Hydrogen Production Operation

New Ball Valve Technology with greater performance

ABSTRACT

It is estimated that over 10 million tons of hydrogen are produced annually in the US. Hydrogen is an essential element used in the production of many chemicals and the processing of our country's grain products into useful bio-products and is being studied as a future renewable energy resource (Lipman, 2011). The production of hydrogen gas is typically produced from fossil fuels through a steam reforming process and more recently through biomass such as glucose. In any of these scenarios, the production process creates abrasive and corrosive by-products in the form of carbon black or similar powders that foul, erode, and damage control valves. Traditional control valves have been shown to require frequent maintenance and repair but the QuadroSphere® trunnion ball valve offers some unique features to prevent valve failure and prolong its life in hydrogen production service.

Chemical plants in the Midwest use hydrogen to process food products and produce various grades of propylene glycol, which is processed into industrial fluids such as anti-freeze. These plants utilize many types of isolation valves in the process including steel ball valves. Experience has shown that some traditional ball valves require repair due to the abrasive nature of powdered additives or hydrogen production byproducts such as carbon black dust. Additives and dust can coat the sealing surfaces of valves and fill cavities in the body, which contribute to valve leakage and inoperability. The long distance transmission of gas in pipelines can also produce grit and scale that can further cause wear on the valve sealing surfaces. Damage and leakage to the isolation valves prevent effective isolation of production systems and lengthen planned outages.

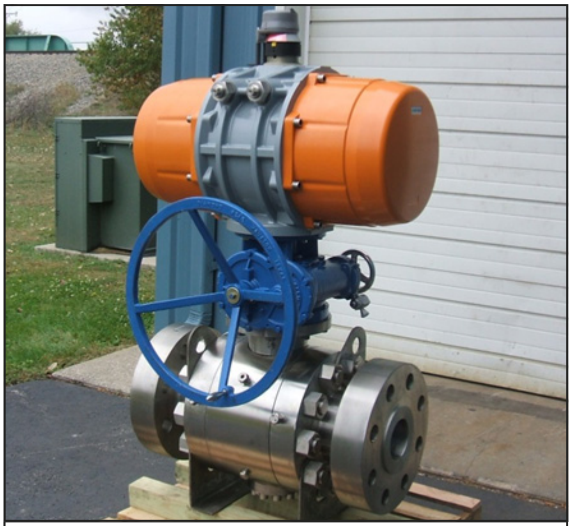

Figure 1. QuadroSphere® Ball Valve for Abrasive Hydrogen Service

Due to the abrasive and high pressure conditions of the hydrogen production and delivery processes, severe service valves are required. After several costly valve maintenance and repair shutdowns at a plant in Illinois, some of the existing isolation ball valves with unidirectional seating and high leakage rates were replaced with 4 NPS and 6 NPS Class 2500 QuadroSphere® soft-seated, trunnion ball valves shown in Figure 1. The structural integrity of the QuadroSphere® ball valve is assured because it is manufactured and tested in accordance with ASME B16.34 for Steel Valves. Not only does this valve provide the integrity of an ASME forged steel valve, but QuadroSphere® trunnion ball valves by design provide full bi-directional seating and an unrestricted flow path to both increase flow and reduce valve wear.

The QuadroSphere® is suited for high pressure gas containing powdered by-products due to its unique ball geometry. As illustrated in Figure 2, the non-essential surfaces of the ball are recessed in all four quadrants. A typical ball would be spherical on the closed ends of the ball. The QuadroSphere® ball has recessed, flat faces on the closed ends combined with recessed areas on the top and bottom of the ball. These recesses create additional flow paths that allow the flow and particulates to move freely above, below, and around the sides of the ball when moving from the closed to open position. This enables a flushing action and removal of solids from the body cavity (see Figure 3). In addition, there is seventy percent less ball-to-seat surface contact area during cycling, reducing wear during cycles.

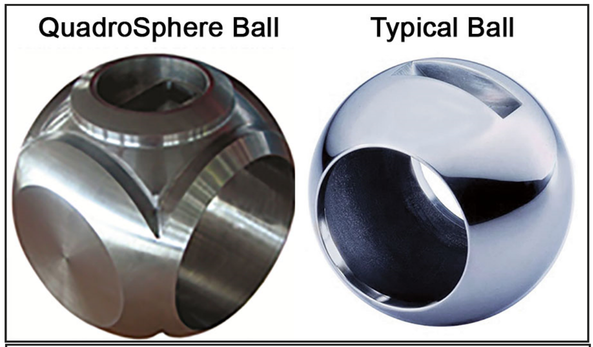

Figure 2. Unique Contoured Ball with seat

The remaining spherical surfaces on the ball form a raised sealing surface in both the open and closed positions. Another benefit is provided because the stainless steel ball is hard-chrome plated for increased wear resistance. Furthermore, since the surface area of the ball is reduced, there is an enhanced wiping action between the edges of the ball sealing surfaces and the valve seats as it cycles open and closed. The result is a self-cleaning, severe-service, resilient seated valve with longevity similar to a metal-to-metal seated valve.

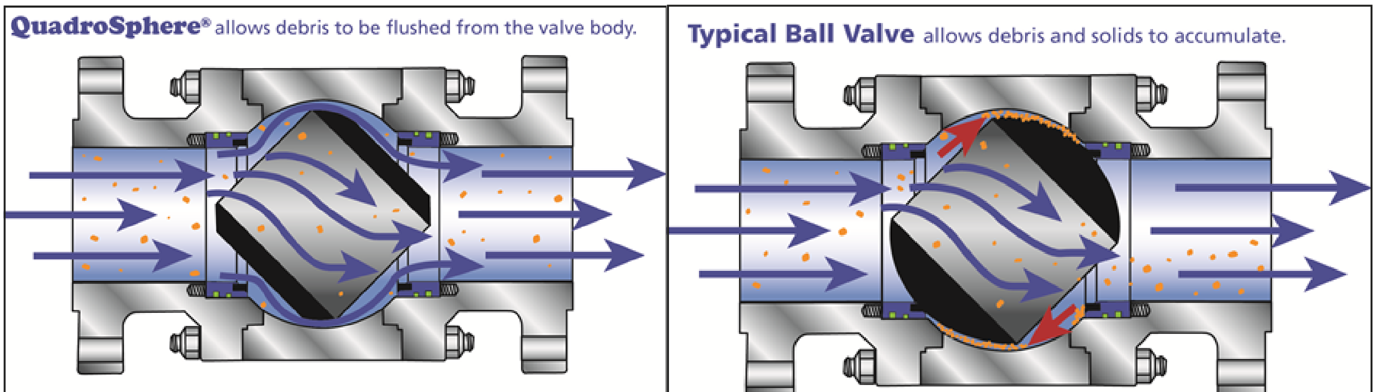

Figure 3. Flushing action of the QuadroSphere® Ball Valve

As shown in Figure 4, API trunnion ball valves are equipped with floating seats on both ends of the valve. The resilient seats are contained in metal rings that float axially in pockets in the valve body. When pressure occurs on either end of the body, the seats are automatically forced tightly against the ball to provide a tight bi-directional seal. However, the seats can be configured to be either self-relieving or double-isolating. The seats shown in Figure 4 are self-relieving so that if the pressure in the cavity between the two seats exceeds the pipeline pressure due to thermal expansion or decompression of the system, the seat rings will move away from the ball and automatically relieve the cavity pressure back to the pipeline. This configuration is defined as double-block-and-bleed (DBB).

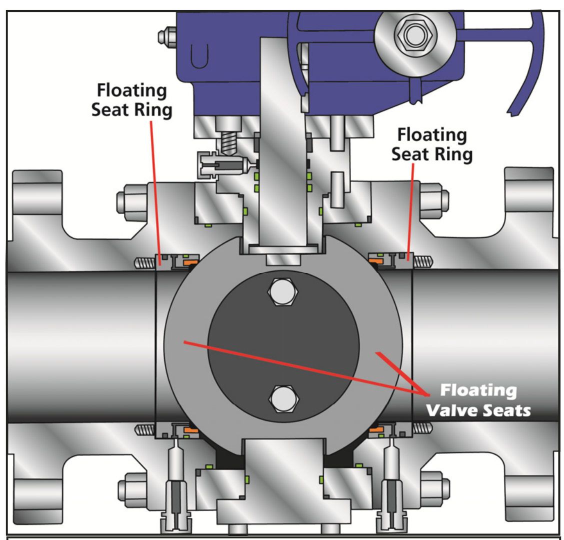

Figure 4. QuadroSphere® Ball Valve Seats

Figure 5a illustrates how a DIB seat provides a redundant sealing function. In the upstream or leftmost seat, the line pressure in the pipeline exerts a pressure force across the annular area bounded by the seat O-ring and the seat insert, thereby pushing the upstream seat to the right toward the ball. In the downstream or rightmost seat, any cavity pressure or leakage from the upstream seat will exert an opposing pressure force across the annual area bounded by the seat insert and the seat O-ring, thereby pushing the downstream seat to the left toward the ball. Hence, the DIB configuration (Figure 5b) provides two independent pressure barriers to isolate the line pressure and provide safe and reliable isolation of the system (Partridge, 2011). To avoid overpressure in the ball cavity due to thermal expansion, an automatic cavity pressure relief device is provided.

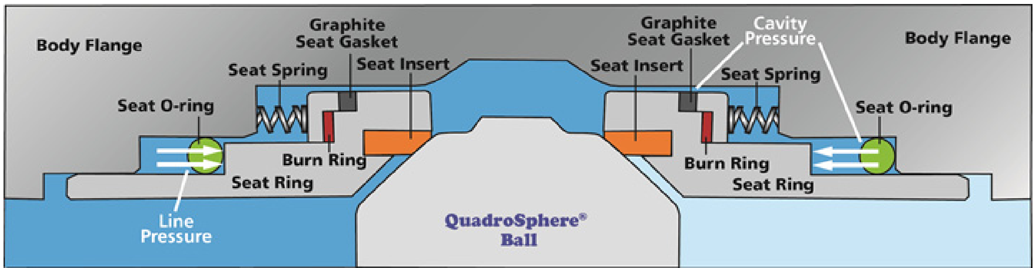

Figure 5A. Double Piston Effect Seats

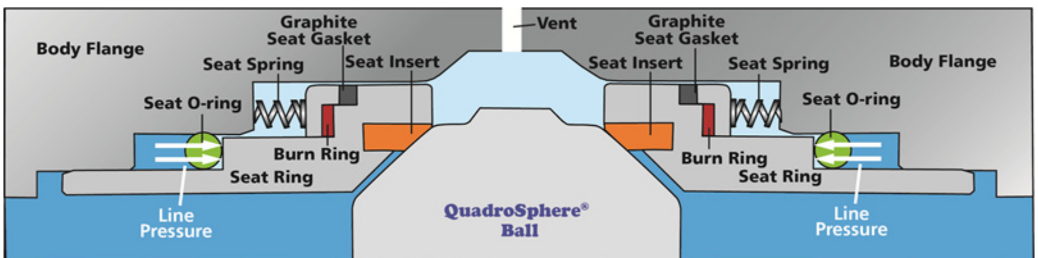

Figure 5B. Double-Isolation-and-Bleed (DIB)

The longevity of this trunnion ball valve in hydrogen production service is enhanced by the materials of construction. Given that the process runs at 2100 psig and a temperature range of 100 to 200°F with intermittent temperatures to 430°F, the resilient seat was fabricated from polyether ether ketone (PEEK), which is a relatively hard engineered thermoplastic polymer commonly used in valve applications because of its excellent mechanical properties at elevated temperatures. The PEEK seat mates with hard-chrome plated seating surfaces on the stainless steel ball. The hard-chrome plating is applied to the polished ball surfaces using an electrolytic process to provide a smooth and consistent wear-resistant surface hardness of 60-65 Rockwell C. The O-ring seals in the valve are molded with a special anti-explosive decompression (AED) Viton polymer. AED material is precision molded to prevent the permeation of high pressure gas into the material, which can cause cracks or fissures in the material if the valve were to rapidly decompress allowing the entrapped gas to rupture the O-ring.

Another feature of the QuadroSphere® trunnion ball valve is its forged steel construction of the body and ball. The initial forming process associated with forged construction helps eliminate porosity and cracks sometimes experienced with cast products. The secondary heating and forming processes of the valve components add further grain structure realignment, thereby providing additional structural integrity to the part (Johnson 2015). Moreover, the forging process ensures superior surface finishes and eliminates the need for weld repairs.

By incorporating the advanced design features of the QuadroSphere® trunnion ball valve over the last five years, the hydrogen production facility has improved performance, reduced maintenance frequency and achieved greater overall system reliability.

References

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About the Author

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