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BALLARD

INFORMATIONAL

High Performance Fuel Cell Stack

Innovations in Proton Exchange Membrane Fuel Cell Stack Design

High Performance Fuel Cell Stack:
Innovations in proton exchange membrane fuel cell stack design

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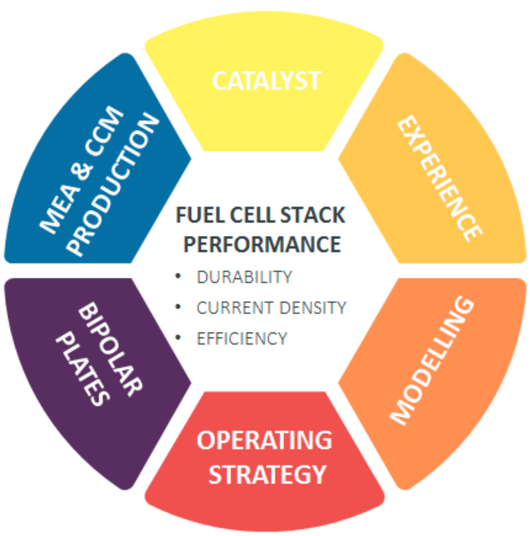
Introduction

Ballard's ongoing drive to improve proton exchange membrane (PEM) fuel cell technology keeps us at the forefront of innovation in our industry. Ballard's team of experienced engineers, our intellectual property, and our state-of-the-art facilities all contribute to our leadership position in this rapidly evolving field. At Ballard, we are committed to implementing technology advancements that reduce fuel cell costs and increase performance.

To achieve this, we rely on our depth of experience to explore and implement technical innovations in PEM fuel cells. To give you a glimpse into our current technology, we are sharing insight into our Technology Solutions program to develop Audi's fuel cell stack.

Fuel Cell Stack Design Considerations

Ballard has more than three decades of experience in the design and manufacturing of PEM fuel cell products. During that time, we have commercialized several generations of products with a relentless dedication to performance and innovation. These advances have only been achieved by leveraging years of fundamental PEM fuel cell stack design experience and balance of plant knowledge to make critical design choices to meet the requirements of highly demanding motive duty cycles.



The design of a fuel cell system is a complex trade-off involving considerations of many factors. These include performance, product cost, fuel efficiency, heat rejection, lifetime, reliability, recyclability, design for service, design for manufacturability, codes and standards, the hybridization strategy and freeze start capability. The application requirements determine the key fuel cell stack features and result in customization of components where economically viable.

In motive applications, products are expected to operate in the most extreme climates and conditions, over a range of duty cycles with no compromise in performance or durability.

Key Components

At Ballard, we design fuel cell stacks from the ground up, using proprietary materials and know-how to trade-off each of the product attributes. The entire system must be designed starting from the core materials using the right mix of technology building blocks and system operating strategies. The lowest cost or highest performance solution is not always the most economical lifecycle cost solution.

Ballard has refined its accelerated stress tests based on field data, testing, modeling, and our fundamental understanding. Through this work, we have developed a wide variety of technology "building blocks" for fuel cell stacks:

- Anode and cathode catalysts which combine the right mix of durability, loading, and performance.
- Catalyst coated membrane and membrane electrode assemblies that are designed for high performance, long life, continuous roll manufacturing and reduced defects.
- Seals designed for long life, high volume manufacturing, and high power density.
- Bipolar plates developed using a variety of materials.
- Membrane additives to improve durability.

Catalysts

At Ballard, we have developed proprietary catalyst treatments and anode catalyst layer designs that greatly mitigate degradation, while reducing system control requirements. This, in turn, reduces material and manufacturing costs. We have anode designs that tolerate many hours in adverse conditions, compared to just seconds to minutes of tolerance without our proprietary treatments and designs.

Ballard continues to actively research and achieve exciting results with advanced catalysts for better performance and durability while supporting our goal of further reducing platinum content in our fuel cells. Our novel catalyst layer design achieves higher performance with greater durability than conventional catalyst layers. Our high performing design results in a five times durability improvement compared to a more conventional design using the same alloy catalyst.

In our laboratory, some very promising next-generation catalyst designs are delivering up to seventeen times higher activity than conventional platinum catalysts.

Membrane Electrode Assemblies (MEA)

The MEA is a critical component of the PEM fuel cell that must meet exacting performance standards for the fuel cell to work properly. Within the context of the Audi fuel cell stack development program, the goal was to design the MEA to maximize the power density.

Ballard's MEA development activities draw from extensive field experience to support step changes in durability with each subsequent design and product iteration. The use of an accelerated testing and modeling approach developed and validated over numerous product iterations enables continuous cost decreases and gains in power density, operational robustness, and reliability, with a calculated risk tolerance for new technology introduction. Of particular focus is the relationship between cathode catalyst loading and fuel cell stack lifetime, to assist in making electrode design and composition choices for a successfully durable product. Strategies to lower catalyst loadings and move to higher current operation and power densities include incorporating high activity catalysts as well as improving proton conductivity and oxygen transport by incorporating advanced ionomers.

Ballard is also focusing on reducing the cost of the MEA in four key ways:

- Improving the power produced per unit area of the MEA and using less material where possible.
- Working with our suppliers and modifying our process equipment to maximize the utilization of the materials supplied in rolls.
- Designing and operating the manufacturing processes that have a high first-pass yield.
- Reducing the amount of labor needed to assemble MEA plates and stacks through efficiencies and automation.

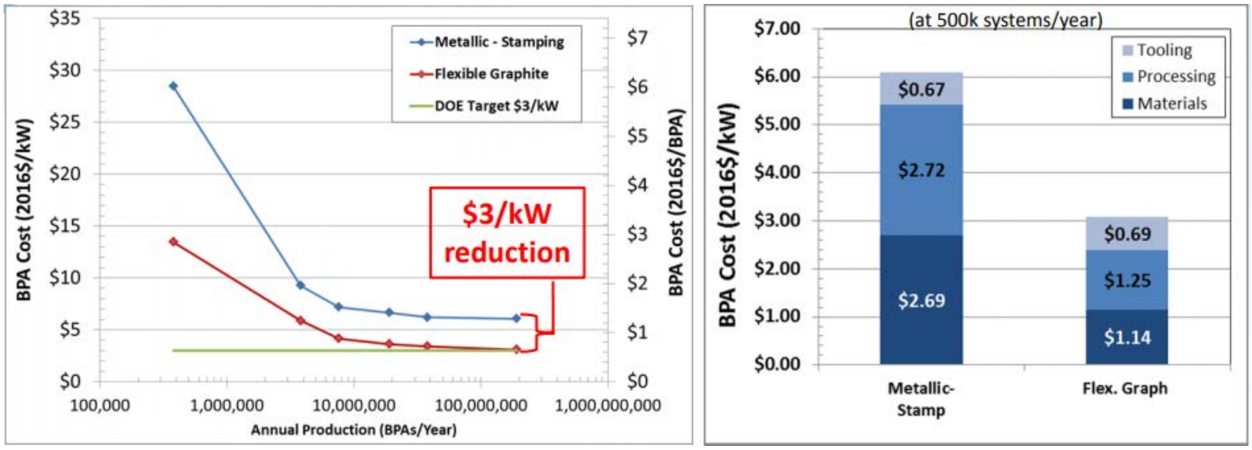
Bipolar Plates

An important fuel cell design consideration is the material selected for the bipolar plate for the fuel cell. The bipolar (or flow field) plate is a key component, connecting each cell electrically, supplying reactant gases, and removing reaction by-products from each unit cell.

Bipolar plates can be made from various materials, with the most common being graphitic carbon or metal. Trade-offs must be evaluated to balance both material performance and cost-effective manufacturing processes.

Ballard has the capability and expertise to develop both metallic and non-metallic plates that exceed intermediary technical targets on the path to commercialization for light- and heavy-duty applications.

A recent cost study by Strategic Analysis Inc. has shown that graphitic carbon-based plates are edging out metal for the plate material of choice, particularly when durability requirements are considered.



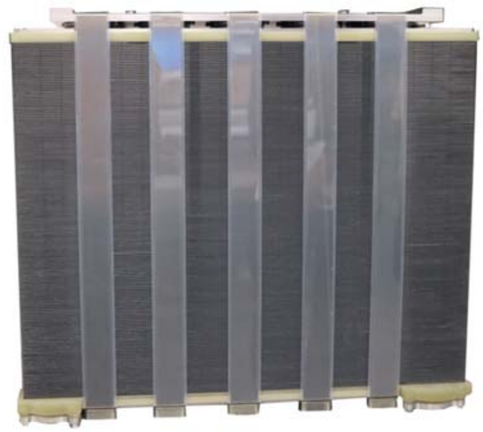
Source: Brian James, Strategic Analysis Inc., Fuel Cell Systems Analysis, Project ID# FC163, US DOE Annual Merit Review, May 1, 2019.

The study indicates that flexible graphite carbon plates are amenable to high volume production, and the estimated plate costs are substantially lower than stamped metal plates at all production volumes.

Performance & Technical Specifications

The outcome of our multi-year Audi fuel cell stack development program is a high performance fuel cell stack designed to stringent automotive quality standards. The product incorporates our latest technology, design, and materials to meet the requirements of the most demanding motive applications delivering one of the highest fuel cell stack power densities in the industry at 4.2 kilowatts per litre.

This fuel cell stack provides up to 130kW of stable electrical power over a wide range of operating and environmental conditions. It can be configured to different power outputs to meet customer requirements and has an efficiency of 52% at the beginning of life, based on the lower heating value.



High performance fuel cell stack

Product Specifications	
Rated Power	130 kW
Mass (dry)	55 kg
Power Density	~4.2 kW/L, ~4.7 kW/kg excludes plate hardware
Length	484 mm
Width	555 mm
Height	195 mm
Fuel	ISO 14687-2
Oxidant	Air up to 2.5 bara
Coolant	DI water or fuel cell grade glycol
Max Coolant Temperature	95°C
Operating Temperature	-15°C to 95°C
Min. Start Temperature	-28°C
Storage Temp. (<12 hrs)	-40°C to 95°C
Storage Temp. (long term)	2°C to 40°C

Validation testing of the full fuel cell stack continues, including:

- Shock and vibration testing
- To prove compliance to automotive durability requirements
- Minimum start temperature to -28°C

Conclusion

Fuel cell systems must be designed based on the application duty cycle. The ideal fuel cell stack for a particular motive application is the result of complex trade-offs between cost, stack design attributes, active area sizing (peak efficiency point), and durability, with the ultimate goal to achieve an attractive total cost of ownership for wide acceptance of the technology.

With the design tools and core technologies available at Ballard, we can tune each of the layers of the MEA for a given application to improve function, durability, life cycle cost, and power density. We have a range of proprietary anode and cathode catalysts, electrodes, membrane additives, seals, and plate materials from which we can quickly design and build new products.

Ballard-designed fuel cell stacks integrated into Audi's propulsion systems will deliver outstanding automotive fuel cell performance, including power density over 4kW/L, low weight, high durability, and robust freeze start capabilities. The fuel cell stack developed for Audi establishes a new industry standard for power density, performance, and product reliability.

Ready to capitalize on Ballard's experience and expertise to advance your commercial fuel cell program? Contact us today.