New flow-through valve design targets improvements in reciprocating compressor efficiency, reliability, and serviceability

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Over the last three decades, original equipment manufacturers (OEMs) have dedicated significant time and resources toward improving the design of reciprocating compressors valves, and rightfully so. Multiple studies have shown that among all compressor components, valves are the leading cause of unplanned downtime. Valve design and configuration also directly influences a compressor's energy efficiency, maintenance schedule, and turndown capabilities.

The introduction of the MAGNUM™ valve in the late 1990s marked a milestone in compressor valve development by setting a new standard in terms of industry reliability and efficiency.[1] Additional improvements were realized in 2012, with the release of the MAGNUM Hammerhead valve, which features a higher effective flow area (EFA), translating to lower energy losses and increased compressor efficiency.

Siemens Energy has now taken the next step in valve design by introducing the MAGNUM™ Plus, which combines proven features of the standard MAGNUM and Hammerhead concepts, along with new innovations to meet evolving operator requirements for higher compressor uptime, reduced power consumption, and lower OPEX.

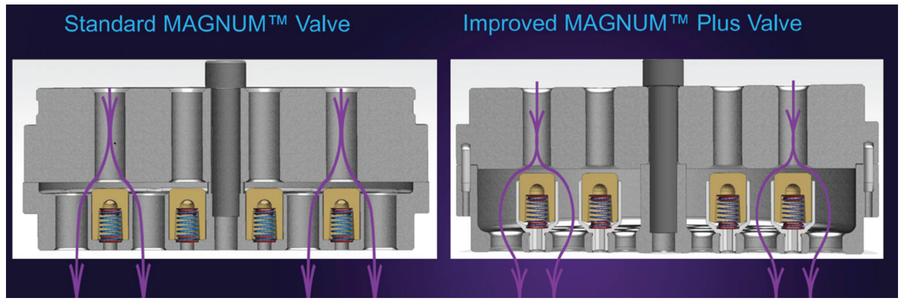

FIGURE 2. **FLOW PATH OF STANDARD MAGNUM (left) VS. MAGNUM PLUS (right)**

MAGNUM Plus design overview

The MAGNUM Plus can be installed in any brand or configuration of reciprocating compressor and supports speeds up to 1,800 rpm and differential pressures up to 3,000 psi. It is designed for gases of any molecular weight but is particularly well suited for hydrogen applications, which put unique demands on compressors in terms of efficiency, reliability, and in some cases (such as electrolysis plants), flow flexibility.

Advanced computational fluid dynamics (CFD) and finite element analysis (FEA) were employed to develop the MAGNUM Plus valve's unique geometry.

Figure 2 above shows the cross section of both the standard MAGNUM and the new MAGNUM Plus valve design. As seen, the main differentiator of the MAGNUM Plus is that valve elements are no longer moving in the stop plate. The framing component for the axial movement of the valve element is now a cup (pocket), which is threaded into the stop plate.

This unique component design decouples the outlet flow area from the valve element functional area, increasing the EFA on the outlet side, while simultaneously enhancing the EFA within the valve functional area. Although the new concept increases the overall height of the build, it comes with the benefit of higher gas throughput.

FIGURE 1. **MAGNUM™ PLUS VALVE COMBINES FEATURES OF THE STANDARD MAGNUM AND MAGNUM HAMMERHEAD VALVES**

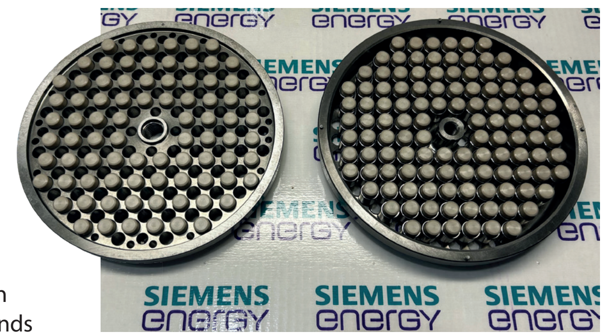

FIGURE 3. **TOP VIEW OF STANDARD MAGNUM (left) VERSUS THE MAGNUM PLUS (right)**

Additionally, the ratio of valve elements to valve diameter has been increased, as has the number of outlet flow holes. Figure 3 shows a top view of a standard MAGNUM (left) versus the MAGNUM Plus (right).

Reducing compressor power consumption

Valves play an important role in a compressor's overall efficiency. An optimized valve design allows the compressor to deliver the highest flow rate of gas at the desired pressures by consuming the least amount of energy. Maximizing the valve orifice or EFA is key in this regard, as it results in less flow restriction and pressure drop, and lower power consumption.

Minimizing power consumption is desirable in all compressor applications. However, it is especially critical in proton exchange membrane (PEM) electrolysis (i.e., green hydrogen) plants that rely on intermittent power sources, like wind and/or solar.

Another design factor that impacts efficiency is valve clearance. As valve clearance increases, compressor flow is reduced. The MAGNUM Plus valve, with its relatively small moving element and optimized distance between elements, is specifically designed for low clearance, yet has an EFA higher than the standard MAGNUM and equal to that of concentric ring valves.

The valve lift configuration also influences EFA. A higher EFA can be achieved by increasing valve lift, but only up to a certain limit. The geometric characteristics of each valve type determine this limit of lift, beyond which more flow area cannot be obtained. Laboratory tests measure the flow coefficients at various lifts, allowing flow areas to be obtained for each valve type.

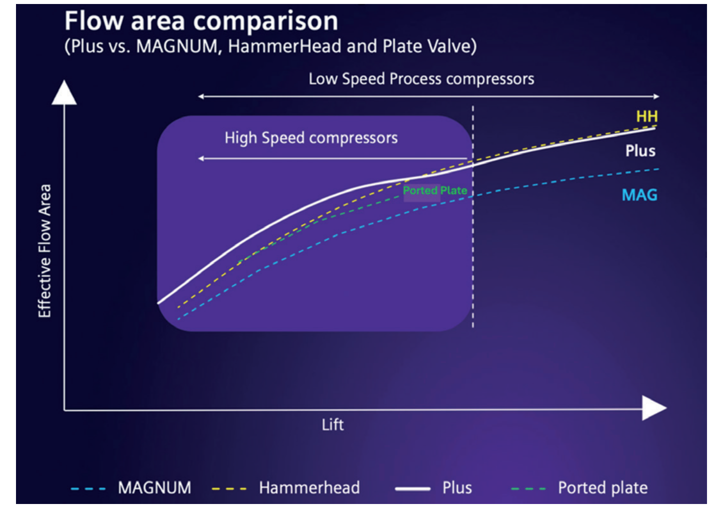

FIGURE 4. **FLOW AREA COMPARISON OF DIFFERENT VALVES**

Figure 4 shows EFA flow test results from a MAGNUM Plus valve versus other common valve designs. As seen, the MAGNUM Plus exhibits the highest EFA in low lift configurations, which are representative of hydrogen compression applications.

In 2024, a MAGNUM Plus valve was installed as part of a pilot project in a reciprocating compressor serving a hydrogen plant (refinery application). The performance of the compressor was compared with a second identical compressor in the plant which utilized only standard MAGNUM Valves.

Over the course of nine months (~7,000 hours of runtime), horsepower was measured by an independent third-party on three occasions. The test results showed a 1.6% reduction in power loss using the MAGNUM Plus, which was consistent with theoretical calculations performed by Siemens Energy's design team.

Meeting requirements for increased valve reliability

Although efficiency is becoming a more important performance metric for many end-users, valve reliability has remained the top priority across virtually every compressor application.

The moving elements in the valve are subject to stresses imposed by differential pressure (DP) and impact forces. The moving element must be strong enough to resist the impacts and DP force when it is closed against the valve seat, as well as impact forces when it is opened against the stop plate.

As valve lift increases, so too does the impact velocity when the element returns to the seat or stop plate. This creates stress and accelerates wear and tear on valve components, including the seat and sealing elements. The causal relationship between valve travel distance and decreased valve life is widely known and has been the focus of several studies over past decades.

Reducing valve lift is advantageous. However, as previously discussed, doing so also reduces EFA, leading to higher pressure drops and increased energy losses.

A key advantage of the MAGNUM Plus valve is that its unique geometry and design increases EFA without a corresponding increase in lift. The travel distance of the MAGNUM Plus element is approximately one-third lower than a standard MAGNUM element in the same compressor configuration.

Other notable features which have been incorporated to support longer valve runtimes include:

- "Open" design concept to reduce particle build up
- Bottom bevel added to reduce point stress and prevent fractures associated with flat contact surfaces
- Multi-poppet design is tolerant against over-lubrication, liquid carry over, and will continue to function with damaged elements
- Corrosion resistant valve spring materials
- Proven materials used for stop plate (Nodular Iron, 17-4PH SS, SAE AISI 4140)
- Low stress spring design

Siemens Energy anticipates that these features will support extended run times versus previous valve designs.

Designed for serviceability

Serviceability is an important factor to consider in the context of a compressor's total cost of ownership (TCO).

To support ease of maintenance, the MAGNUM Plus valve utilizes threaded cups which hold the valve elements. If either a valve element or a cup becomes worn, the threaded cups can be unscrewed and replaced. The procedure can be performed quickly (i.e., in a matter of minutes) and requires no special tools or training, as would typically be required with other valve types.

Additionally, unlike plate and ring valves, the MAGNUM Plus valve uses a single element for all valve sizes, which simplifies inventory management.

Continuously improving

Established designs like the standard MAGNUM and MAGNUM Hammerhead valves continue to meet and exceed the requirements of operators across a broad range of industries. However, with new compression applications emerging to support various decarbonization use cases, particularly in the context of hydrogen, the demands being placed on reciprocating compressors are evolving. This, in turn, has created a need for innovations in valve design.

The MAGNUM Plus was designed to address this need and represents the next step in valve development by combining many proven characteristics of past MAGNUM variations with novel features aimed at incrementally improving compressor efficiency, uptime, and serviceability.

REFERENCE: [1] J. Sanford, S. Chaykosky. Valve performance: A key element for reliability and efficiency of reciprocating compressors in hydrogen applications. COMPRESSORTech^2. March 2023.

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