



## ***Overcoming Valve Failure In Molecular Sieve Service***

Rising Stem Ball Valves Maximize Revenue by Increasing Unit Uptime



***Experience In Motion***

## Introduction

Molecular sieve units are used throughout the petroleum industry for the deep dehydration and purification of natural gas. Properly dried gas is essential for product purity and to mitigate, if not eliminate, the corrosive effects of hydrates and acidic contaminants on system equipment.

These units perform a number of missions: producing feedstock gas for refineries and petrochemical plants; processing liquefied natural gas (LNG); and extracting natural gas liquids (NGL). They are also widely found in ammonia production. Molecular sieve units are often referred to as dryers, adsorption trains or dehydration units. Among the most essential equipment used in these units are the multiple sets of switching or frequent cycling valves. The selection of this type/design of valve is critical for product purity requirements and optimized unit operation.

### General Description Of A Typical Molecular Sieve Unit

A molecular sieve is a microporous structure composed of crystalline aluminosilicates, or zeolites. The outstanding characteristic of these materials is their ability to undergo dehydration with little or no change in crystalline structure. The empty cavities in activated molecular sieve crystals have a strong tendency to recapture the water molecules that have been driven off. This tendency is so strong that if no water is present they will accept any material that can get into the cavity. However, only those molecules small enough to pass through the pores of the crystals can enter the cavities and be adsorbed on the interior surface. This sieving or screening action makes it possible to separate smaller molecules from larger ones and thus, it is a highly effective medium for dehydrating and purifying gas.

Molecular sieve units usually contain two or more vessels packed with zeolite-based adsorbents, i.e., molecular sieve beds (see Figure 1). While wet gas is processed in one of the vessels (i.e., the adsorption column), the other is in regeneration mode.

Before entering the adsorption vessel/column, the gas is mostly stripped of water and contaminants (e.g., H<sub>2</sub>S and CO<sub>2</sub>) by a coalescer or separator. The adsorption process then takes place as the gas continuously flows downward through the fixed bed molecular sieve until the zeolites are nearly saturated with the remaining water and contaminants. When the concentration of solute in the exit gas reaches a threshold, the valves are switched, directing the gas flow to a second vessel/molecular sieve bed. The saturated bed in the first vessel is then regenerated.

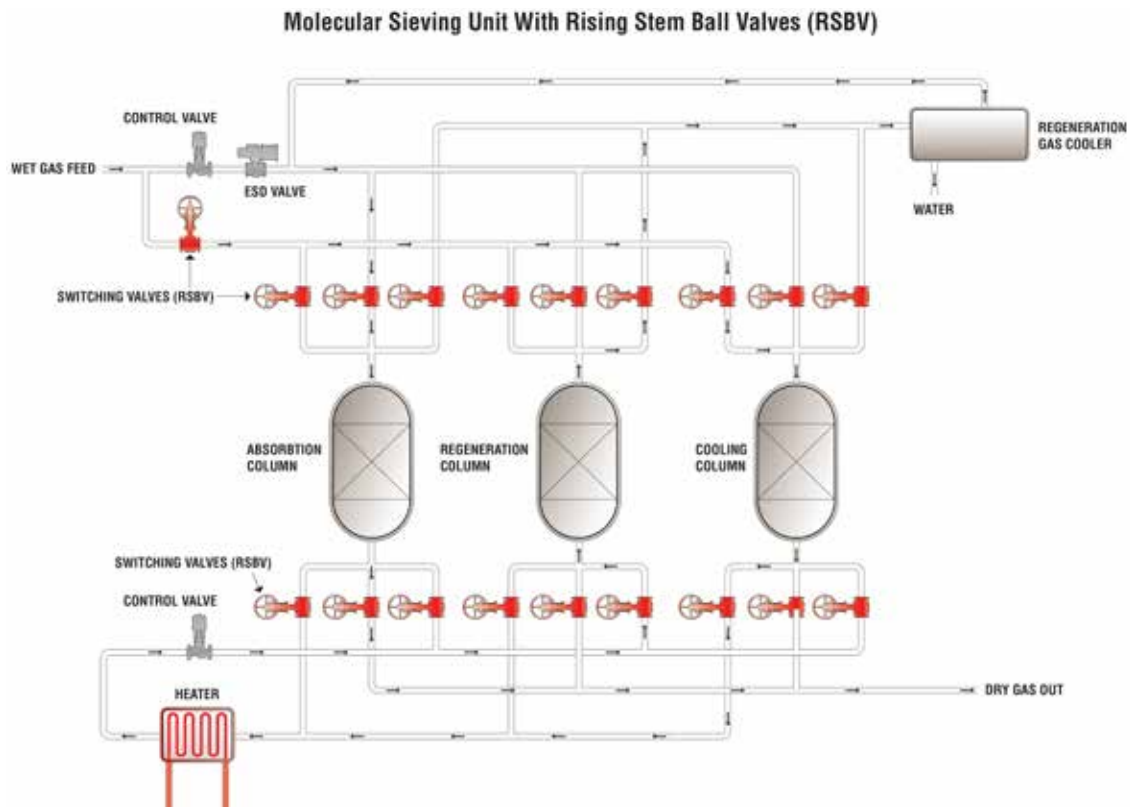


Figure 1: Example of a molecular sieving unit with RSBV switching valves (Note: This diagram is intended for reference only and should not be considered an actual process diagram.)

Regeneration is accomplished by heating the saturated bed with hot gas at high temperatures, varying from 200°C (392°F) to 315°C (600°F). After regeneration, the bed is cooled with inert gas. The flow is then directed to a gas separator to remove the condensed water and recycle the remaining gas to the adsorption vessel.

Depending upon the type of molecular sieve installation, this is usually a continuous process, with three cycles every 24 hours for seven days a week over a minimum five-year period without shutdown until planned maintenance.

## ***Operational Challenges For Switching Valves***

As with any critical process service, valves used in molecular sieve units must perform with maximum availability and reliability. Unexpected outages or unplanned maintenance cannot be tolerated. Granular catalyst carryover can abrade valve seats and seals, causing process leakage and contaminated product. High regeneration temperatures may also be an issue as rapid system pressure drops over the vessels can damage the adsorbent, increasing the wear and tear on the valves in frequent cycling service.

### ***Process Particles***

During regeneration, the desiccant routinely emits a gritty, dust-like powder which can escape the columns and enter the piping and valves. This abrasive dust can quickly erode valve seats and seals. For enhanced unit availability and increased process throughput, considerable care must be taken in the selection of both valve type and its materials of construction. These decisions will significantly mitigate potential seat damage and optimize the sealing capabilities of the switching valves.

### ***Fluctuating Temperatures***

The temperatures in this continuous process fluctuate from 200°C (392°F) to as high as 315°C (600°F) with relatively fast ramp-up when regenerating. The switching valves must be able to withstand these fluctuating temperatures, particularly in terms of rapid heating of the trim/internal materials in relation to the body material. Correct machining tolerance during manufacture is crucial to account for the thermal expansion characteristics of the various materials used in valve construction.

### ***Fluctuating Pressures***

In addition to rising and falling temperatures, pressures also fluctuate during the various stages of frequent cycling. These stages include: gas in/gas out; regeneration in/regeneration out; pressurizing; and depressurizing. Maximum operating pressures in hydrocarbon processing can reach 100 bar (1450 psi). This requires not only absolutely reliable high-performance internal and bi-directional seat seals but effective external atmospheric sealing to address regulatory safety, health and environmental issues. Therefore, valves must be designed for continuous cycling — three to four times a day in a severely hostile service environment.

### ***Stringent Leakage Rates***

The importance of leak-free valve performance in molecular sieve service cannot be overstated. For the deep gas drying process, it is imperative to meet the required specifications for optimum NGL purification and products processing. Any leakage caused by the switching valves will lead to compromised product quality output. Furthermore, leaking valves can retard catalyst performance by allowing the formation of hydrates, which will extend the sequence cycle and thus result in production losses. To prevent leakage and maintain process efficiency, the minimum acceptable seat leakage requirement for frequent cycling valves is specified to Class V shutoff per ASME (ANSI) FCI-70-2. Moreover, stem/gland packing design must satisfy the latest and most stringent fugitive emissions limits of all governing regulatory agencies.

## ***Switching Valve Design Options***

Three valve designs are usually found in molecular sieve unit switching valve service: (1) metal-seated ball valves; (2) metal-seated, triple off-set butterfly valves; and (3) metal-seated, non-contacting, rising stem ball valves. The rotary valve options are relatively inexpensive to purchase and may perform adequately in the near term. Operators, however, have generally found them to be deficient in sealing capability, expected service life and total cost of ownership. Process disruption, high MRO expense and the inability to deliver a minimum of five years of continuous service between planned shutdowns have all been persistent negatives.

More specifically, metal-seated ball valves have four key shortcomings:

- Stem/gland packing cannot be easily accessed or adjusted to prevent fugitive emissions over time.
- Their lack of a top-entry bonnet design makes in-line inspection or maintenance impossible.
- The continuous contact of the two seats against the ball results in increased torque and constant wear, which damages the seat/ball sealing surfaces and increases the risk of leakage.
- Their spring-loaded seat design makes it impossible to increase seating force externally from the valve.

Metal-seated, triple off-set butterfly valves share some of the same drawbacks, including the lack of a top-entry bonnet and the inability to easily inspect or adjust the stem/gland packing arrangement, plus the following:

- Their body style reduces flow volume and is further restricted by the disc which is constantly present in the flow path.
- The disc reduces the open flow area, resulting in low Kv (Cv) values (see Table 1).
- There is slight seat contact while opening or closing, which may result in leakage.
- Its spring-loaded or laminated seat design prevents an increase of external sealing force.

*Table 1. Average Kv (Cv) Values for Class 600 Butterfly Valves Versus RSBV*

Size DN, mm (in)	Triple Off-Set Butterfly Valves (Typical)	Rising Stem Ball Valves (Typical)	
	Kv (Cv)	Kv (Cv) Reduced Bore	Kv (Cv) Full Bore
100 (4)	180 (210)	560 (650)	1400 (1620)
150 (6)	520 (600)	680 (790)	3765 (4360)
200 (8)	910 (1050)	1735 (2010)	8200 (9500)
250 (10)	1470 (1700)	3490 (4040)	10 45 (12 100)
300 (12)	2375 (2750)	6310 (7310)	15 700 (18 200)
400 (16)	4490 (5200)	8715 (10 100)	36 600 (42 400)

For most molecular sieve unit operators, the preferred switching valve type continues to be the purposefully engineered rising stem ball valve (RSBV) with its friction-free linear movement and mechanically energized metal seat. Its time-tested service record has proven it to be the only suitable design for optimal long-term performance in severe applications, delivering unequalled reliability and availability. Of the three valve types, the RSBV is best at satisfying the competing priorities of cost versus performance.



*Flowserve Valbart™ Rising Stem Ball Valve (RSBV)*



*Flowserve Valbart VB3 side-entry, trunnion-mounted ball valve*



*Flowserve TX triple-offset, high-performance butterfly valve*

## ***The Virtues of the RSBV Design***

The RSBV has been designed specifically for critical and severe services where uptime and reliability are paramount, including molecular sieve unit operation. In particular, the RSBV prevents process leakage and product contamination in high cycle applications while maintaining high flow rates. Its most unique feature is a helix system that opens and closes the valve without stem rotation (see sidebar). Since it unloads the ball from the seat before starting rotation and maintains a purely linear motion through the stem/gland packing arrangement, the RSBV provides outstanding reliability in high cycle applications with excellent seat and seal endurance.

The RSBV design also has maintenance-friendly features. The stuffing box-type gland packing (including gland and gland flange) remains accessible and thus eliminates the need for special tools when adjusting or repacking the stem seal. More importantly, top-entry access allows visual inspection inside the valve without removing it from the piping.

### ***Proven Valve Design***

The design of the RSBV allows it to effectively handle reactor catalyst dust/powder scaling without compromising the leakage resistance of the valve. By design, the ball is not in contact with the seat as it moves into and out of the open or closed position. During the closing operation, it is pushed toward the single mechanically energized metal seat by the helix-shaped stem. There is no rubbing or sliding contact and, therefore, no leakage caused by wear and tear of components. This allows frequent cycling without wearing out the seat. Both the seat and ball sealing areas are furnished with Stellite® 6 weld overlay. This hard facing of the sealing areas ensures extended life of the valve while minimizing maintenance activities, such as seat replacement.

### ***Robust Materials of Construction***

The RSBV is constructed to meet the specifications for pressure/temperature ratings per ASME (ANSI) B16.34 and is designed for high working temperatures up to 315°C (600°F). It is capable of handling fluctuating temperatures due to the optimum selection of materials, including metal-to-metal seating, graphite stem packing, and stainless steel spiral-wound bonnet gasket with graphite body. The stem material is of high quality stainless steel alloy 17-4 PH, which provides excellent hardness and corrosion resistance. Furthermore, accurate machining tolerances are applied to meet thermal material expansion coefficients. Heavy wall thickness to API 600/API 6D provides extra corrosion allowance.

### ***Compliant to the Most Stringent Requirements***

The RSBV meets the highest standards for seat and stem packing leakage rates. Usually for molecular sieve service, ASME (ANSI) FCI 70-2 Class V shutoff is specified to ensure process optimization and prevent the formation of hydrates in the dryer beds. A combination of special lapping techniques and the Stellite 6 weld overlay applied to the seat and ball sealing areas helps the RSBV achieve the seat leakage rate of ASME (ANSI) FCI 70-2 Class VI. The RSBV design has also successfully passed fugitive emission testing according to ISO 15848 through third party inspection.

## ***Helix Coil Stem***

### ***Easy Operation With Low Maintenance***

The RSBV is a single-seated ball valve that uses a unique helix system for opening and closing the valve. The linear-only operation of the stem makes it an excellent choice for frequent cycling and, hence, an optimum solution for molecular sieve application. Each linear operation, from opening to closing and back again, is a friction-free movement between the seat and the ball that significantly reduces valve wear and minimizes routine maintenance. Valve operation during the opening and closing is explained below.

### ***Open Position***

In the fully open position, the stem is raised to its maximum limit with no contact between the ball and the seat. The valve in its fully open position provides a clear through flow.

### Open to Close Position

The downward linear movement of the helix passing through the roller bars on the top of the ball causes the ball to rotate 90 degrees (see Figure 2, Area 1). There is still no contact between the ball and the seat during movement which maintains the friction free/non-rubbing nature of the valve.

### Fully Closed Position

In the fully closed position, the ball is now turned 90 degrees and mechanically wedged toward the seat by the upper part of the helix-shaped stem, which is flat and angled (see Figure 2, Area 2). The movement of the ball toward the seat achieves the positive metal-to-metal sealing when the valve is fully closed. The amount of external actuation force also controls the amount of seat loading to maintain leak-free sealing.

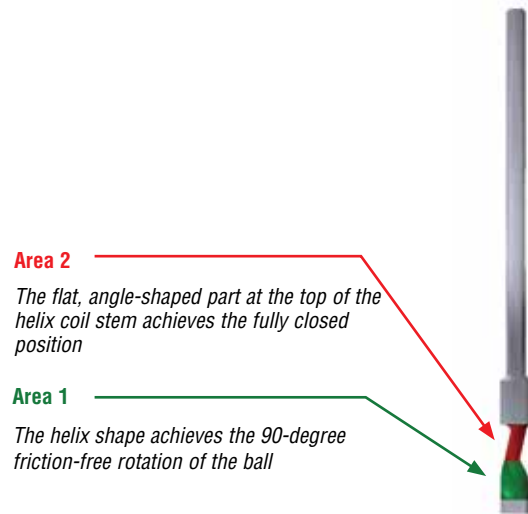


Figure 2: The RSBVs helix-shaped stem provides friction-free movement between the seat and the ball.

## Actuation For Switching Valves

Frequent cycling valves are generally equipped with actuators. In most cases, the specification calls for linear pneumatic actuation, which can be either double-acting (failing last position) or spring-loaded to open or close (fail open/close). When supplied with an actuator, the RSBV with the helix stem design ensures seamless, smooth and completely linear operation (since the stem does not rotate). Additionally, hydraulic dampers can be mounted to the double-acting actuators to prevent any shock at opening, thus ensuring extended service life for both actuator and valve.

There are important parameters to consider in order to properly size the actuators. These include actual differential pressure (i.e., maximum shutoff pressure) and whether the valves need to be uni- or bi-directional. Also, for a long operational lifetime, it is important to consider valve operating speed. The recommended operating speed for switching valves in molecular sieve service is around two seconds or slower per inch diameter. Faster operating speeds are not recommended.

The actual valve opening thrust can differ from the thrust to close. Therefore, using two separate 3/2 solenoids with air filter regulators is recommended to manage the air pressures and fine-tune the actuator output. Of course, other control system configurations are also possible. When the valve/actuator unit has been installed, it is recommended that all controls and tubing be checked for possible transportation damage before commissioning the unit.

As molecular sieve valves are typically used for both on-off and frequent cycling service, it is not necessary to perform “partial stroke” testing. Position indication is ascertained either by:

- A common, visually inspected, mechanical position indicator, or
- Limit switches — proximity or mechanical types — installed at the RSBV with remote communication of position status to the control room.

All control components such as solenoids, filter regulators, pilot valves, check valves, etc., are usually mounted to a stainless steel panel or enclosed in cabinets.

## Installation, Operation And Maintenance Of Switching Valves

### Installation

Before installing switching valves, it is important that the piping is checked and cleaned effectively by flushing the lines. This will eliminate any debris or other obstacles left in the system that could damage valve internals and other equipment. When installing the valves, the flow direction must be checked and valves must be mounted according to the flow arrow indicated on the valve bodies. Usually, the switching valves are mounted on a horizontal line with the actuator in the vertical position. Other mounting positions need to be verified with the valve manufacturer.



## **Operation, Startup**

The very first startup of new dryer units can sometimes cause problems, such as excessive amounts of broken catalyst or dust from the reactors entering into the system caused by incorrect loading or a rapid de-pressurization of the vessel. Also, the internals of the depressurizing valves can be damaged by cavitation due to high-speed flow at opening. Therefore, the de-pressurizing should be gradual and some kind of flow control must be considered to protect not only valve internals but also all other equipment mounted in the system.

## **Maintenance**

Once the startup of the new installation has been successfully completed, RSBV switching valves need simple preventive maintenance, including:

- Annually verifying the tightness of bolts, drains, vents and any other devices fitted (such as the tubing of the controls)
- Periodic greasing of the anti-rotation stem guide
- Checking the sealing performance of the packing and the tightness of the gland bolts
- Checking the sealing performance of the body/bonnet gasket and tightness of the bolting
- Whether actuated or manually operated, confirming open-and-close operation is smooth and without shock/slip

Detailed project-specific documents, especially the Installation, Operating and Maintenance Manual, should be retained and safeguarded.

For actuators, the specific manufacturer's Operating and Maintenance Manual needs to be followed. Every customer has his own specific policy on spare parts; however, no spare parts are required for startup. It is recommended to procure soft seals like gaskets, stem packing sets, actuator repair soft kits, etc., for one or two years. Customized spare parts solutions may be prudent for extended periods of valve operation.

## **Trouble-Free Operation Of The Molecular Sieve Unit**

As we have seen, molecular sieve unit service is a "difficult application," characterized by widely fluctuating process temperatures and pressures which are further pronounced by the abrasion of granular catalyst carryover and desiccant dust. The resultant problems are particularly acute on the performance of critical unit equipment, including switching valves. As seats and seals wear, rates of leakage and product containment accelerate, leading to inordinate levels of valve maintenance and possibly to premature failure. These inevitabilities cause expensive process interruption and even more costly unplanned unit shutdown.

The RSBV remains the valve of choice for molecular sieve unit service. It consistently delivers unprecedented reliability and unit uptime with an average MTBR of five years, due to its purposefully designed seat and sealing action. Its flow rates easily eclipse those of other valve designs, making it a highly efficient selection in all respects. In total, the RSBV unquestionably provides the lowest total cost of ownership in molecular sieve switching valve service. And these savings are further amplified when supported by an attentive, technically competent valve supplier/partner.

In summary, great care should be exercised in the selection and specification of molecular sieve unit switching valves. Valve type, sealing dynamics, materials of construction, actuation and controls are all essential issues requiring intense scrutiny. Request documentation — installation/application lists, customer testimonials, performance/service proof — from prospective suppliers to assist you in the RFP evaluation process. In doing so, you will significantly enhance your ability to achieve your unit's operational and financial performance goals.



*RSBV installed in Molecular Sieve Service*

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