus the bearing, minimize the handwheel actuating torque, already reduced by piston balancing.

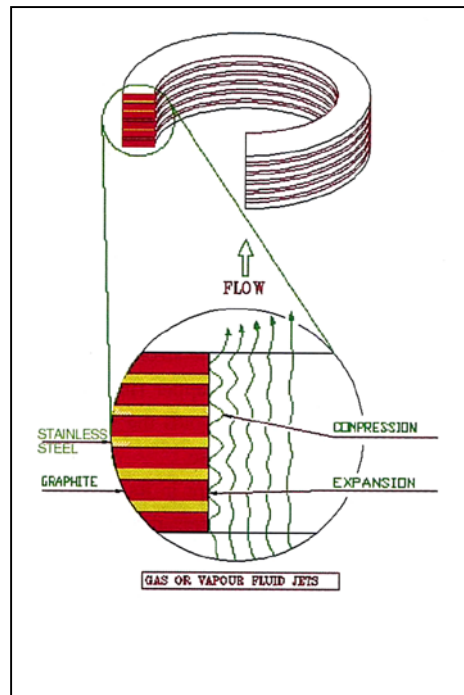
As the bonnet in this case is a pressure boundary retaining part, an added tightening joint has been included which provides an environmental valve tightness which is com-

pletely independent of the upper valve ring, a static joint between body and bonnet (see Figure 3, part 35).

This added ring is not really necessary since the valve upper ring alone ensures a total tightness, but in the unlikely event of an upper ring failure, this ring with its triangular shaped section would be pushed by internal pressure towards its recess between body and bonnet, so creating a pressure seal effect (autoseal ring).



**Fig. 3: Cross-section of a piston valve, balanced piston design**



**Fig. 4: Cylindrical internal wall of the bottom ring**

### Line tightness and environmental tightness

A second remark which arises at this stage of description is: "this valve will surely offer a complete and reliable inline tightness, but what about the external tightness?". Well, consider that both seat ring and upper ring, which are kept in their alignment by bonnet together with lantern, are also kept in their common axis by chambers (A) and (B) in the body.

Now the stem/piston connection is "relatively loose", i.e. stem axis and piston axis can slant (angle and plane) within a properly designed tolerance. This means that the piston is floating and self aligning with the two rings, independently of stem (the stem controls the piston axial travel only).

As the said construction and alignment tolerances as well as the surface machining degree of piston and chambers are well within the ring elasticity, a tight contact between piston and rings and between rings and chambers is ensured around 360 degrees and also all along the piston stroke as far as the upper ring is concerned. This is why a perfect inline and external tightness are guaranteed.

### Resistance to fluid flow erosion

A third advantage often noted is that the piston valve is able to withstand elevated pressure differentials and relevant high fluid velocities and offers a tight shutoff when closed afterwards. In fact, examination of a bottom ring which has been operating for a long time with a fluid flow under high differential pressure shows no erosion at all on its surface.

This can be explained by considering the cylindrical internal wall of the bottom ring, which is in contact with the fluid flowing through the valve (Figure 4). The peripheral fluid jets meet, and in a sense cross, layers of graphite and layers of stainless steel, alternatively.

The graphite, being a soft material, allows a certain initial expansion to the fluid jet, but the stainless steel layer imposes a compression soon after, the following graphite layer gives again a trend of expansion and so on for the entire path through the ring. The thickness of the graphite and stainless steel layers is such that the initial expansion

is reversed into a compression very sharply, therefore the extreme peripheric jets are practically stopped onto the wall and a fluid veil is formed to protect the ring. The same also happens in a tube at a relatively low fluid velocity: the peculiarity of the alternate graphite and metal layers is that of producing such veil even with an elevated fluid velocity; on the opposite, a metal to metal could not stick such a protective fluid veil and would face the erosion directly, possibly being quickly damaged.

(This argument will be thoroughly discussed in an upcoming article by Mr. Angelini in Valve World, entitled "Thickness sizing of graphite sheets for the piston valve seats".)

### Range of performance

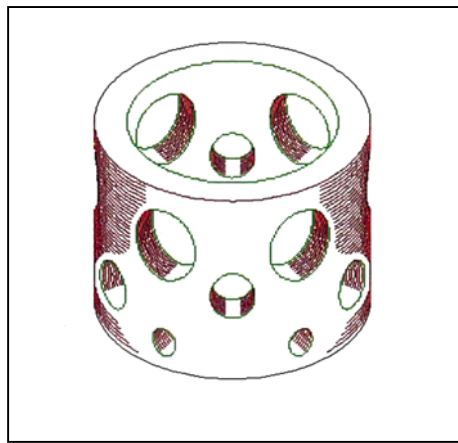
A piston valve is a high performance valve and guarantees its characteristics for a long period of time. Nevertheless the assembly is such that the tightness could, if necessary, be restored by simply checking the torque of bonnet nuts (2.4).

The advantage (certainly unique among any other type of valve) is that this one external operation not only restores the environmental tightness but also the inline tightness: by turning the nuts and pushing on bonnet both rings are "squeezed" (the lantern is free to translate along its axis) therefore also the bottom ring will improve its tightness. Moreover the piston valves are equipped with Belleville washers (2.6) on the stud bolts. If the torque is unchecked for a long period of time, or sudden consistent variations of temperature or pressure occur, the nuts may not push enough on the bonnet; in that case, the elasticity of these springs would move the bonnet towards the rings and lantern, thus maintaining a certain degree of thrust.

Given the chemical and mechanical stability of the rings, the need for Belleville washers is very exiguous and the washers are included rather as an added safety means.

### Modern piston valve rings

The descriptions above of how the piston valve withstands erosion and remains tight, have already introduced the technological improvement hinted at in the beginning of this paper: it is the reinforced lamellar graphite ring which makes all the difference.



**Fig. 5: A piston/cage control valve is among the most modern types of control valves; such cages offer several flow characteristics, obtained by means of successively calibrated holes in the lantern throughout the stroke of the piston**

The piston valves of the past used to be equipped with asbestos/rubber compound rings, which performed very well as far as tightness under normal operating conditions was concerned; however high pressure drops (for example, steam blow-down) and high temperatures (for example, heat transfer oil) were the limitations. Now these limitations no longer exist: the limit of operating conditions imposed to a piston valve are those of the metal case.

That is the operating conditions allowed to a piston valve of a given rating, range over the whole temperature interval of the body/bonnet material, and any pressure within the valve rating, can be an inlet/outlet differential pressure.

As regards materials, carbon steel and stainless steel piston valves of up to 2" in size conform to API 602 800 lbs as far as wall thickness, passages, stem diameter are concerned, as well as construction materials, test and all pressure/temperature conditions considered by this rating.

### Range of applications

Apart from certain applications which are not compatible with graphite (PTFE rings have to be mounted with an obvious limitation of admissible pressure drop and temperature) a piston valve with reinforced lamellar graphite rings can cope with any process fluid chemically compatible with graphite and stainless steel, which is quite a

variety of fluids, including steam, water, hydrocarbons, thermal oil, most acids and alkalis, and most of the chemical products being treated in industrial plants. Therefore in a given plant, or station, the piston valve can be considered the standard valve for all normal applications within its rating and dimensions.

A few chemical companies have actually set up their valve maintenance method based on computerized program of interventions, and use of piston valves. The improvement of seat and upper ring technology has now extended the time between two interventions to such a length that modern piston valves could be considered as "maintenance-free valves"

### The piston valve as a control valve

The operating flexibility of piston valves reaches the domain of fluid flow control: it has been shown that in a piston valve the fluid medium flows across a cage.

A piston/cage control valve is among the most modern types of control valves; such cages offer several flow characteristics, obtained by means of successively calibrated holes in the lantern throughout the stroke of the piston (see Figure 5).

A further advantage of a graphite seat ring piston valve over a metal seat piston/cage control valve is its exceptional rangeability. Whilst it is beyond the scope of this paper to make an exhaustive comparison between the rangeability of a common control valve and that of a piston valve it should be remembered that a graphite seat ring piston control valve is obviously also a tight shutoff valve, and near the closure the flow rate is controlled by the passageway between piston and bottom ring.

The valve reaches its tightness gradually and regularly, still controlling minimal flow rates at high differential pressure, that is with a minimum Cv which is much less than 0.1 per cent of total Cv. The seat closure tightness, a typical problem with control valves, is hereby resolved. (The author would be glad to provide further information about this topic.)

### Construction materials

The piston valves can be manufactured with many combinations of construction materials, depending on the various types and rat-

ings as well as the process fluids involved or ambient requirements; this paper is restricted to information about the most common executions (generally available ex manufacturer stock).

The standard production is based on material schedules (material lists), composed of basic combinations of materials which are suitable for the various functions requested to each valve component and which are suitable to be assembled together: in this way, a few different material schedules cover a wide range of operating conditions.

Each material schedule is relatively flexible (for instance a valve part may be made of carbon steel in its forged or cast version and also according to DIN or ASTM specs) in order to meet conditions imposed by size, rating, international standards; but the list of further materials available can be found in the catalogues or supplied directly by manufacturers.

#### Maintenance

Since a piston valve is made to withstand tough operating conditions it does not need much care. Essential recommendations to be observed in order to ensure a proper and ef-

ficient operation are:

The lower and upper ring seat surfaces in the body (chambers (A) and (B) of Figures 1 and 2) and the high grade machined surface of piston: surfaces should not be scratched when removing or fitting new rings. The rings: when checking the bolting torque ensure that the valve is closed; the bottom ring will adhere to seat chamber, cage and piston, so being pressed equally from all sides, there is no risk of losing its shape.

#### Tests, certification, type approvals

All piston valves undergo the quality controls and performance tests required by the official standards, from the raw material certification and cross check, to the final tests (the manufacturer should be certified PED and ISO 9001); usually the valves should bear the PED label, and a pressure test report should be supplied, conforming to PED and complete with a CMTR for pressure boundary parts, which is equivalent to other standards, as for example DIN 50049 3.1 B inspection certificate. Other quality control levels and certifications can be met, on re-

quest, with relevant extra costs and delivery times to be agreed with manufacturer. In order to support your confidence on piston valves, you can ask for homologation certificates such as:

'Fire Safe' API 6FA and BS 6755 by Lloyd's Register of Shipping,  
TA LUFT by TUEV,  
Druckbeh V §22 by TUEV,  
Certificat de resistance au feu by Elf. ■

#### About the author



Mr Raffaele Angelini, who graduated in 1959, has been dealing with design of automatic devices such as control and safety valves transmitters, gauges, etc,

since 1963. He is currently involved in the development of instrument lines, including low noise control valves high differential pressure valves, glass and magnetic level gauges.

