

HOW ARE TESTING AND FAILURE MODE ANALYSIS CRITICAL IN ACCELERATING THE TRANSITION TO NET ZERO?



Simon Cleghorn is a 23-year associate at W. L. Gore & Associates (Gore) and currently a Global Product Specialist in the Clean Energy division. We spoke with Simon about Gore's fuel cell product testing capabilities and how they are critical

to product development and customer needs in a rapidly growing industry.



What are Gore's testing capabilities and how do you use them to benefit fuel cell system/stack manufacturers?



At Gore our goal for our products is to "do what they say they will" – and this means continuing to invest in a deep understanding of our product's fitness for use, from raw materials and product design to post-mortem

analysis.

As a result of this commitment to our customers, we have developed extensive in-situ and ex-situ testing capabilities. In the context of fuel cells, in-situ testing involves assembling and testing products in fuel cell hardware.

In-situ fuel cell testing is the primary tool that we use to understand the power density and durability of our membrane as a function of the operating conditions in the cell and its interactions with other cell components, which can greatly influence membrane performance. We can use both AC and DC techniques to understand the processes that govern performance and the materials contribution and their changes over time.



Ex-situ testing may typically involve chemical and physical analysis as well as mechanical testing of the membrane electrode assemblies (MEAs), membrane or its constituent components. At Gore we have developed ex-situ testing specific to our membrane products, such as liquid and vapor phase Fenton's testing, as well as leverage our enterprise-wide

analytical and characterization capabilities, for example, the use of typical analytical tools such as EDS and XPS to identify contaminants in the membrane itself.

We apply our suite of testing capabilities in multiple areas. It informs new technology and product development, and ensures the repeatable, reliable performance of the products we provide to our customers, where product release testing is critical to our quality control and change management in this dynamic and rapidly scaling industry. It also helps us understand the performance of products in our customer's end-application, of which post mortem analysis is a critical component.



How does Gore consult/ collaborate with its customers throughout the testing process?



At Gore our goal is to closely collaborate with our customers, as this is the only way we can really

understand how our products are working within their systems and applications. This collaboration also provides the greatest insight into knowing where innovation is needed to solve problems and understand the needs for the next generation of products. Ultimately, this can accelerate time-to-market and protect the customer's investments by finding the most cost-effective solution.



We have worked to develop a wide range of test methods and models, including accelerated testing that correlates or replicates the customer's use of the membrane product. This helps us better understand and predict performance for the customer so that we can recommend the best product from our membrane portfolio, or suggest changes that the customer could make to the way they operate or design their fuel cell system.



What is Gore's approach to post-mortem analysis, and how does this benefit the customer?



Post-mortem analysis is essential for continuous learning and improvement of our membranes. We'll have close discussions with our customers about the product performance limitations or failure modes, and understand their strategies to operate the fuel cell stack.



Let's imagine the customer observes a product failure, such as premature high gas crossover through the membrane. Gore performs a post-mortem analysis on the product while working with the customer to develop a possible hypothesis for the failure mode(s). As the discussion progresses, the postmortem approach and experiments may become more targeted:

At this point in problem solving, we may take different avenues:

- Gore may recommend an alternative membrane solution which would be more robust in the customer stack;
- The customer and Gore could explore alternative stack design or systems operation solutions that reduce the stresses leading to membrane failure, or;
- Gore and the customer collaborate to develop accelerated stress testing and other models to simulate the failure mode and enable new material development.

At the end of the process, Gore's product and the customer's operational solution should be integrated to achieve the desired goals.

Our approach and testing tools are customized to the problem we identify in the initial discussions with the customer. As we explore new requirements for a customer's application, we are constantly expanding and improving these tests to keep up with a rapidly

developing industry.



How does Gore's product analysis (in-situ and ex-situ) differ from its competitors?



Gore is a pioneer in the proton exchange membranes (PEMs) fuel cell industry, and a leader in membrane characterization and testing. No other companies have the industry experience or track record that we do; for decades, we've supplied in volume a broad range of customers in different fuel cell end applications, from transportation to back-up power generation.

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Gore has developed ePFTE-reinforced PEMs and MEAs which are used by nearly all major system developers worldwide. Having been at the forefront of the industry since 1994, we have dedicated significant time, resources and investment into repeatable and reliable testing. This has resulted in a deep understanding of materials-structure-performance relationships, and accelerated test methods that can rapidly advance our technology.



Our extensive, enterprise-wide analytical tools and capabilities massively reduce turnaround time in problem-solving, saving customers thousands of testing hours. Gore's high-volume manufacturing capacity and supply security helps us develop and release new products quickly and efficiently.



What are the key benefits to a holistic failure mode analysis?



Understanding failure is the first step towards solving it – and developing solutions that reduce the risk of future failure and pushes our industry forward. Investigating failure mechanisms facilitates the development of accelerated tests that result in improved PEM products. In turn, this strengthens the application support we can provide for our customers.

The fuel cell industry is still in a developmental stage, but moving rapidly towards mass commercialization. By testing and observing field returns, we can establish where innovation and investment are needed most – from both Gore and the customer's perspective. Failure mode analysis also helps us anticipate future application requirements and how we can develop our products to meet them.



What are some notable impacts Gore has achieved with its failure mode analysis?



Our team was one of the first to publish some of the membrane durability tests which are cornerstones of the industry today. For example, Gore was a pioneer in adopting and publishing open circuit voltage tests in the late 1990s, which have become an industry standard – and a common test for both material and stack developers to evaluate membranes. In 2004, we collaborated with our customers to develop the first in-situ relative humidity test to understand the mechanical properties of our membrane, after closely analyzing failure modes.

Our testing capabilities also enable us to provide a secure supply of high quality products. On the manufacturing side, tests are critical to monitor our raw material supply and ensure our high standards are met. Rapid scale-up is a challenge in this

growing industry, so fast and reliable tests support effective change management and enable targeted innovation. We save our customers time and money by providing confidence in our products, making rapid improvements and reducing time-to-market. Our customers trust our data to allow them to focus on their highest priorities.



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Simon Cleghorn is W. L. Gore & Associates global product specialist. He is a PhD electrochemist with close to 25 years' experience working in the field of polymer electrolyte membranes for fuel cells and other applications.

If you wish to learn more about Gore and its GORE-SELECT® Membrane technology, please visit <https://www.gore.com/alt-energy>.

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