Bidirectional sealing ball valves in power applications

**Ball valves have become common place in high pressure steam and water service in power plants. However, it is critical that these ball valves be installed in the correct flow direction. If pressure comes from the downstream side, valve damage could result. There are also examples where valves are installed in the correct flow direction but under certain conditions, pressure is applied from the reverse direction. For vents and drains, this could happen if several valves discharge into a common header such that this header becomes pressurized while one of the valves has no upstream pressure.
In addition, when equipment is installed in parallel for redundancy, the inlet and outlet isolation valves could see reverse pressure when closed. This may be applicable for feed water heaters, feed water pumps, control valves or bypass valves. In these cases, a bidirectional sealing valve is necessary.**

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Small valves:

Typically, small valves in vent and drain service, below 2" bore size, are floating ball valve designs. In these metal seated ball valve designs, the downstream seat is integral or fixed to the body. On the upstream side, a spring loads the ball using a non-sealing pusher seat (Reference Figure 1). The ball is not attached to the stem so that it is free to float; however, under reverse pressure (pressure from the downstream side when the valve is closed), there is no sealing ability. In fact, damage could occur since the spring could flatten under such loading. The proper valve design is critical for these valves to accommodate the bidirectional conditions described above.
A patented valve design for bidirectional sealing (US Patent 8,201,574) is shown in Figure 2. The key features of this design are:

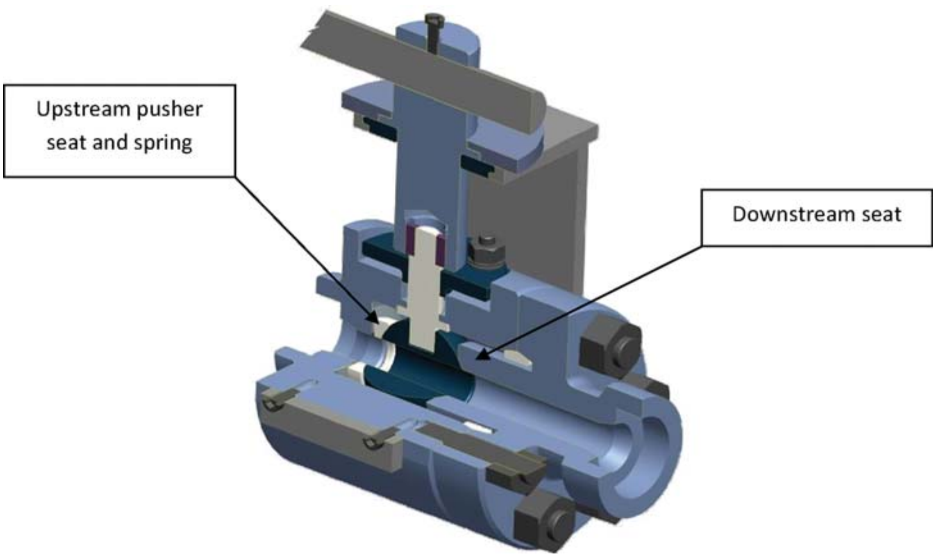

Figure 1. Typical Vent/Drain Valve.

- A standard valve body and ball may be used. Only the spring and upstream pusher seat are changed and the seat holder is added to convert the valve from unidirectional to bidirectional sealing.
- All sealing in the reverse direction is achieved by metal to metal sealing. These surfaces are mate lapped prior to assembly.
- The seat holder seals statically in the valve body cavity bottom. This is not a make-break seal but a continuous metal to metal seal. The area and diameter are controlled so that reverse pressure forces the seat holder into the body to achieve a tighter seal as pressure is increased.
- The spring is compressed within its elastic limit on initial assembly. The spring is not exposed to the reverse pressure differential. For this reason, it is not flattened by reverse pressure which would cause the ball-to-seat load in the forward direction to be reduced. If this happened, forward direction leakage would occur.
- The seat holder is placed in the body with a tight tolerance on the outside diameter. The upstream seat outside diameter taper is in close proximity to the taper in the seat holder. As the valve is cycled these relationships keep the upstream seat centered and prevent cocking of the upstream seat.
- The seal between the upstream seat and the seat holder is achieved by sliding contact between these two angular surfaces when reverse pressure causes the ball to push the upstream seat into the seat holder. The angle is chosen so that it is not a locking taper. The angles on the seat

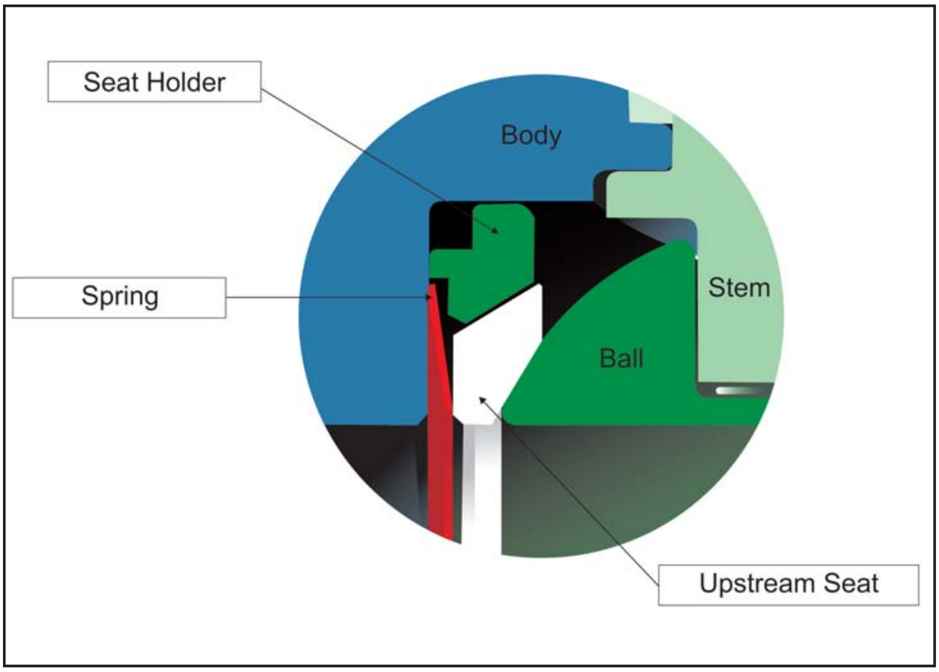

Figure 2. Reverse Sealing Arrangement.

holder and upstream seat are such that the circumferential contact band is optimized to insure a reliable metal to metal seal. This sliding contact also will wipe off any particles between the tapers and not crush them such as could happen in linear make-break surfaces.

- Flow does not go past the tapered surfaces of the seat holder and upstream seat seal. This means that this seal surface is not subjected to flow erosion.
- The initial spring deflection/load is controlled for proper ball to seat load in the preferred direction and to prevent overstressing the spring in the reverse pressure direction.
- Since the seat holder to body seal is static it requires no hard coating. Also since the seat holder to upstream seat seal is a controlled area sliding taper, no hard coatings are normally required on these tapered surfaces. However, for certain applications, the tapered surfaces on the upstream seat and seat holder may be coated with a hard coating. The ball to upstream seat seal is provided with mate lapped hard coatings on these spherical surfaces. This is because the ball is in rubbing contact with the upstream seat under reverse differential pressure as the valve is cycled.

Large valves:

For valve applications requiring larger valves, 2" bore and above, trunnion metal seated ball valves are required for bidirectional sealing. A trunnion ball valve is defined as a ball valve design where the ball is supported in the body so as to be held in-line with the stem. In this configuration, the centerline of the ball spherical surface and the centerline of the stem diameter are identical. Under operating conditions, the ball does not move from this position or "float" upstream or downstream. Typically the ball is supported by a surface in the body which carries the pressure end loads. This design is shown in Figure 3. There are seats on each side of the ball that are spring loaded into the ball making it a true bidirectional sealing valve.

In a severe service metal seated trunnion ball valve, seat design is the critical component. The seat must be able to withstand elevated temperatures experienced in power applications; therefore materials like Viton® and PTFE® are not acceptable. A static seal between the seat and body and a dynamic seal between the seat and ball are required. The static seal must be Grafoil® to withstand the elevated temperatures, and the dynamic seal is metal-to-metal hard coated. The seat is spring loaded into the ball with upstream pressure assisting with sealing on the upstream side of the ball. The ball is fixed in the body by the trunnions and the seat moves to engage the ball.

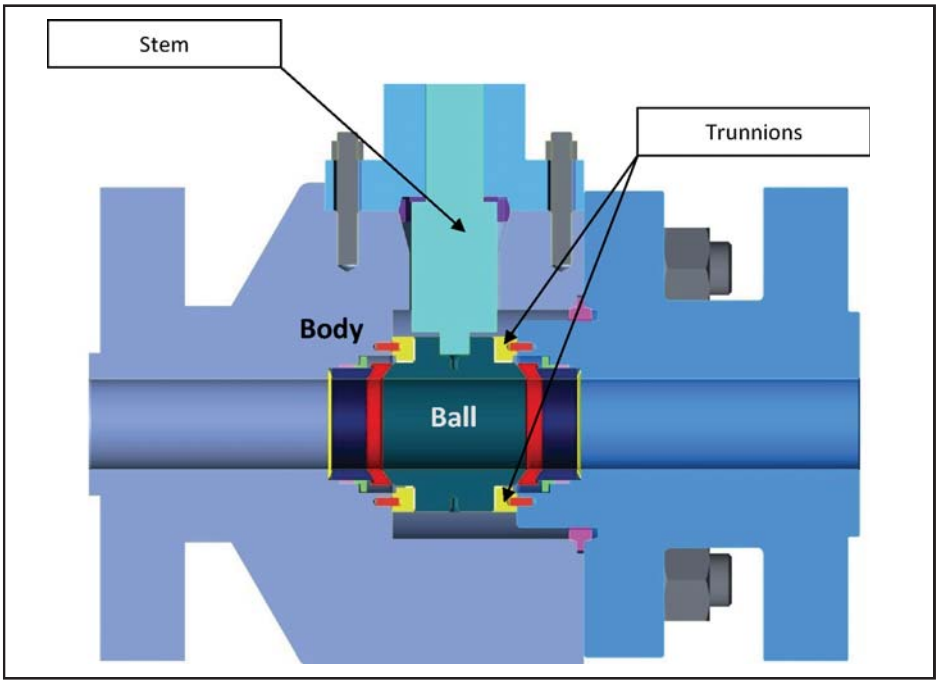

Figure 3. A Typical Trunnion Ball Valve.

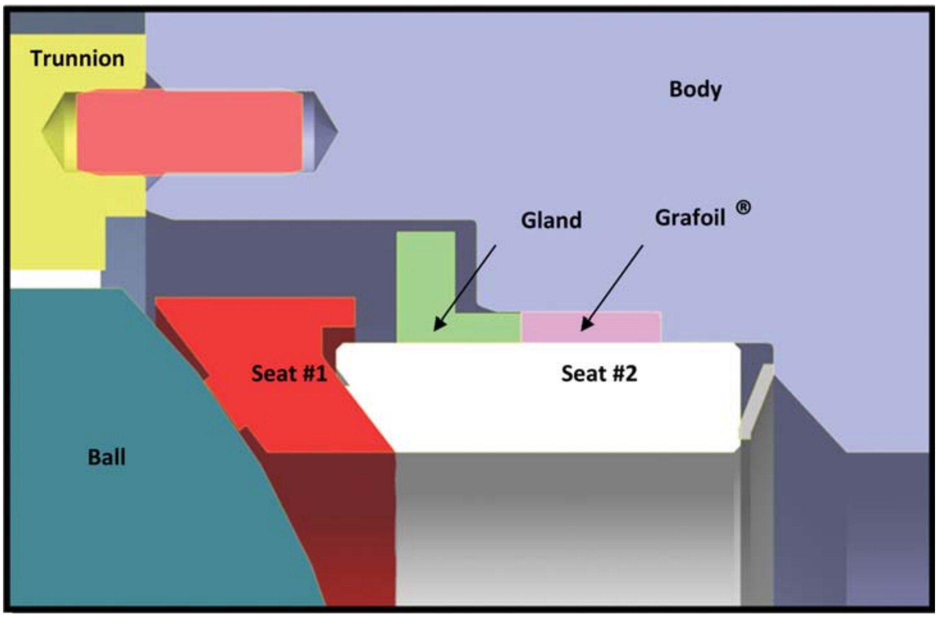

Figure 4. Two Piece Trunnion Seat.

In typical metal seated trunnion ball valves with one seat on each side of the ball, sealing problems are common at elevated temperatures. Since the ball is fixed in all directions by the trunnion arrangement, for the seat to properly seal against the ball, it must be perfectly aligned with the ball sphere. If the sphere is shifted, even slightly up or down or left or right to its ideal position, then the seat would need to exhibit rotary movement to conform exactly to ball position. The rotational angle may be less than 2 degrees but it still requires an angular movement of the seat. Since the typical seat-to-body seal, which uses Grafoil®, prevents this movement there will not be a perfect contact between the seat and ball. Point loads might occur at the ball-to-seat interface which could lead to galling, high torque and valve lockup. Note that this movement is accommodated if o-rings or plastic seals are used between the seat and body but such seals cannot withstand elevated temperatures.

In addition, if Grafoil® is to be used as the static seal, it must be externally energized and have minimal clearances to prevent extrusion. Grafoil also has no spring-back so that it must be continually loaded by outside means to maintain a seal. Live loaded stem packing and gland configurations use this arrangement. If the seat is sealed in the body by a gland, it will be rigidly held in place so that only *axial* movement is allowed. This *axial* movement is facilitated by the springs so that the seat engages the ball.

To achieve reliable sealing between the seat and ball, the *axial* movement must be decoupled from the *rotary* movement. This requires a two piece seat on each side of the ball (Patent Pending) as shown in Figure 4. Such a design, which provides bidirectional sealing, has the following innovative features:

- The seat #2 only moves axially.
- A Belleville spring pushes the seat assembly into the ball.
- Pressure from the upstream side energizes the ball-to-seat sealing.
- The seat-to-body seal is a gland energized Grafoil® packing of the same design as the stem packing.
- The gland may be live loaded to maintain packing load and prevent bolts from loosening in service.
- Seat #1 is allowed to rotate to engage the ball.
- The ball-to-seat is mate lapped as is current practice.
- The seat #1 to seat #2 seal is essentially a static seal that does have some slight rotary movement between components and requires that both mating surfaces be hard coated.
- The interface between seat #1 and seat #2 is spherical and is mate lapped over a very small area.
- Seat #1 contains a stop shoulder to prevent over rotation of this seat as the ball is cycled.
- Seat #1 can only rotate a limited amount depending on valve tolerances for the maximum ball offset. Typical rotation is limited to 2 degrees or less.

Conclusions:

In power applications, when ball valves are specified, they should be bidirectional sealing valves. In small size vent and drain floating ball valves this prevents valve damage and leads to longer valve life. In larger trunnion ball valves this insures equipment isolation is preserved under all conditions.

About the author

Marvin E. Beasley is currently President and Technical Director of Virgo Engineers, Inc.-EVS Valves Division located in Stafford, Texas. He is a Registered Professional Engineer (mechanical) in Texas and holds several valve patents. In addition, he has published numerous technical articles related to valves, and currently serves on Piping & Valves API standards writing committee. He is active in community volunteer work including mentoring and instructing students in the Capstone Design Course at the University of Houston Mechanical Engineering Department. He also served in the US Navy as a nuclear submarine officer. He is married with two children and 7 grandchildren, and has completed over 20 marathons.