Donaldson
FILTRATION SOLUTIONS

ADVANTAGES OF ePTFE-REINFORCED COMPOSITE PEM IN FUEL CELL STACKS

Membrane Filtration

Added durability with high power density lowers total cost of ownership

The development of hydrogen fuel cell technology was a big step toward a cleaner, decarbonized energy future. To ensure that fuel cells remain a viable energy solution, their high power density must be combined with long-term durability in order to lower their total cost of ownership.

For more than 15 years, Donaldson has worked with global, industry-leading companies to commercialize highly-engineered expanded polytetrafluoroethylene (ePTFE)-reinforced proton exchange membranes. That work has resulted in membranes that are thin, efficient, and durable and provide low resistance for optimum current density.

We have a deep understanding of how ePTFE properties – such as thickness, modulus, ultimate strength and anisotropy – affect the long-term durability of fuel cell stacks. That expertise allows us to offer ePTFE products that are optimized for ePTFE-reinforced composite PEM in fuel stacks, an improved alternative to non-reinforced PEM fuel cell membranes.

HOW A FUEL CELL WORKS:

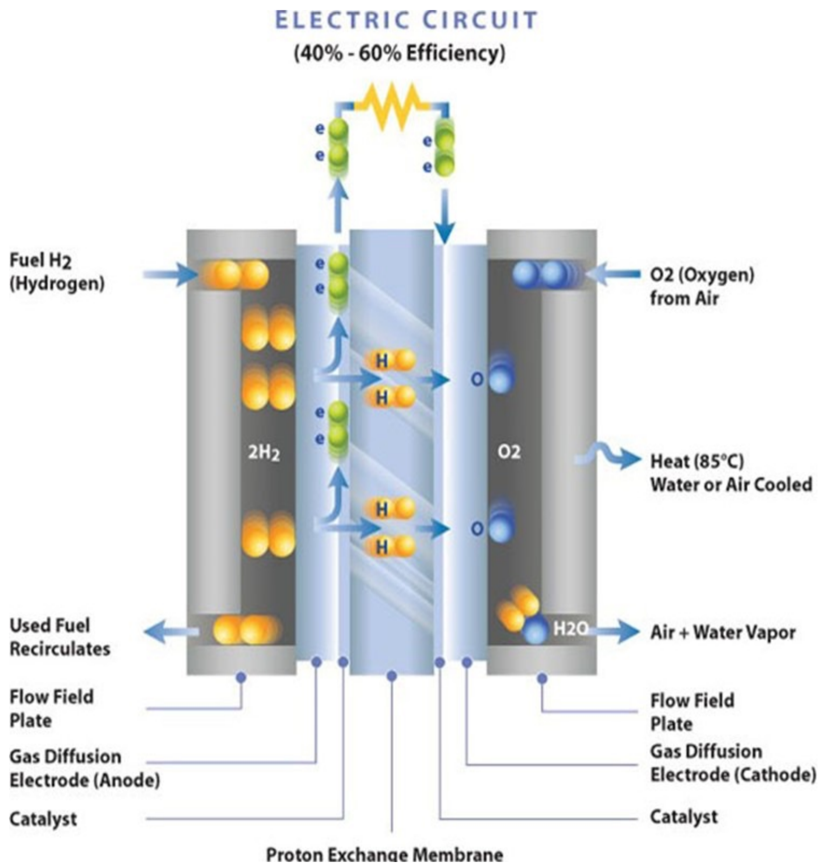


Figure 1: Generic fuel cell

The schematic in figure 1 shows a generic fuel cell. Hydrogen and air enter into the anode and cathode separately and diffuse into the catalyst layer (electrode), where an electrochemical reaction takes place to generate current. A porous layer (gas diffusion layer) is usually placed between the electrode and flow channel to evenly distribute reactants.

Anode:	$H_2 \longrightarrow 2H^+ + 2e-$
Cathode:	$2H + 2e- + {}^1/_2O_2 \longrightarrow H_2O$
Overall:	$H_2 + {}^1/_2O_2 \longrightarrow H_2O$

The equation above shows the basic electrochemical reactions for proton exchange membrane (PEMFC). During operation of the fuel cell, the anode facilitates the conversion of fuel (such as hydrogen) to electrons and protons. The generated proton passes through the membrane ionomer layer, while electrons are forced to flow through an external circuit. Finally, protons, electrons, and oxygen react at the cathode to form water.

CATALYST COATED MEMBRANE (CCM):

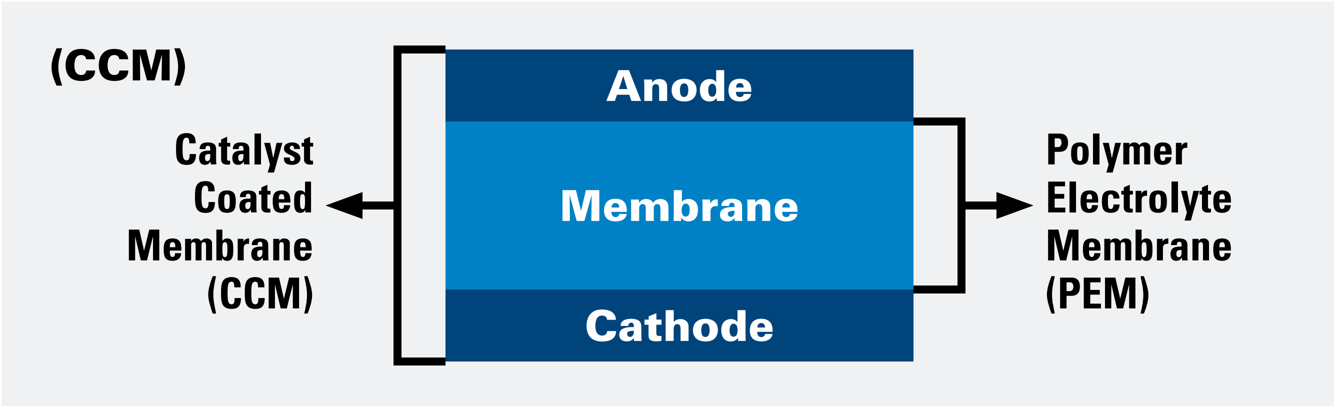


Figure 2: Schematic of a CCM

A catalyst coated membrane (CCM) is a crucial component of PEMFC. A CCM is composed of an anode, a cathode, and a polymer electrolyte membrane ionomer layer (e.g., perfluorinated sulfonic acid), which serves as the electrolyte. The anode and cathode comprise appropriate catalyst layers and are bonded in layer form to the PEM. Electrochemical reactions during fuel cell operation take place in CCM.

POLYMER ELECTROLYTE MEMBRANE (PEM):

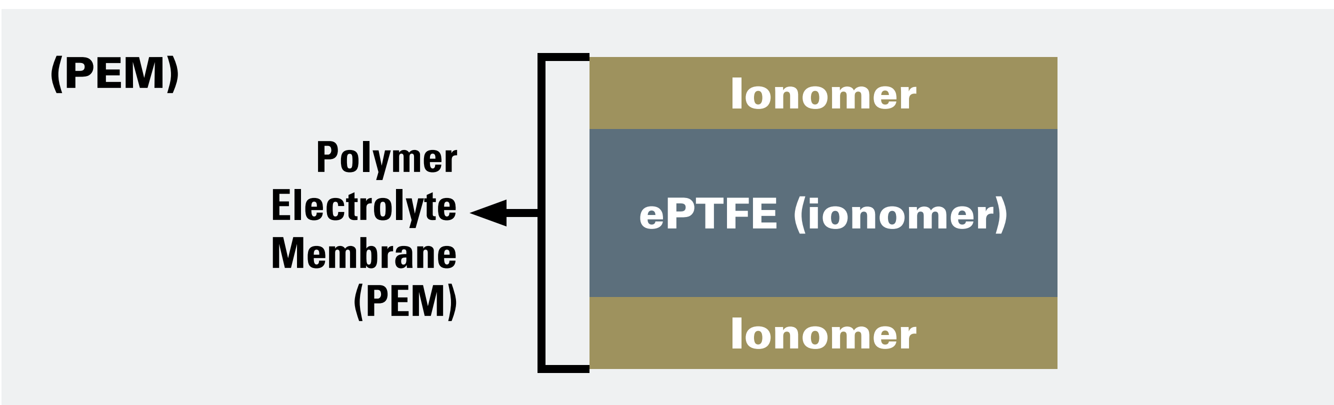


Figure 3: Schematic of a PEM

The main functions of the PEM in fuel cells are to separate the anode and cathode gas, transport protons, insulate the electrons, and provide mechanical support for the anode and cathode layers.

WHY PEM REINFORCEMENT MATTERS:

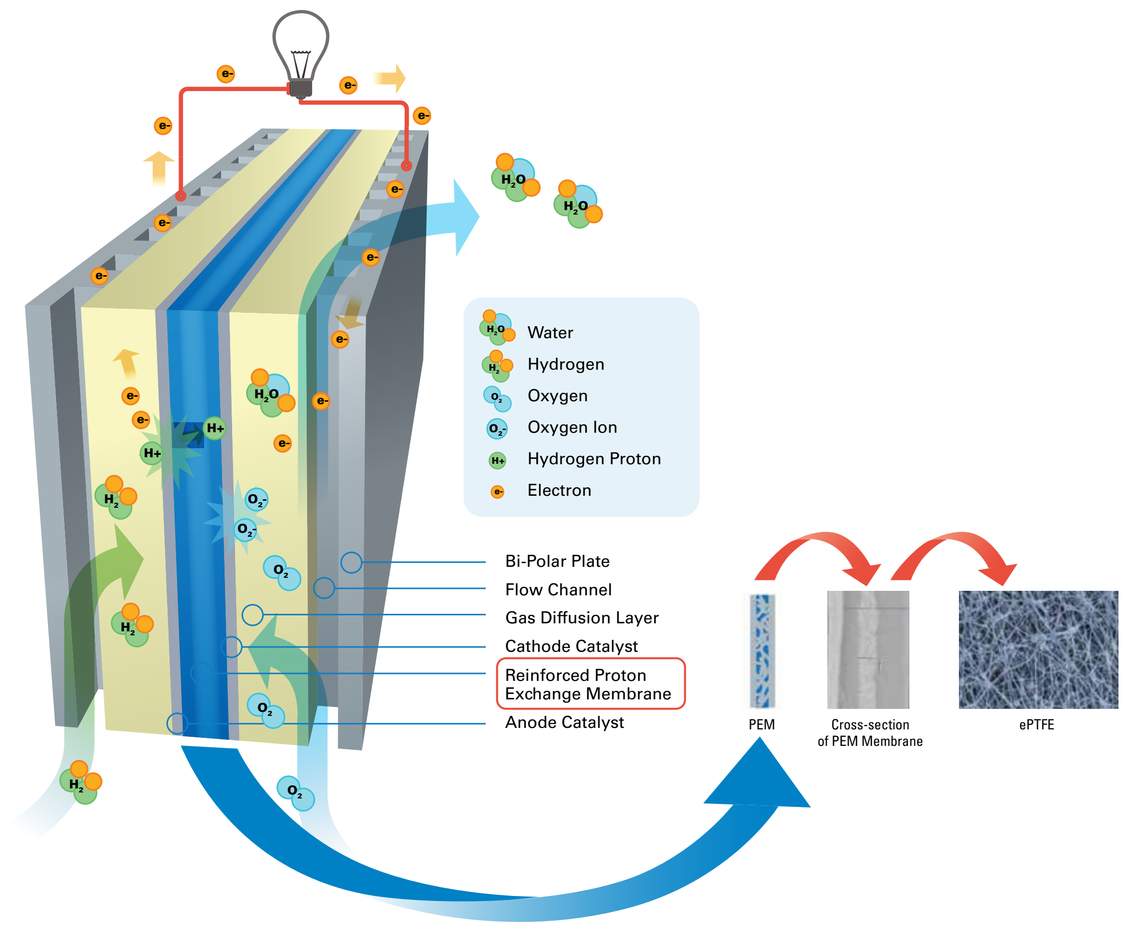


Figure 4: ePTFE Backbone for MEA

During fuel cell operation, the PEM swells as it absorbs water at high relative humidity and shrinks as it loses water at low relative humidity. This repeated swelling/shrinkage cycle leads to high mechanical stress in the PEM and subsequent mechanical failure.

The durability and longevity of the PEM can be significantly improved with ePTFE reinforcement. During the swelling/shrinkage cycle, the strong mechanical strength and chemical inertness of ePTFE creates a "holding force" that can counterbalance the swelling/shrinkage force generated. Therefore, ePTFE-reinforced membranes show significantly better mechanical durability than dense membranes (non-reinforced).

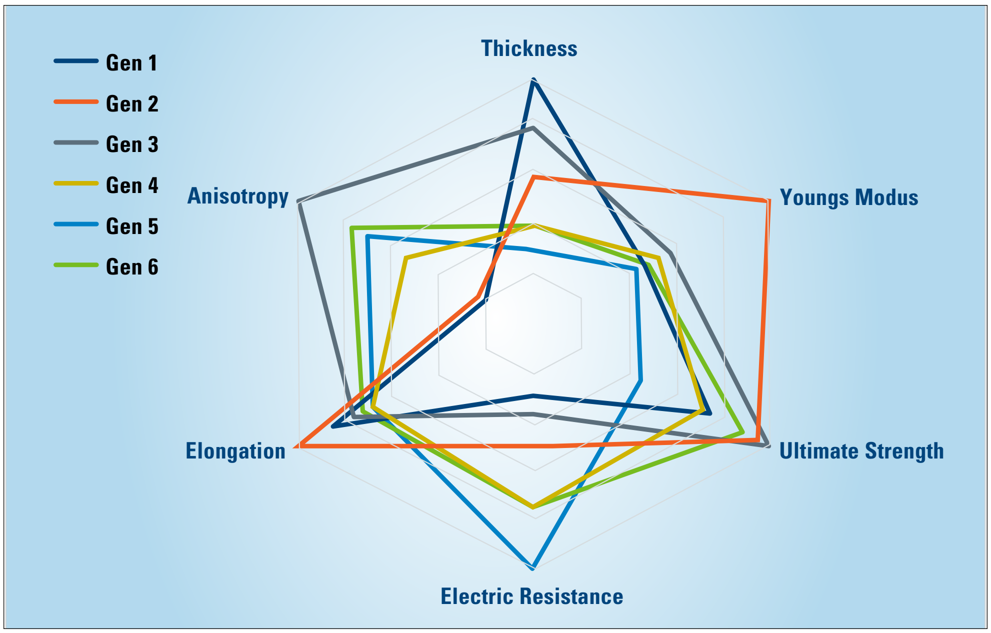
In fact, US DOE durability targets of 8,000 hours for light-duty vehicles and 30,00 hours for heavy-duty vehicles cannot be achieved without engineered PEM membrane with ePTFE reinforcement.

In addition, thinner, highly efficient ePTFE membranes can provide this crucial reinforcement while helping maintain high current density, which allows for fewer cells in a stack, reducing overall weight. They can do this without compromising strength, performance or power generation.

APPLICATION SHOULD DETERMINE SPECIFIC ePTFE STRUCTURE:

Most proton exchange membranes need to be precision-engineered for each specific application. For example, the requirements for stationary fuel cell vs. light-duty vehicles vs. heavy-duty vehicles are very different. Therefore, access to a broad range of ePTFE structures used as reinforcement for PEM membrane allows OEMs to specify both the required ePTFE reinforcement and the chemistry to optimize fuel cell performance.

To meet the wide variety of OEM needs, Donaldson has developed different generations of membrane for various applications. Our product offerings provide engineered design solutions for each of these unique applications, as shown in figures 5 and 6.



This graph assists with matching the optimal ePTFE reinforcement with your application

Figure 5: PEM/ePTFE Property Correlation

Tetratex™ Membrane Product Codes	Value Proposition	Application / Market
Gen 1	Thick and durable	Stationary fuel cell
Gen 2	Medium strength and lowest hydrogen cross-over	Passenger vehicles, heavy-duty vehicles, backup power
Gen 3	Durable and high strength	Heavy-duty vehicle
Gen 4	High current density and durable	Light duty, fork lift range extender
Gen 5	Highest current density and lowest resistance	Passenger vehicles
Gen 6 (currently in development)	Highest current density, lowest resistance & most durable	Heavy-duty trucks

Figure 6: Donaldson guide to membrane selection based on end-market application.

THE RIGHT MEMBRANE MAKES A DIFFERENCE:

Donaldson's extensive portfolio of proprietary Tetratex™ ePTFE membranes has evolved over decades of research and development, continuing to meet strict industry performance requirements, while supporting OEM appeals for reduced stack size and lower total cost of ownership. Tetratex is manufactured and distributed solely by Donaldson, with an emphasis on high-quality manufacturing and customer service to help ensure consistent supply and timely delivery.

By offering multiple ePTFE hydrogen fuel cell membrane technology options to meet a range of specifications and applications, Donaldson provides OEMs and Tier 1/Tier 2 suppliers with:

- Thin membranes that support requirements for high current density while maintaining mechanical durability of stack.
- Reduced stack size and weight.
- Superior mechanical durability and high strength for long service life.
- Consistent, reliable performance.
- Flexibility to specify the ePTFE membrane independent of the coating, allowing OEMs to choose the optimal membrane/coating solution, rather than a pre-set (unoptimized) solution.

Donaldson.

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