# Development of Megawatt Scale PEM Electrolysis: A Culmination of Cell Design and System Advancements

Katherine E. Ayers, Everett B. Anderson, and Larry C. Moulthrop
Proton OnSite
10 Technology Drive, Wallingford, CT 06492

Over the past two decades, water electrolysis based on proton exchange membrane (PEM) technology has evolved from use in military and aerospace applications such as oxygen generation for life support, to commercial applications of increasing scale. Example industrial markets are shown in Figure 1 below. On an equivalent output basis, PEM electrolysis competes on price with alkaline liquid systems, and offers safety and logistics advantages vs. other sources of hydrogen as well.

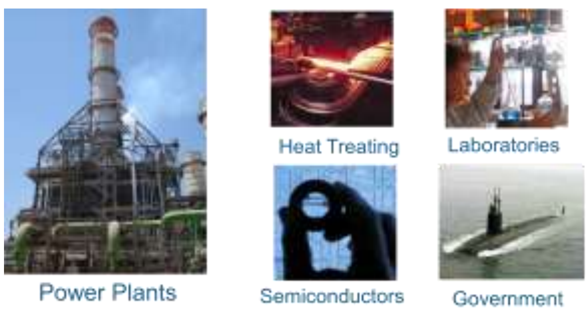


Figure 1: Existing Markets for PEM Electrolysis

Still, for energy markets, both capital cost and operating costs need to be reduced, particularly at the cell stack level which is the major contributor to both areas. Over the past 5 years, focus on cost and efficiency has demonstrated pathways for significant improvements, leading to a 2012 DOE R&D award to Proton OnSite and Giner for advancements in PEM electrolysis. At Proton, key recent accomplishments include demonstration of over 50% reductions in cell cost and demonstration of 74% efficiency at 2 A/cm$^2$. Key areas of study include thinner, more durable membranes, higher activity oxygen evolution catalysts and improved catalyst utilization, and improved bipolar assembly designs and coatings.

These advancements form the foundation for more capable and cost effective cell stacks. Proton's commercial cell stack output has increased from small stacks for laboratory applications to over 20 kg/day, with the next larger stack platform in development. Similarly, Proton has production stacks up to 2800 psi hydrogen pressure, and has demonstrated direct electrochemical production of hydrogen at 5000 psi (Figure 2).


Figure 2: Evolution of Proton Cell Stacks in Output and Pressure

Traditionally, very large scale electrolysis has been limited to alkaline liquid based technology, which has limited turndown capability and more complex balance of plant to manage the hazardous electrolyte. However, as PEM electrolysis has been proven at larger scales and longer durations, several companies including Proton OnSite have announced development of megawatt scale PEM electrolysis as the preferred approach for energy storage applications. Proton's approach has been to lead system development with stack development. This talk will focus on development of the bipolar assembly for the stack, from development of subscale stack designs and coatings for protection against oxidation and hydrogen embrittlement, through scale up to larger active area and cell count.

The stack to the far right of Figure 2 will serve as the stack module for the MW system. In development of the original bipolar plate for this stack, flow distribution was an important parameter to optimize in order to ensure uniform flow over the large active area. Computational fluid dynamics modeling was performed on concepts to analyze the oxygen-water distribution (inset Figure 3). A three cell stack based on this design has operated for over 20,000 hours as shown in Figure 3, and a prototype stack has operated for over 1500 hours. Parallel development in lower cost designs is being integrated into the large active area stack and will result in ultimate decreases in stack capital cost of over 70% on a $/kg $H_2$ basis.

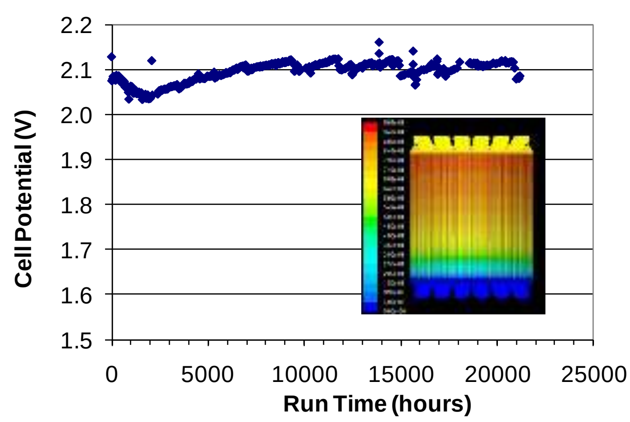


Figure 3: Average Cell Potential, Large Area Cell Stack

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