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High temperature ball valves

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1 Introduction

This paper describes a new design concept for high temperature ball valve applications. The temperature limitations are those applicable to the materials used, and in particular for graphite, which are quite high for nearly all types of fluids with the exception of oxygen and oxidation type media.

The primary innovation of this new valve concept resides in the original seat design and in the selection of the materials for the seat ring and packing.

Figures 1 and 2 show the cross-sections of the subject ball valves. The two sections are identical, with the exception of item 35, which is fitted only in figure 2. This element and its function will be further defined in the description of the seat rings.

2 Description of the seat rings

As indicated above, the innovation resides mainly in the seat rings of the subject ball valves. This is best represented by:

- The selection of the materials of the rings.
- The extra sealing function assigned to the seat rings.

Abstract

This paper describes a brand-new design concept for high temperature ball valve applications. In particular for applications in a corrosive fluid environment at temperatures up to 550°C (1022°F) or at higher temperatures with other types of media. The primary innovation resides in the new and original seat design concept, and in the materials for the seats and packing. The patented semi-soft seat sealing concept insures nearly indefinite bubble-tight seat tightness throughout the full range of operation, including at the maximum rating. The materials and the design of the seats have been proven to be greatly effective in the handling of high pressure drops in ball valves; particularly when lamination damage potential exist due to flow of high velocity and high pressure steam and water, with pressure drops from operating to atmospheric. They are also equally effective in the handling of abrasive containing fluids, while offering very low operating torque for any operating condition, when compared to other ball valve designs under similar conditions, and which will be quantitatively shown in this paper. Substantial field trials and experiments have demonstrated that the subject ball valves are maintenance-free. However, if for any reason, maintenance is ever required, the seat replacement is simple and inexpensive thanks to the low cost of the seats and their

ability to auto-adapt to the ball. The new patented design eliminates all seat machining and allows for easy mating of the ball and the seat, thus eliminating the need to replace the complete ball and seat assembly as it is normally done in metal seated ball valves. As a result of this new and original ball valve seat concept, the ball is intrinsically fire-resistant and, of course, has passed all the tests specified in the various applicable international standards. In addition, in the unfortunate event of a plant fire, there is no need to replace the valve ball if it is exposed to the fire as it maintains its ability seal and readily operates without repairs. The performance of this new ball valve design, after it is exposed to fire, is practically the same as when the valve was new. Furthermore, given the characteristics of the stem packing, the valve is environmentally friendly as it permits very limited, often immeasurable, fugitive emissions. The design has been tested and approved in accordance to the requirements of TA LUFT of Germany. The paper's main conclusion is that, given the originality of the design, this new ball seat concept yields both an excellent high temperature, fire-resistant, very environmentally friendly ball valve with long life seat tightness, which is economical to operate when compared to all other currently existing valve designs for similar operating conditions.

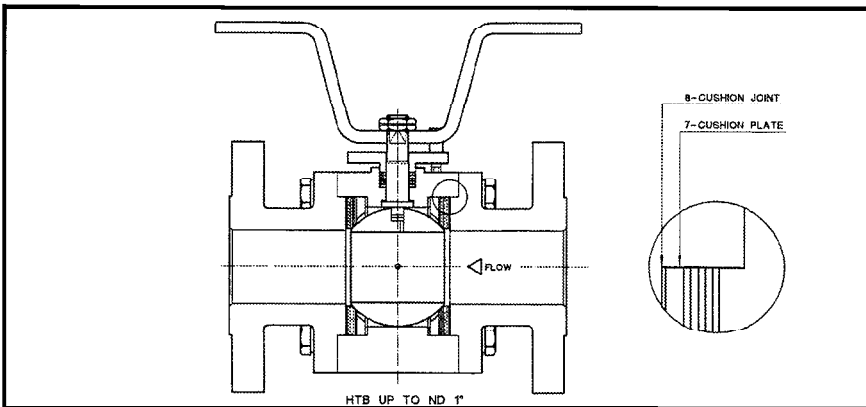


Figure 1.

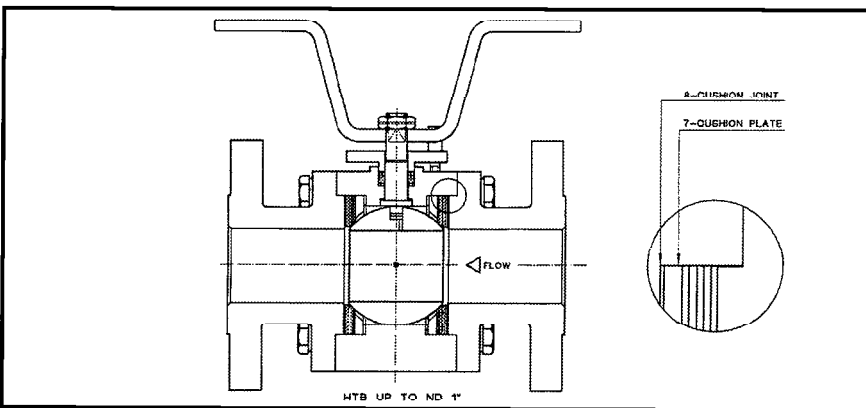


Figure 2.

- The sizing of the components of the seat rings.

The seat rings are made of laminated expanded graphite layers with alternating layers of very thin metal. These expanded graphite layers are compressed during production and assembling to such a level that they will withstand the shearing stress generated by the operating pressure and, at the same time, maintain their elasticity to permit the necessary tightness when the valve is shut off.

Within these loading conditions, the relationship of graphite stress versus strain is linear and the elasticity remains constant, meaning that neither settlement nor hardening takes place, even at high temperature application. Furthermore, the selected graphite density of these seat rings is such as to completely prevent the absorption of liquid which would lead to two potentially damaging effects, namely reducing the ability to withstand loading capacity and also the build-up of inner pressure. As it can be seen, enclosed water pockets generate a highly non-uniform pressure distribution during the compression of the ring and also high inner pressure, if the volume of any water bubbles expands too rapidly during temperature increases. Therefore, before be-

ing installed, the graphite ring must be completely dry, and its direct contact with the liquid media to be sealed can only be permitted after complete compression of the rings has taken place.

Analysing figure 1 we realise that the seat ring has two functions. It seals against the ball and therefore it stops the flow when the valve is closed. Further, it seals towards the environment. In fact, except for the packing, there are no other sealing elements than the seat ring. The sealing surface on the ball is conical, while the outwards sealing is cylindrical and is obtained by the contact of the outside diameter surface of the ring with the embedding surface of the body. The latter sealing depends on the machining and design tolerances of the two elements in contact. It should be noted that we have over fifty years of experience with soft seated cylindrical sealing. In actuality, this configuration is only used in valve sizes up to and including one inch full bore, although it could be used for bigger sizes. The reason for the change in the bigger sizes is mainly a matter of economy. A certain ratio must be maintained between the outside diameter and the thickness of the ring in order to avoid the geometric twist of the ring while it is fitted into of the body, given the imposed design tolerances. Therefore, for sizes larger than one inch, a thicker seat ring is needed and, consequently, a bigger body, both of which would impact the ultimate cost of the valve. Furthermore, it would be more difficult to properly compress thicker rings between the body and the valve ends.

So, in order to avoid the above noted inconveniences, we use an extra ring, which we refer to in the following text as the autoseal ring (item 35, figure 2). This ring is made of compressed graphite. The autoseal works by having the inner pressure of the ball valve compressing it against the body and, at same time, against the ends thus avoiding any external leakage. It is an application of the well-known pressure seal valve concept. As a result, the thickness of the seat ring will be of the minimum value necessary for the sealing on the ball. As shown in figures 1 and 2, the seat ring is pressed, not directly between the body and the end, but with the interposition of a rigid metal ring (item 7 of figures 1 and 2) so that it is completely contained on all sides with the exception of the conical sealing surface. The ring is precisely enveloped so that the graphite is prevented from drifting sideways. This embodiment allows an adequate uniform compression on the ring surfaces in order to obtain the correct density of the graphite. Once the necessary density is obtained, the seat ring does not need any further adjustment during the operation no matter what the operating conditions are within a given valve's pressure class rating. In fact, when the ball valve is delivered, body and ends are in metallic contact, without any possibility of further compression. Item 8 is only a cushion joint.

Apart from the external dimensions of the seal rings which have to geometrically guarantee the initial sealing against the ball and the environment, the correct sizing of the layer or stack thickness is essential to insure long lasting duration of the seat ring while in operation. Let us then examine how the conical

have fully confirmed the above. The question is, why does this happen and why is the graphite not destroyed? Experience has shown that despite its excellent static sealing quality, only limited use can be made of expanded graphite as the seat material of valves which are subjected to fluid flow and alter-

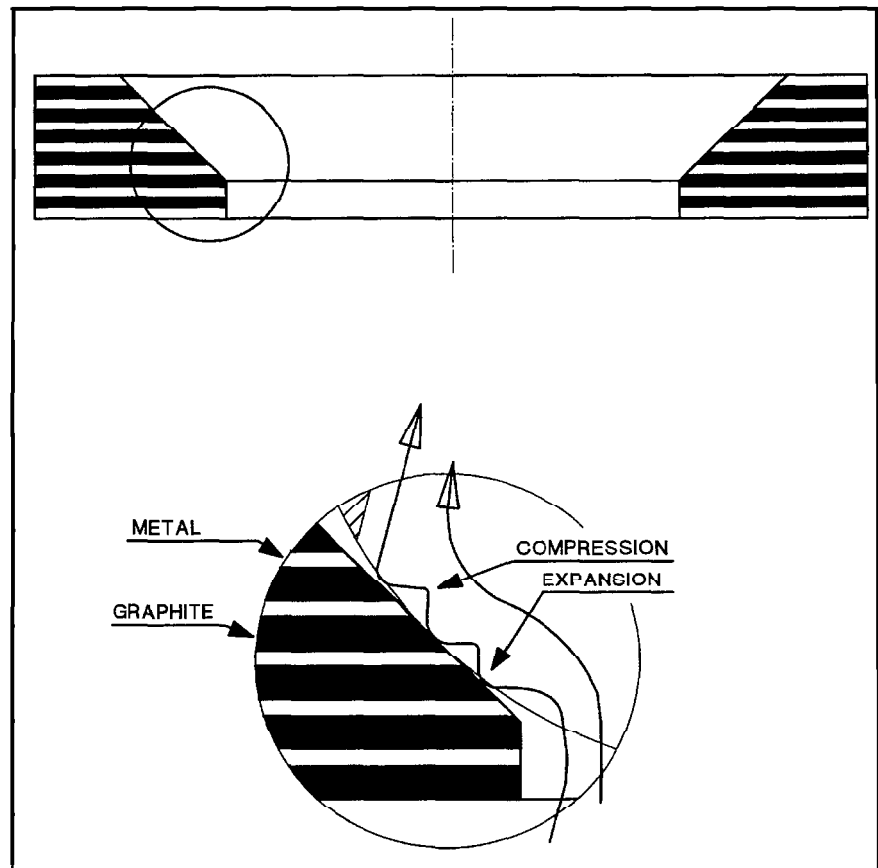


Figure 3.

surface of the seat ring (figure 3) behaves once it is exposed to fluid flow during the opening and closing operations. The flow crosses a series of alternating layers of metal and graphite. Since fluid is under pressure it will tend to expand every time it encounters the graphite layer, which is the more yielding of the two materials. However, the expansion that takes place is minimal because of the successive, very close, layer of metal, which tends, once again, to choke the fluid flow. These successive series of expansions and contractions prevent the fluid from finding a preferential passage parallel to the ring axis, thus preventing the potential for creating a permanent flow path that would lead to erosion. This erosion path could get progressively deeper and deeper with time, thus predisposing the seat to failure during subsequent closure stages, as is often the case with valve seats made of homogeneous materials. It happens as if a very thin layer of liquid is held back on the groove generated in the layer of graphite, as it is compressed by the fluid, and which is then protecting the seat. Now, since the graphite has not suffered erosion during the fluid lamination, the complete seal is maintained. Ample experimental results

nately act as sealing element. The case has been thoroughly studied in the case of piston valves, when the use of asbestos was banned, with disastrous results. This was found to be due to the poor resistance of the graphite against fluid jet erosion and to the shearing stress where an isolating valve may be required, at any time, to seal a vessel after a fluid flow has crossed its seat. Graphite layers, whose thickness corresponds to the length of the fluid path through the seat (typical thickness of ball valve seat ring), become deeply eroded in a short time by the fluid flow under relatively low pressures. For this reason assembling several thinner graphite layers with metallic rings placed between them is not a solution as such, since by reducing the graphite thickness the graphite shearing stress and strain in the proximity of the metal/graphite connecting surface is not eliminated. We have to keep in mind that metal and graphite have to undergo an identical strain with a Young modulus of the former, being around one hundred times that of the latter. Thus we have to check whether a thickness value can be estimated where the strain is so limited that the weakness induced by the shearing is so reduced that an erosion cannot

be triggered off and that the seat tightness is then assured when the valve is closed under pressure.

A theoretical analysis has been made in order to evaluate the shearing stress of the graphite in a layer as a function of the flowing fluid conditions and of the distance between the two metal sheets containing the graphite layer.

Subsequently, extensive experiments have been performed on ball valve rings using a test loop producing saturated steam at various pressures covering the range of pressure rating of the valves. Rings with different graphite layer thickness and different axial pre-loading have been taken into consideration. The conclusions of the analysis and of the tests have demonstrated that the erosion of the graphite depends very much on the shearing stress generated by the fluid pressure in relation with the thickness of the graphite layers, and on the axial preload of the construction of the ring applied during the as-

sembly. It was found that the assembly preload could not be varied across a wide range due to the necessity of maintaining the correct elasticity of the graphite layer. Therefore, it became necessary to act mainly on the layer thickness in order to determine the correct value that would substantially avoid the triggering of the erosion phenomena, thus preserving the seat for the next closure. This was subsequently quite satisfactorily accomplished.

3 Packing

The standard packing (figures 1 and 2) is made of layers of graphite alternating with metal layers.

In this application the layers are not crossed by flow but have only to assure sealing against a static pressure, even under high temperature conditions. The thickness of the layers does not have the same importance as for the seat rings. The packing is adjustable at

any time but, again, it does not need any adjustment, being preloaded for the worst conditions.

Although standard packing has been known to provide excellent result during various tests, and under many operating conditions at various plants, we have also been required to produce ball valves with special packing.

Figures 4 and 5 show these special packings whose characteristics and features are similar to that of our seat rings as previously discussed.

4 Conclusion

The above described innovations for the design of seat and packing material for use in shut-off ball valves have yielded the following main characteristics:

- Nearly indefinite bubble-tight seat tightness throughout the full range of operation. The design and the selected material of the seat have proven to be greatly effective in the handling of high pressure drops in ball valves even when lamination damage potential exists due to the flow of high velocity and high pressure steam and water. Extensive tests of these seats installed in ball valves used in blow-down applications, using saturated steam at 7 MPa, have been performed with excellent results.
- They are equally effective in the handling of abrasive containing fluids and dirty media. The alternating metal graphite layers of the seat sweep the ball surface cleaning it during every open-close cycle.
- This design distinguishes itself because of the low operating torque for any operating condition within a pressure class rating. Tables 1 and 2 show the torque versus fluid pressure at ambient temperature, and the torque versus saturated steam pressure. It clearly shows that the torque values are quite low if they are compared with metal seat ball valves, and in fact, they are similar but not greater when compared to those of same size soft seated ball valves.
- Substantial field trials and laboratory experiments have demonstrated that the subject ball valves are maintenance-free. However, if for any reason, maintenance is ever required, the seat ring replacement is simple and inexpensive thanks to the low cost of the seat rings and their ability to auto-adapt to the ball. Thus eliminating the need to replace the complete ball and seat assembly as it is normally done in metal seated ball valves.
- As a result of this original ball valve seat concept, the valve is intrinsically fire-resistant and of course, has passed all the tests specified in the various international standards. In addition, in the unfortunate event of a plant fire, there is no need to replace these ball valves, as they maintain their ability to seal and to operate without

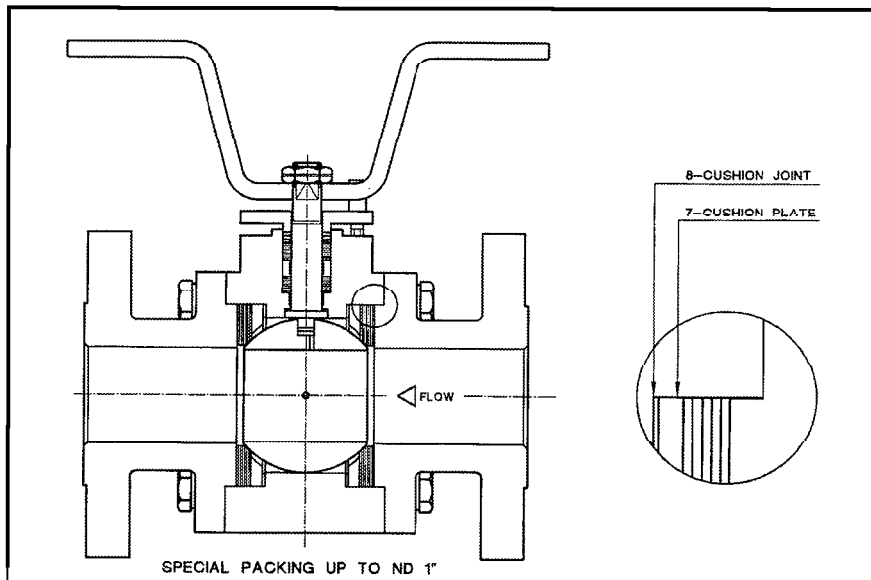


Figure 4.

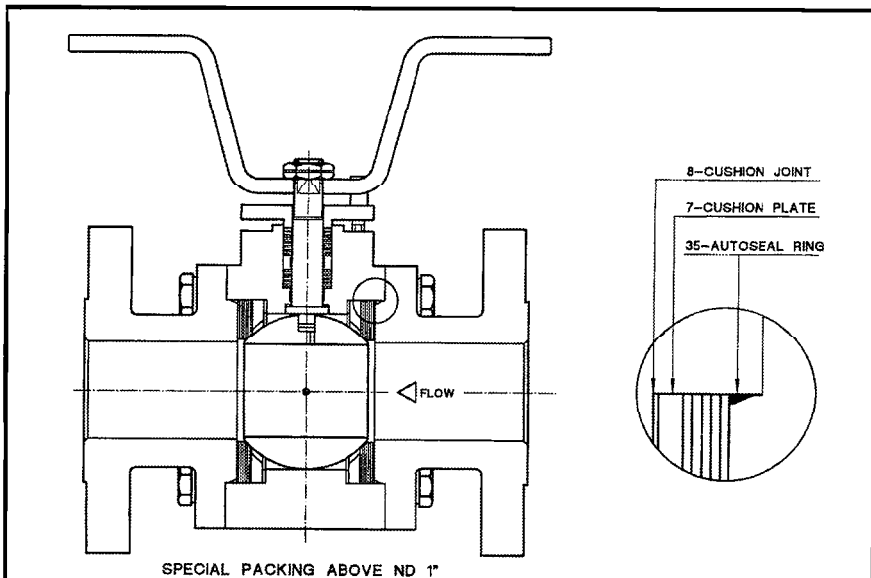


Figure 5.

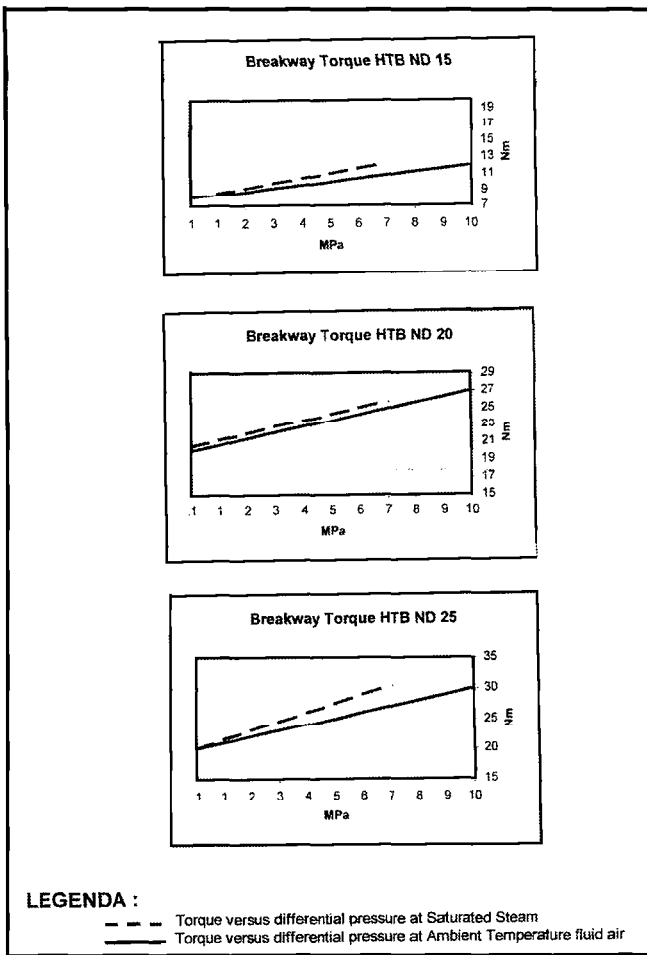


Figure 6.

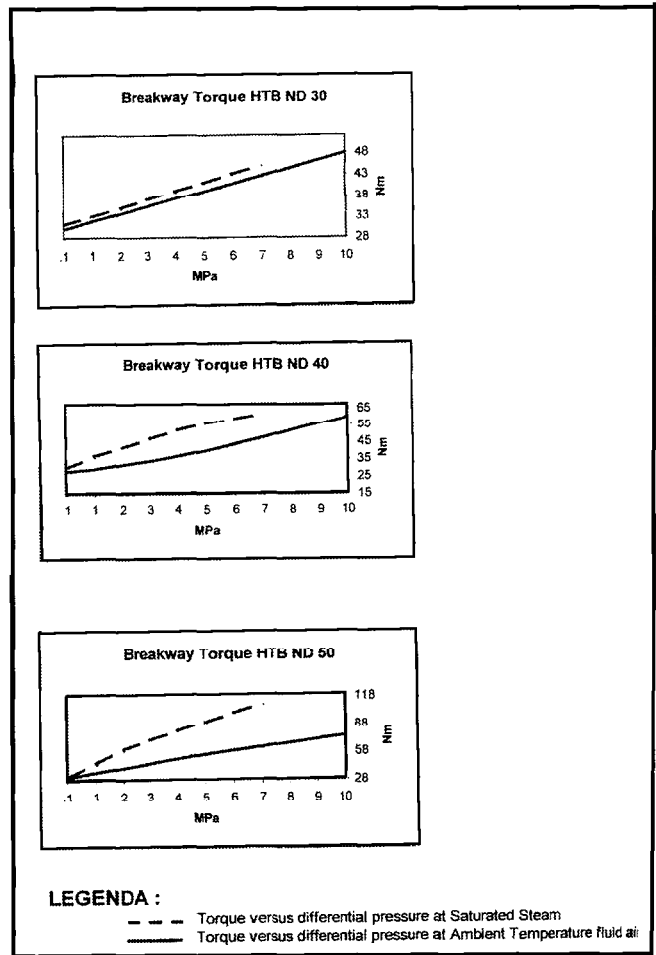


Figure 7.

- repairs. In fact, the performance of this new ball valve design, after it is exposed to fire, is practically the same as when the valve was new.
- Furthermore, given the characteristic of the stem packing, the valve is environmentally friendly as it permits very limited, often immeasurable fugitive emissions. The valve has been tested and approved in accordance to the requirements of TA LUFT of Germany.
 - This paper's main conclusion is that, given the originality of the design, the new ball

valve seat concept yields both an excellent high temperature, fire-resistant, very environmentally friendly ball valve with long life seat tightness, which is economical to operate when compared to all other currently existing valve design for similar operating condition.

I hope that the above has been of interest. Thank you for taking the time to be here today. I will now entertain any questions.