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Mech 549 Fuel Cell Technology

Oct. 30, 2007

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Fuel Cell Stack Design

- Fuel Cells are “stacked” to place bipolar cells in series and increase voltage and power
- Major stack issues:
 - Volume and weight
 - Cooling methods
 - Sealing
 - Clamping

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Stack Design Objectives

- Minimize Volume, Weight, Cost
- Satisfy other constraints to maintain high fuel cell performance

Conventional Stack Layout

- Bipolar plate / MEA in alternating arrangement
- Some internal humidification

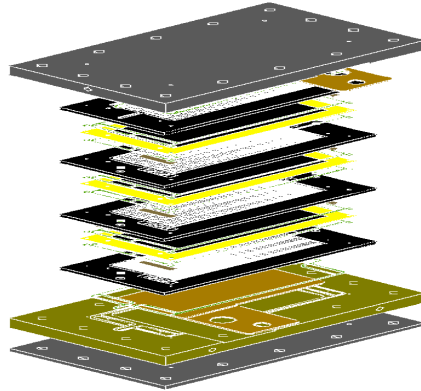
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Stack Assembly

- Built up from discrete MEA, Bipolar plate components.
- Discrete seals at each layer
- Compression applied through tie rods or straps
- Manual Assembly

Stack Components

- 3 cell un-humidified stack



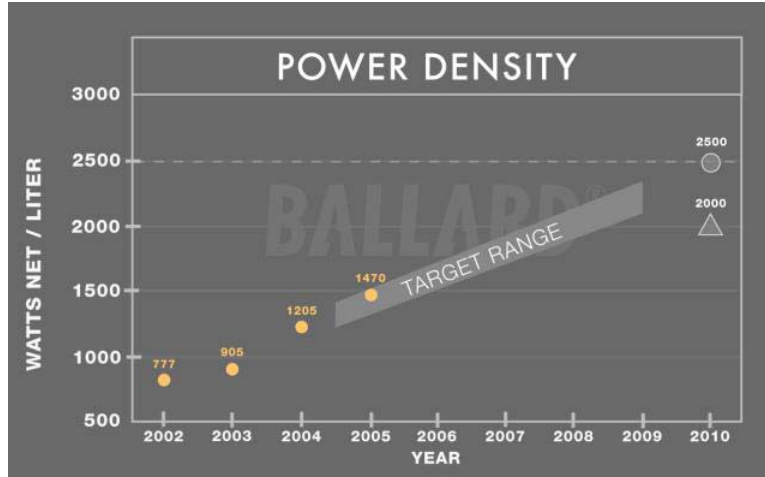
MEA Layer
Bipolar Plate
Seal
Current Collector
Insulator
Compression Plate

PEM Stack Evolution

- Major advances in fuel cell power *have not been in the area of electrochemistry!!!*
- Cost and performance targets have been reached through better engineering:
 - Tighter integration of components
 - Reduced materials use
 - Better integrated manufacturing

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PEMFC Stack Power Density



Source: Ballard Power Systems

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PEMFC Stack Cost



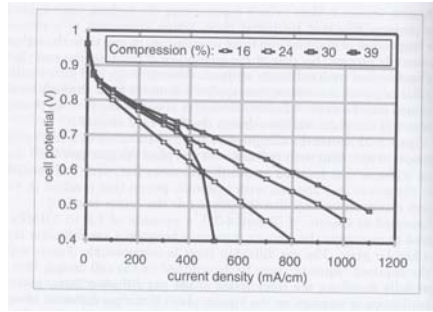
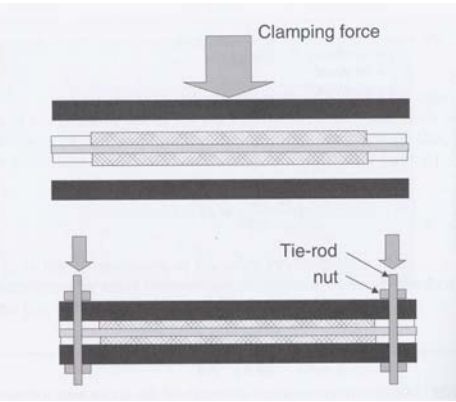
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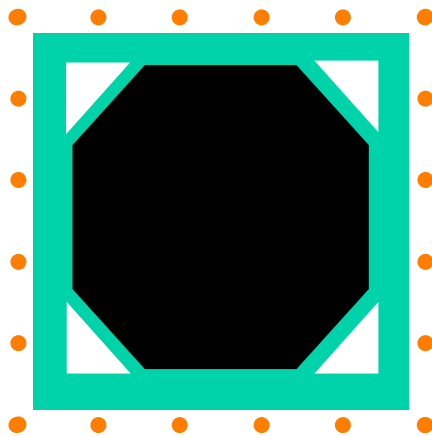
Compression & Clamping



Source: F. Barbir, *PEM Fuel Cells*, Elsevier, 2005

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Early Stack Layout



Tie Rods

Bulk Manifolds

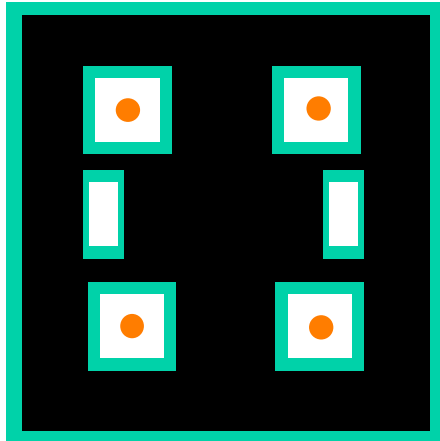
Active Area

Seals



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Alternative Clamping

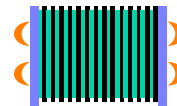


Internal Tie Rods

Bulk Manifolds

Active Area

Seals



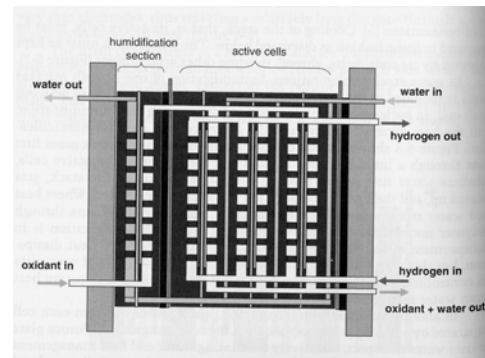
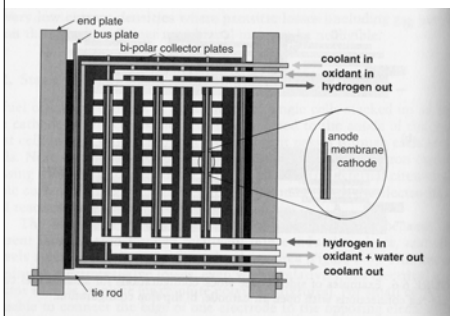
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Humidification



Source: F. Barbir, *PEM Fuel Cells*, Elsevier, 2005

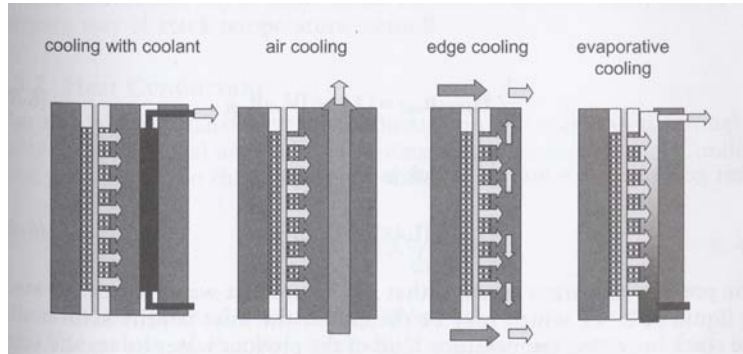
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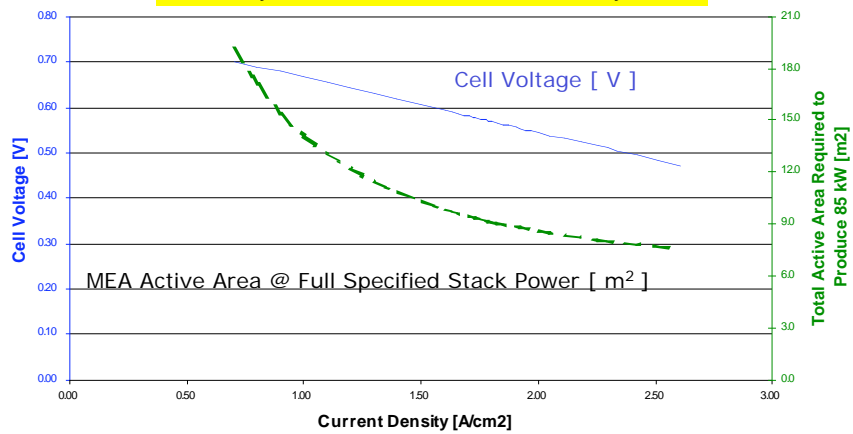
Cooling



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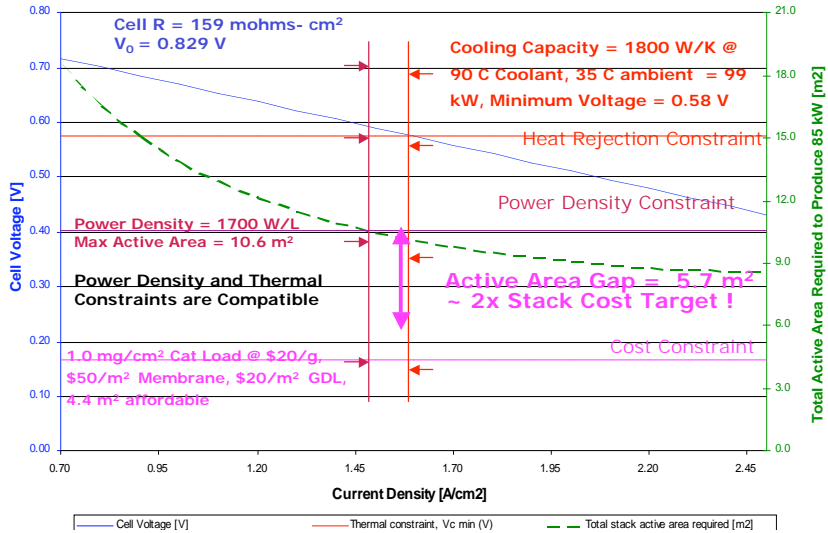
Cooling Requirements and Bounded Design Space

Automotive Fuel Cell Design Space
Courtesy: Pat Hearn, Ballard Power Systems



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Design Space: Baseline Example



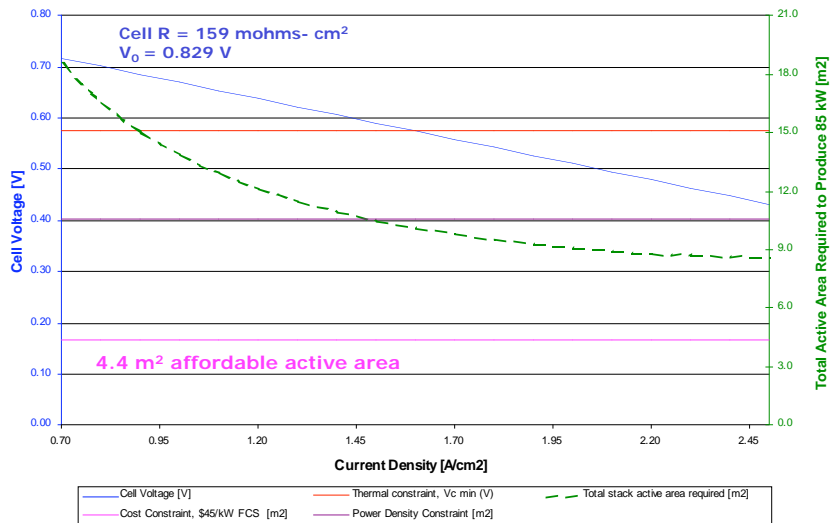
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Baseline



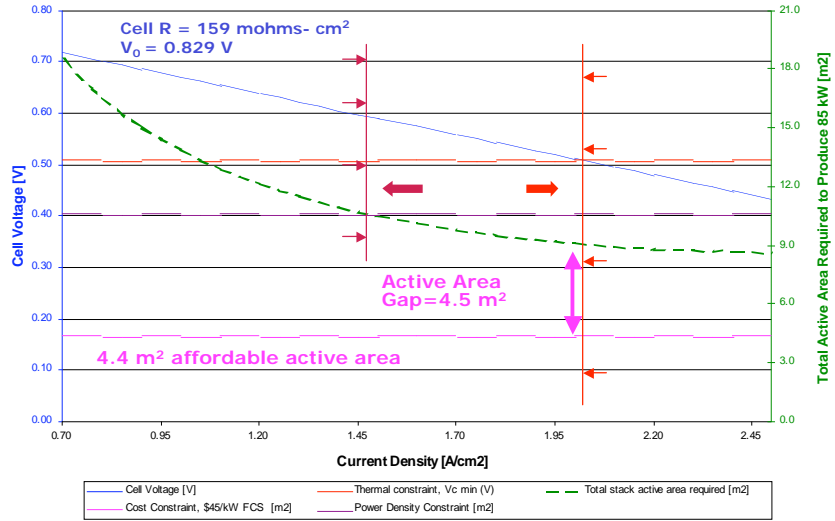
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Baseline with +25% Cooling Capacity



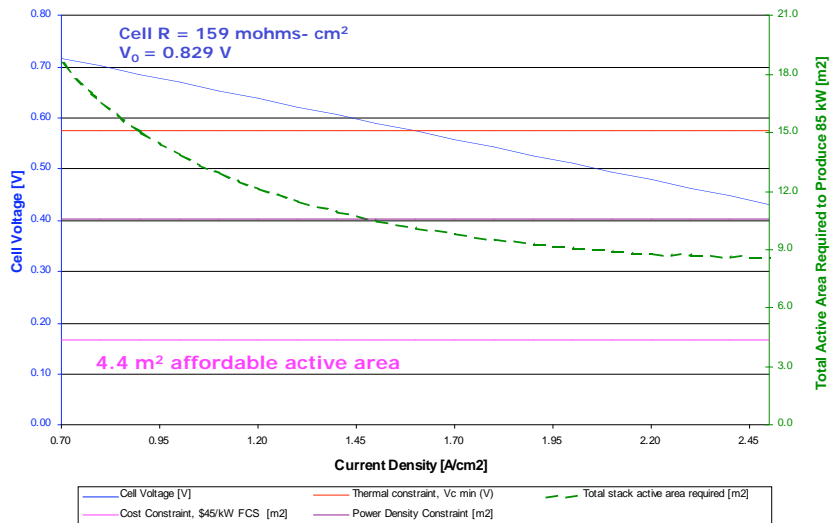
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Baseline



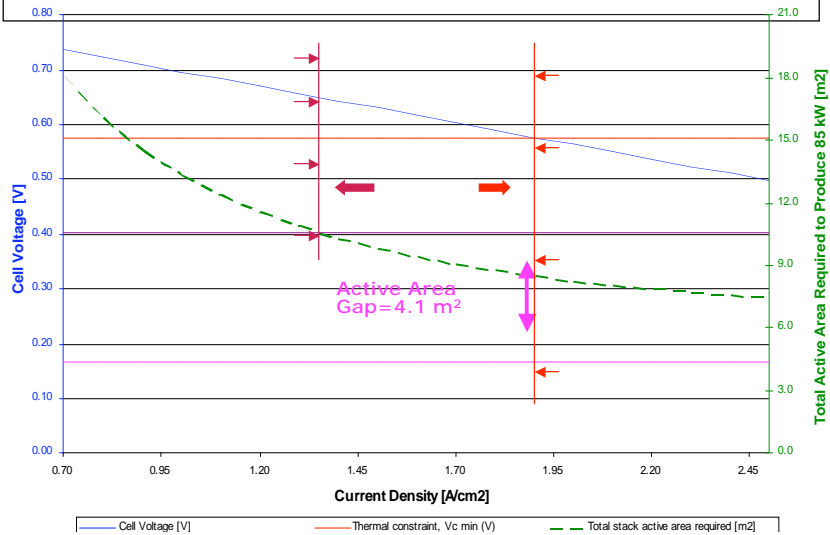
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Base Case –20% Cell Resistance



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Other Stack Designs

- The 'Plate & Frame' stack is popular and is the only stack being contemplated for large volume production
- Other approaches to stack design can be considered and may have merit in the long run.

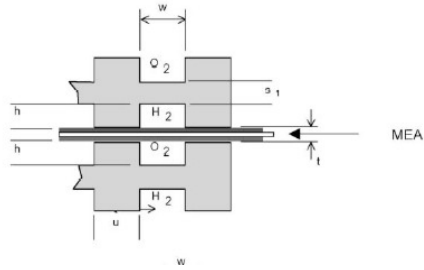
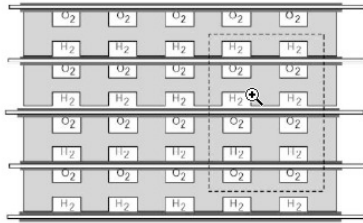
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Alternate Geometries: *Virtually everybody does this*



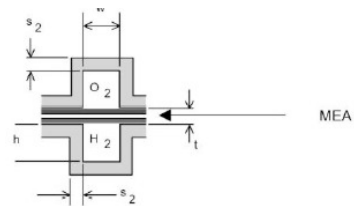
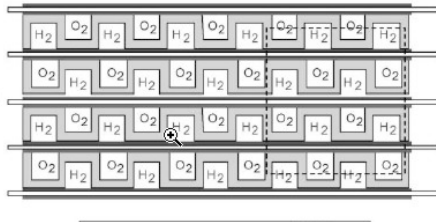
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Alternate Geometries: *A simple change*



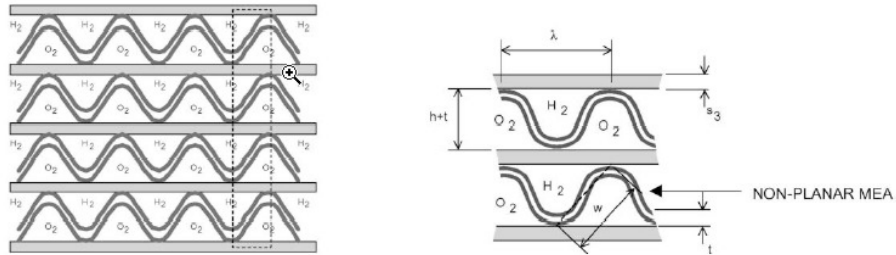
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Alternate Geometries: *The Wave Cell*



Ref: W.R. Merida, G. McLean, N. Djilali, 'Non-Planar architecture for proton exchange membrane fuel cells', *Journal of Power Sources*, 102, pp. 178-185, 2001

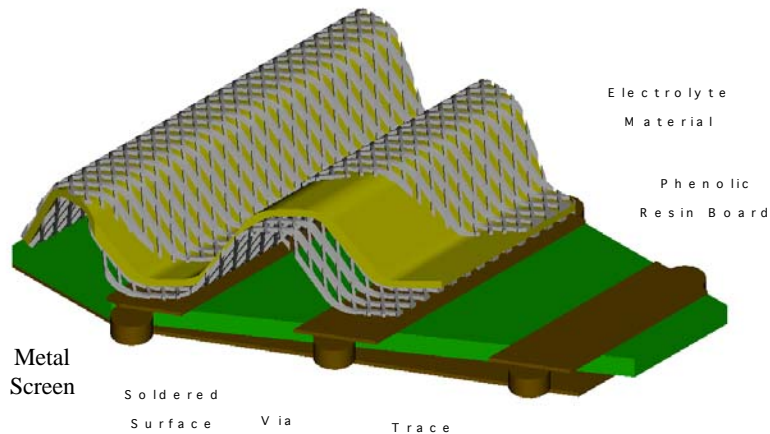
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Integrated MEA / Bipolar Plate



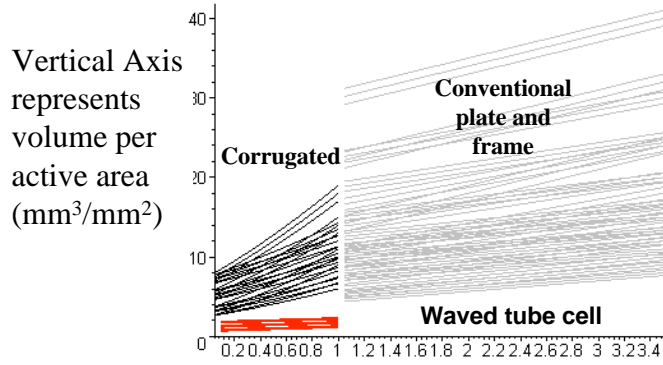
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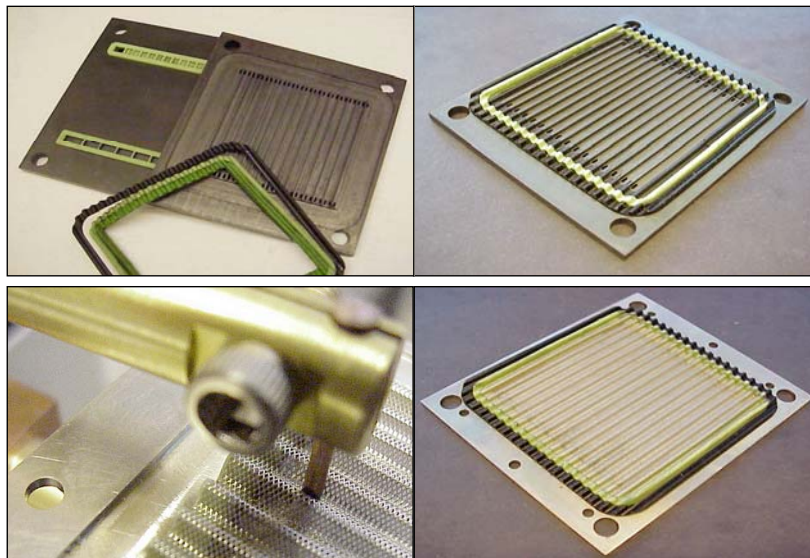
Volume Comparison



Horizontal Axis represents critical minimum thickness (mm)

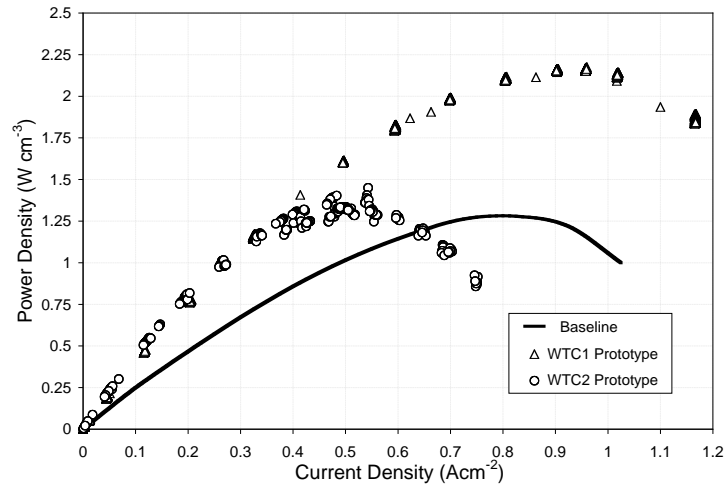
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Wave Cell Prototypes



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Wave Cell Power Density



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Other Stack Issues

- Contact between plates and MEA must be good:
 - Seals must not separate MEA from plates
 - Gaps between MEA and plates cause a low pressure drop path from inlet to outlet
 - Reactants and coolant must be separated and remain unmixed

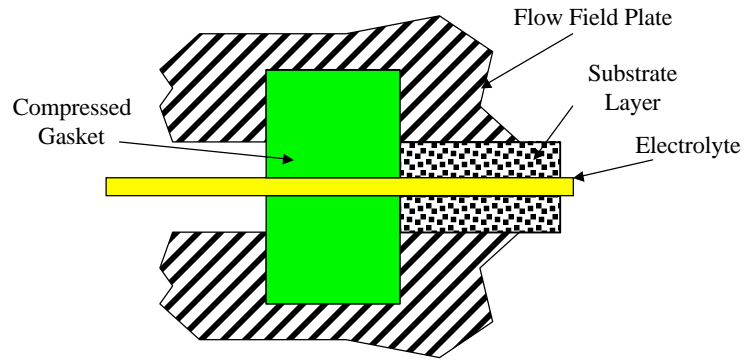
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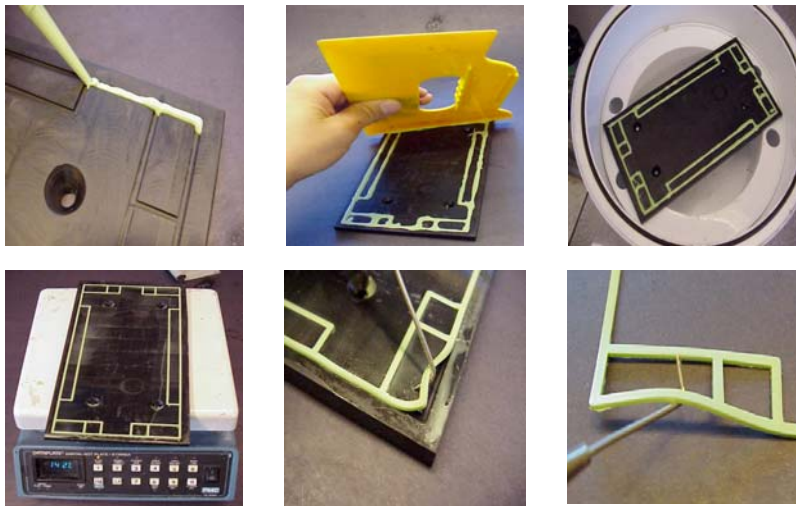
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Correct Gasket



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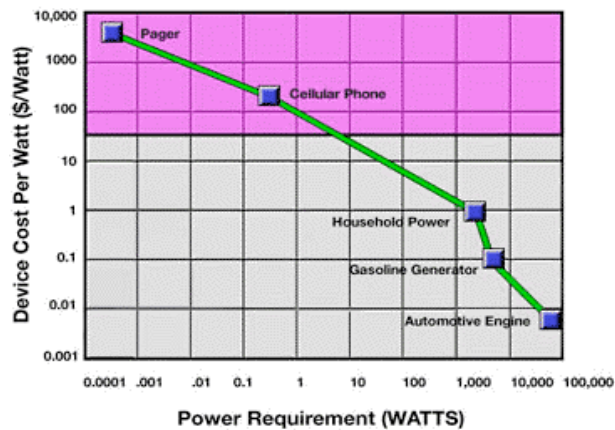
Gasket Casting



Stack Design...

- Big step from single cells to stacks
- Engineering dominates chemistry in these areas
- Stack design requires integration of *many* disciplines
- There are lots of opportunities for improved fuel cells through better stack design

Market Penetration Strategies



Current Market Price/Power Envelope

(source: Manhattan Scientifics)