FLOWSERVE

TECHNICAL ARTICLE

Enabling Clean Hydrogen Compression:
A Breakthrough Sealing Solution

Introduction

As the hydrogen economy rapidly evolves, industries across the globe are under increasing pressure to accelerate the shift toward cleaner, more sustainable energy systems. At the heart of this transition lies a critical challenge: developing technologies that not only deliver high performance and reliability, but also meet stringent decarbonization and emissions reduction targets. Clean hydrogen, particularly green hydrogen produced using renewable energy, is emerging as a cornerstone of this low-carbon future. However, realizing its full potential requires innovation at every step of the value chain, especially in compression and transport, where purity and emission-free operation are paramount.

At Flowserve, we are proud to be at the forefront of this transformation. In close partnership with Everllence, we have co-developed a groundbreaking, water-based mechanical seal specifically designed for oil-free screw compressors used in green hydrogen applications. This first-of-its-kind solution eliminates the need for oil or inert gas barriers, using ultra-pure water to enable truly clean, zero-emission hydrogen compression. It's a breakthrough that not only addresses today's operational demands but helps lay the foundation for a more sustainable hydrogen infrastructure — one that's safer, more efficient, and aligned with the world's climate goals.

Meeting the demands of hydrogen purity and emission-free compression

Green hydrogen production relies on electrolyzers powered by renewable energy to generate ultra-pure hydrogen. Once produced, hydrogen must be compressed, purified, and transported — processes that demand extremely clean, reliable, and efficient mechanical systems.

Traditional sealing technologies for turbomachinery often rely on oil-based or inert gas barriers, which can risk contamination or emissions. To address this challenge, Flowserve and Everllence have co-developed a zero-emission mechanical sealing solution that uses ultra-pure water — the same water used in the electrolyzer process — as its barrier medium.

"For hydrogen applications, we introduced a new sealing design in collaboration with our seal supplier Flowserve," said Dr. Jan Philipp Schnitzler, Head of Engineering, Screw Compressors at Everllence.
"This concept ensures zero hydrogen emissions to the environment and eliminates the need for nitrogen or other buffer media. Only ultra-pure water comes into contact with the hydrogen, preserving its purity throughout the process. Early customer involvement and the close partnership with Flowserve enabled the successful market introduction of this technology."

Why dry screw compressors?

The use of dry screw compressor technology is particularly well-suited for hydrogen compression due to hydrogen's extremely light molecular weight and unique thermodynamic properties. Unlike turbo compressors, which rely on high flow rates and can struggle with the low density of hydrogen, screw compressors are positive displacement machines that compress gas by reducing the volume between meshing rotors. This allows for high pressure ratios per casing and more efficient handling of low-mass gases like hydrogen — especially in small to mid-scale installations.

Screw compressors also offer operational flexibility, making them ideal for the variable loads often seen in green hydrogen production tied to renewable energy sources. They start and stop easily, respond well to fluctuating conditions, and maintain high efficiency across a broad operating range.

Another key benefit is reduced maintenance. Compared to reciprocating (piston-type) compressors, screw compressors feature fewer moving parts and no valves, resulting in longer service intervals, lower wear rates, and reduced downtime — a major OPEX advantage for end users.

"Hydrogen is one of the most demanding gases to compress — it's light, small, and prone to leakage. Screw compressors, when paired with the right sealing solution, offer a compact, efficient, and low-maintenance path to clean compression," said Joe Barker, Senior Engineer at Flowserve. "Our goal was to make a water lubricated hydrogen compressor seal not only possible, but practical for long-term operation."

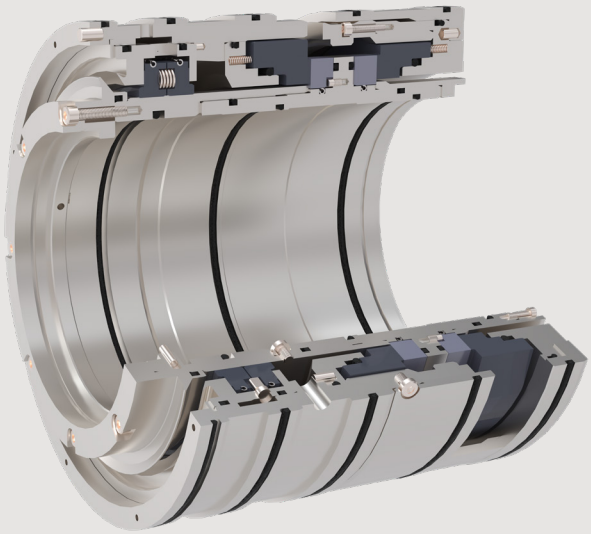
Engineering challenges and sealing design innovations

Developing a mechanical seal capable of operating in oil-free hydrogen compression at continuous speeds exceeding 100 m/s presented a set of engineering challenges few companies are equipped to solve. Conventional seals are typically designed for much lower speeds — often below 25 m/s — and rely on oil or inert gases for lubrication and sealing. Creating a high-speed, water-lubricated seal for hydrogen — one of the smallest, most leak-prone molecules in existence — required a completely new approach to materials, design, and testing.

At Flowserve, we approach complex engineering challenges with a deep well of expertise and a commitment to purposeful innovation. Backed by decades of experience in sealing technologies, rotating equipment, and fluid dynamics, our engineers developed a solution that meets the demanding conditions of oil-free hydrogen compression — while aligning with the industry's critical requirements for zero emissions and absolute gas purity.

This advanced mechanical seal addresses several critical performance factors:

- **Zero emissions and hydrogen purity –** No oil or inert gas contact; the hydrogen stream remains uncontaminated.
- **High-speed operation –** Designed to perform under extreme peripheral speeds while maintaining seal integrity.
- **Thermal management –** Engineered to dissipate and manage heat generation through optimized internal geometries.
- **Leakage control –** Designed for minimal leakage and back-pressure tightness, even in the event of a seal water drop.
- **System integration –** Tailored to fit the unique configurations, process parameters, and operating conditions of our customers' compressors, ensuring seamless mechanical and functional compatibility.



"We see every technical barrier as an opportunity to innovate. Hydrogen compression at this speed, without oil or inert gas, is no small feat — but it's exactly the kind of challenge our engineering teams are built to overcome," said Joe Barker, Senior Engineer at Flowserve. "This seal is a great example of how we combine deep technical knowledge with strong customer collaboration to deliver something truly industry-leading."

Proven performance through rigorus testing

To date, the seal has successfully completed over 400 hours of rigorous testing across Flowserve's validation labs and customer compressor test stands. These tests simulated real-world conditions and stress scenarios to ensure long-term performance and reliability in hydrogen compression environments.

Test scenarios included:

- Continuous and variable-speed operation
- Simulated upset conditions with temperature and pressure fluctuations
- Dry turning during compressor assembly
- Slow roll and emergency trip conditions
- Internal screw compressor testing under the most demanding load cases
- Full compressor acceptance testing in accordance with API-619

The results confirm the seal's ability to maintain integrity, prevent hydrogen leakage, and operate reliably at high speeds and extreme conditions. Two seal sizes have now been fully validated and are ready for operational deployment — providing compressor OEMs and operators with a proven, zero-emission sealing solution that supports long-term efficiency, safety, and compliance.

Collaboration that drives progress

This achievement is the result of deep technical collaboration, combining Flowserve's sealing expertise with advanced compressor engineering. From early concept development to system-level integration and rigorous testing, the project exemplifies how strong industry partnerships can accelerate innovation and solve complex challenges at the heart of the energy transition.

By working closely with our customers and engineering teams across disciplines, we've created a breakthrough that sets a new benchmark for hydrogen compression — and demonstrates the value of co-innovation in driving meaningful progress.

Key Technical Highlights:

- Dry screw compressor application
- Seal speeds exceeding 100 m/s
- Ultra-pure water used as barrier fluid
- Zero emissions and hydrogen purity maintained
- Validated through integrated system-level testing

Learn more about our compressor seal solutions:

Conclusion

This isn't just a new product — it's a pivotal advancement in hydrogen-ready turbomachinery. By eliminating oil and inert gases and using ultra-pure water as a sealing medium, this solution enables truly clean, emission-free hydrogen compression.

It empowers compressor OEMs to develop oil-free systems with greater design flexibility, and gives operators a solution that supports safety, reliability, and compliance — all while reducing total cost of ownership.

At Flowserve, we remain committed to developing technologies that accelerate decarbonization and deliver measurable impact for our customers. This innovation is a clear example of what's possible when engineering excellence and shared vision come together.

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Joe Barker (PE) is an Engineering Specialist at Flowserve Corporation based in Kalamazoo, MI. He graduated from Western Michigan University with a B.S. in Mechanical Engineering. He has over 25 years of experience working with mechanical seal design, sealing systems, and fluid handling equipment. Mr. Barker is an active member of the API692 2nd edition Task Force.

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Dr. Jan Philipp Schnitzler is Head of Engineering for Screw Compressors at Everllence, based in Oberhausen, Germany. He earned his degree in Mechanical Engineering from the University of Duisburg-Essen (UDE) in 2008 and completed his doctoral studies in 2017. In 2014, Dr. Schnitzler joined MAN Energy Solutions (now Everllence), where he served as a team lead for stator parts and contributed as a senior development manager to several projects within the MAN gas turbine portfolio. Since October 2022, he has been leading the engineering department for screw compressors, focusing on the development of high-performance, energy-efficient compression technologies for emerging applications.

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SSTA003167-01 (EN/LTR) December 2025