The oil and gas industry often uses molecular sieves to dehydrate or separate contaminants from natural gas. Such a process involves several operational challenges that put valves under severe strain, potentially causing damage and service disruptions. Triple offset valves (TOVs) represent an innovative solution for molecular sieving due to their design and ability to handle extreme conditions. Using TOVs minimizes the need for, and cost of, maintenance, while offering significant footprint reduction compared to conventional ball valves.

Natural gas molecular sieving processes. A large number of dehydration and purification processes in the oil and gas industry rely on the adsorption principles of solid bed molecular sieves. Made from a micro-porous material, their ability to selectively adsorb gases and liquids makes them widely used across various applications. Smaller diameter fluid molecules separate from the main feedstock via electrostatic attraction or micro-porosity adsorption and remain trapped inside the adsorbent structure.

After use, molecular sieves are regenerated with temperature swings and regenerating gases, which allow full recovery of the trapped molecules while restoring the sieve adsorption capacity. Adsorption dryers are typically equipped with two to four molecular sieve beds, each dedicated to the adsorption of a single molecular type (water, CO₂, mercury, lead, etc.). Water adsorption is a common application in natural gas treatment plants, refineries and petrochemical complexes. It utilizes hard, granular adsorbents manufactured in several types of materials, including aluminosilicates, such as Zeolite, ceramic materials, activated carbon and silica gels.

They usually have a spherical or cylindrical shape and their internal pores allow access to free volumes within their micro-crystalline structure (FIG. 1). Conversely, carbon dioxide (CO₂) removal from natural gas (typically not pre-treated) is a process often handled by using thin membranes to perform a solution-diffusion separation (absorption principle). These membranes, typically made with polymers in spiral shapes, allow fluids to dissolve over their surface and diffuse through their structure, leaving molecules with specific permeation rates trapped inside. With natural gas, the feed gas is separated into a methane (CH₄)-rich stream on the exterior of the membrane and a CO₂-rich stream on its interior. Pressure is the force driving the membrane diffusion, while regeneration processes are undertaken via temperature swings achieved by gas flushed in the opposite direction, seen in FIG. 2.

Solid bed and membrane molecular sieve processes are extremely challenging for valve equipment. Both processes use valves to perform frequent ON-OFF functions to switch one or more vessels from gas purification to regeneration modes. Operating failure can lead to significant plant downtime, product loss, potential environmental pollution and other safety issues.

Critical issues with existing valve solutions. Gas purification valves currently face a number of challenges during both molecular sieve processes (FIG. 3):

- High frequency open/close cycles—typically one every four hours, with a maximum of eight each day
- Frequent thermal cycles—during regeneration mode, the molecular sieve is flushed with hot gas, typically at 350°C. During purification mode, it is brought down to ambient temperature.
- Gas purification residuals (crushed adsorbents) are often present in outlet gases and can pass through screens and flow through the valves towards downstream lines, causing abrasion of sealing components and jeopardizing valve integrity. Conversely, whenever membranes are used for CO₂ removal without pre-treatment, corrosive gases (sour/acid) are present, especially in offshore installations.
- Historically, non-rubbing rising stem (tilting) ball valves have been the standard used in natural gas molecular sieves. The basic design of a ball valve—a ball rotating on soft sealing surfaces with systematic rubbing—is enhanced by introducing an additional mechanical device that allows for a tilt/turn operation and a mechanical camming action of sealing surfaces nearing closure. So far, this has been the most effective response from the industry to tackle the issue related to cycle-intensive applications, such as frequent switching, which would otherwise require recurrent valve maintenance or replacement.
- However, rising stem ball valves of larger sizes and pressure classes are extremely heavy and have a large footprint, generating a number of direct (material use) and indirect (installation) costs that engineers must account for during front-end engineering design (FEED) project phases. The tilting mechanism itself, a variant on a standard quarter-turn ball valve, is subject to wear and can degenerate over time. Although the valve sealing elements may not involve rubbing capabilities, friction is transferred to both the shaft cam (towards core pins) and the S-shaped pin slot. This valve design requires specialized maintenance, including the use of costly spare parts, significant time and effort.

Long-term reliability of non-rubbing, metal-to-metal TOVs. Process designers and plant operators looking for a reliable and cost-effective option should consider using a different type of valve in molecular sieve applications, such as TOVs. They share the same cone-to-cone principle as globe valves (FIG. 4), with one key difference: sealing is performed by applying a quarter-turn rotation. These valves are a more compact design against the symmetrical axes of the pipe/valve eliminate any possibility of rubbing:

- The shaft is placed behind the plane of the sealing surface to ensure a continuous seat path.
- The shaft is placed to one side of the pipe/valve centerline to allow the gas to bypass the seal from the seat during the 90° opening.
- The seat and seal cone centerlines are inclined with respect to the pipe/valve centerline. This third offset rotation eliminates rubbing.
- Pentair Valves & Controls’ Vanessa TOV design with a flexible metal seal ring represents an innovative solution to withstand high-frequency open/close cycles. Due to the non-rubbing design, wear between sealing components is completely eliminated. The whole trim, including bearings and thrust bearing, is designed for heavy-duty services. To protect equipment from frequent thermal and pressure cycles, Vanessa TOVs’ metal-to-metal sealing, a resilient seal ring and torque sealing compensate different thermal expansion rates between trim and body, while ensuring outstanding tightness and removing the risk of valve jamming.

Vanessa Series 30,000 TOVs feature Stellite 21 seat overlays, which offer high resistance to wear generated by the fluid (which may include particulates released from the sieve vessel). The valves also include an easily replaceable one-piece metal solid seal ring, proven across several molecular sieve processes.

The material selection of each component offers the best compromise among mechanical performance, corrosion resistance and equivalent expansion coefficient, making Vanessa TOVs suitable across a wide range of corrosive gases. The cost-effective solution enables the use of a carbon steel body in a corrosive environment by protecting all surfaces in contact with the fluid with corrosion resistant alloy (CRA)-quality weld overlay.

An ongoing trend: replacing rising stem ball valves with TOVs. Rising stem ball valves can be safely substituted by TOVs. Footprint and weight savings can be achieved, especially on larger diameters (> 6 in.) and pressure classes (ASME class 300 and 600), due to lower material use and a more compact body. Vanessa Series 30,000 TOVs require minimum maintenance, which can be easily performed onsite, and their non-rubbing rotation and full metal construction significantly extend the valve life.

Pentair’s first experience in molecular sieve applications dates back to 1999, when the company provided its Vanessa Series 30,000 TOVs to a major end user of offshore operations in Malaysia. Some of the valves replaced rising stem ball valves for a CO₂ membrane system that featured a two to four-hour open/close cycle; those valves were still in operation. Hundreds of rising stem ball valves have also been replaced in gas plants in Mexico in solid bed molecular sieve applications, and there are many more cases of TOV valve evaluation and adoption in response to the recommendations by major molecular sieve process licensors.

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