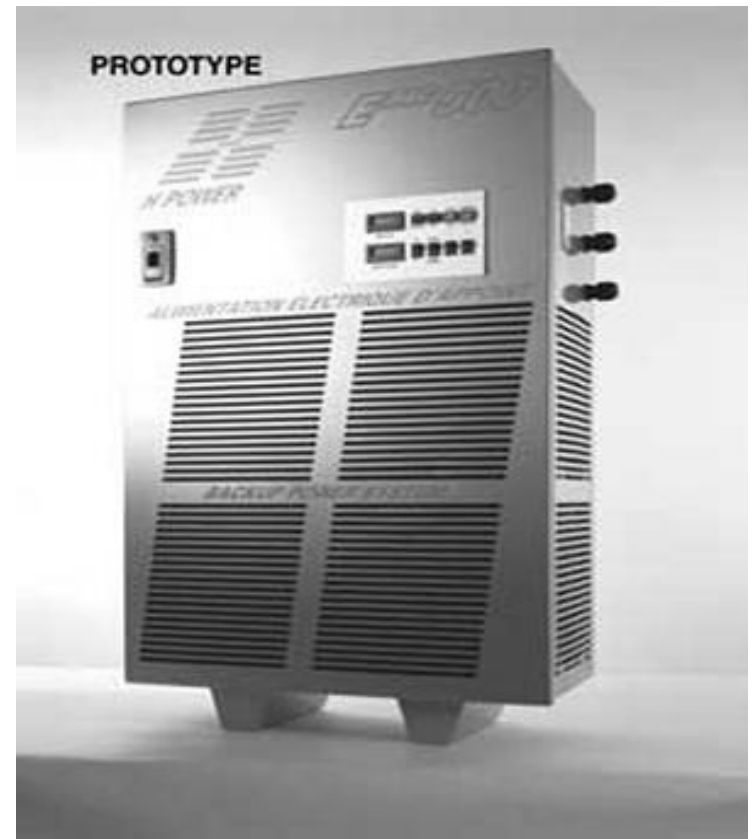


Engineered Structural Composites in Stiffness-critical Fuel Cell Applications



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SPE Automotive Composites Conference

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**QUANTUM
COMPOSITES**

Engineered Structural Composite (ESC) Molding Compounds

- **High Levels of Reinforcement: Typically 50 – 66% by Weight**
- **Specialty / Exotic Resin Systems**
 - **Hybrid Vinyl Ester**
 - **Epoxy**
 - **Polyimide**
- **Unique Combination of Stiffness & Toughness**

ESC Materials – Typical Properties

Material	% Reinforcement	Density LB/IN³	Tensile Strength PSI x E3	Tensile Modulus PSI x E6	Flexural Strength PSI x E3	Flexural Modulus PSI x E6
<u>ESC Materials</u>						
AMC-8590 - Carbon	55%	0.053	36	7.0	80	5.0
QC-8800 - Glass	63%	0.068	50	3.8	85	3.0
<u>SMC</u>						
Polyester - Glass	30%	0.066	12	1.7	26	1.6
<u>Metals</u>						
Al Die Cast		0.098	48	10.4		
Al Wrought		0.098	40	10.4		
Mg Die Cast		0.064	22	6.4		
Steel 1008		0.280	48	30.0		

ESC Application – Fender Support

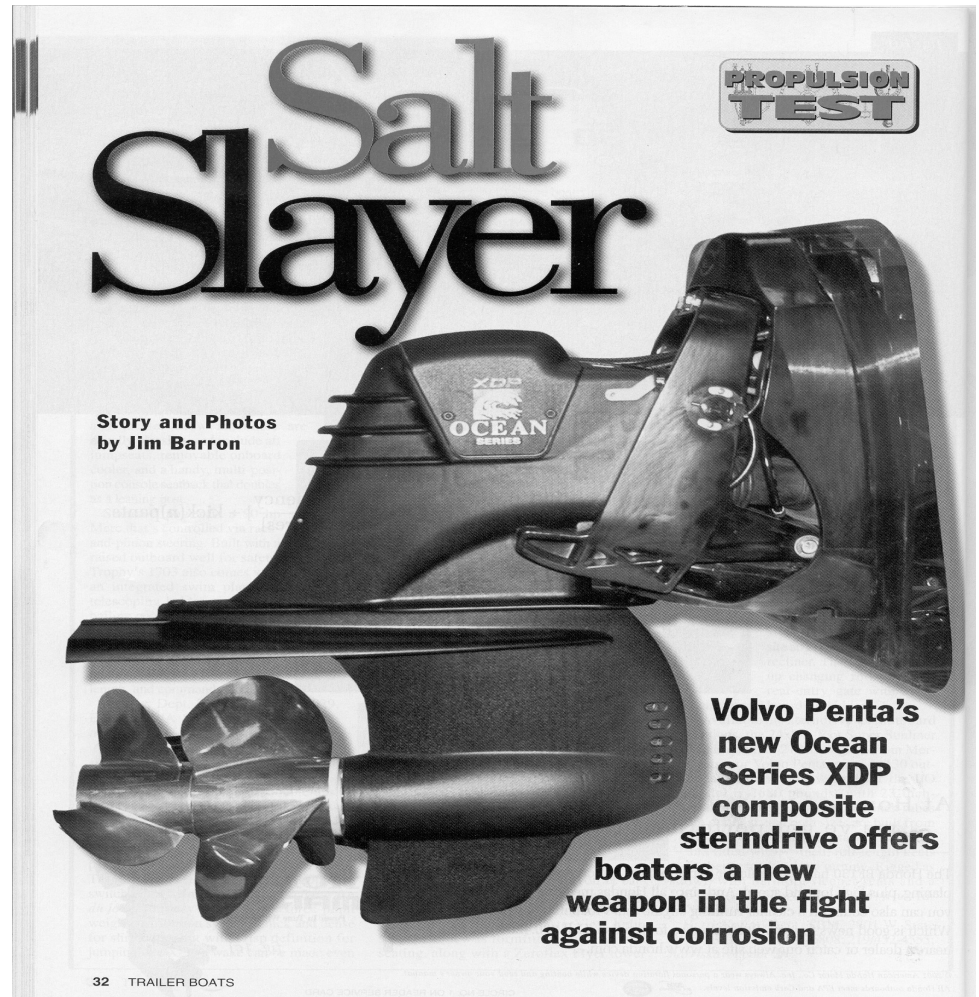
- **Lightweight**
- **High Stiffness**
- **Design Flexibility**
- **Parts Consolidation**



**QUANTUM
COMPOSITES**

ESC Application – Stern Drive

- Corrosion Resistance
- Parts Consolidation
- Impact Resistance



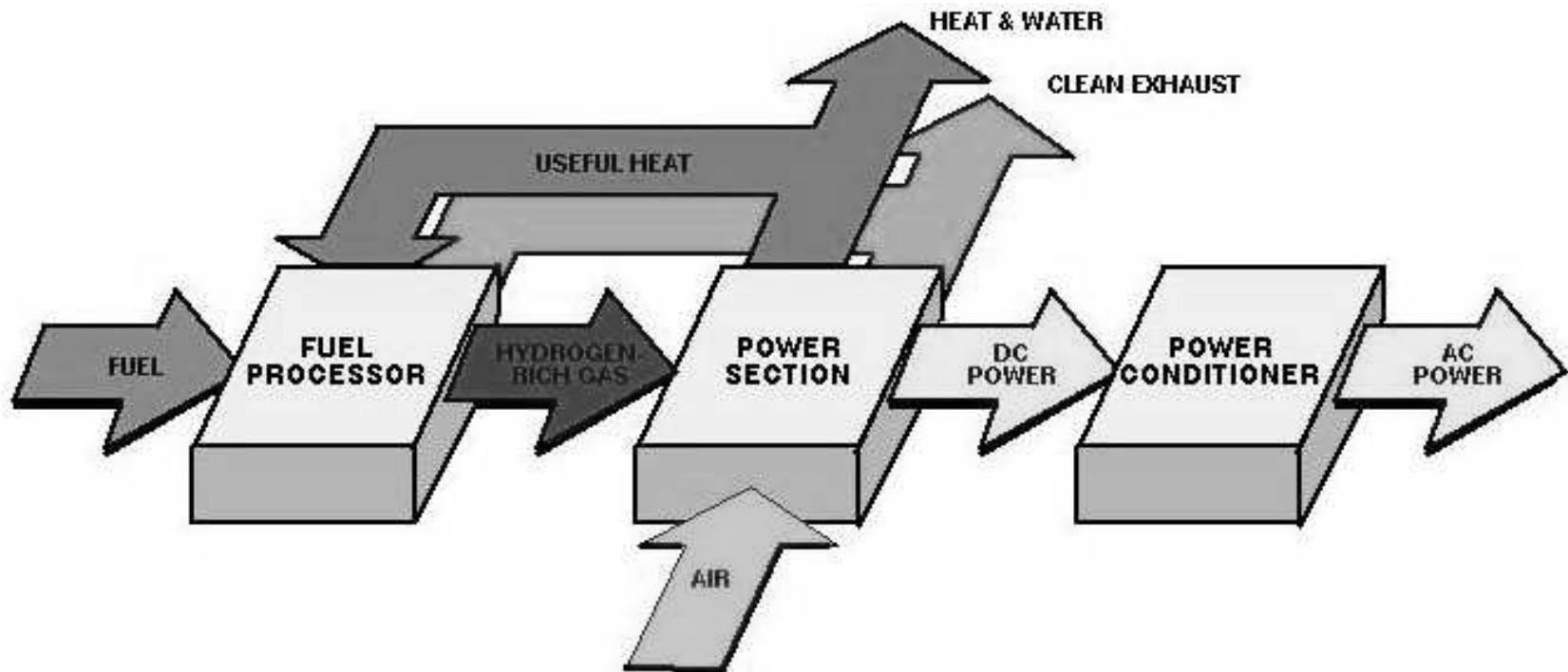
**QUANTUM
COMPOSITES**

Structural Composite Application in Fuel Cells

**QUANTUM
COMPOSITES**

Fuel Cell Power Plant – Major Systems

- Fuel Processor
- Power Section
- Power Conditioner
- Balance of Plant



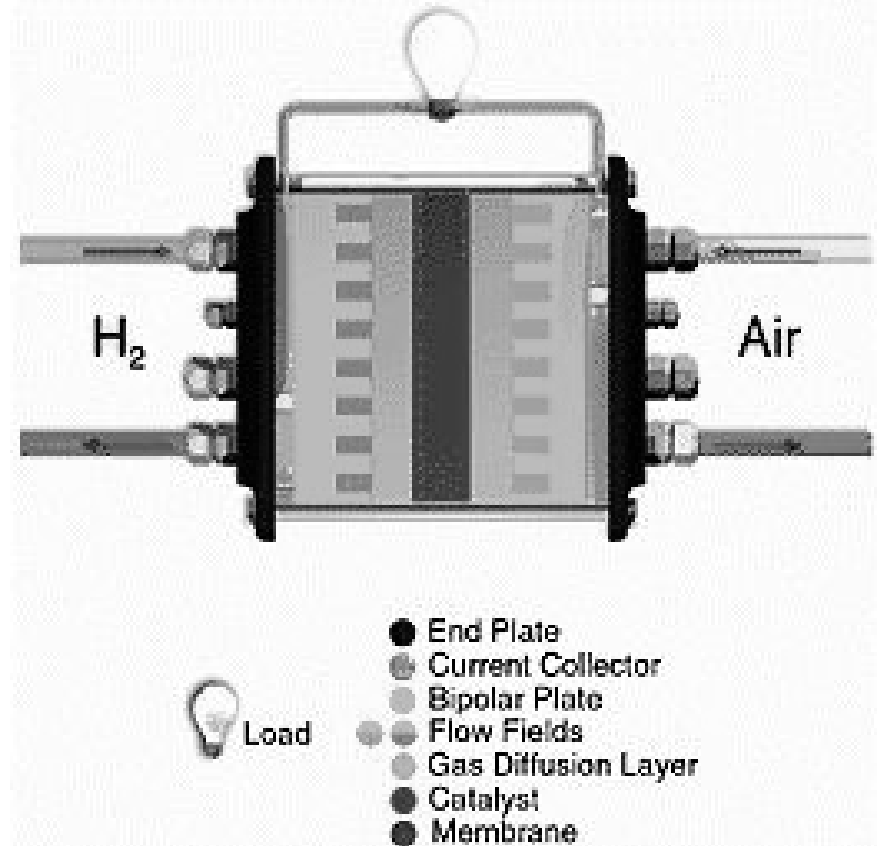
ESC Application – Pressure Plates

Function

- Forms Termini of Power Section
- Aids in Aligning and Sealing Individual Cells
- Provides Point of Connection for Fluid Routing
- May Provide Point for Power Take-off

Performance Attributes

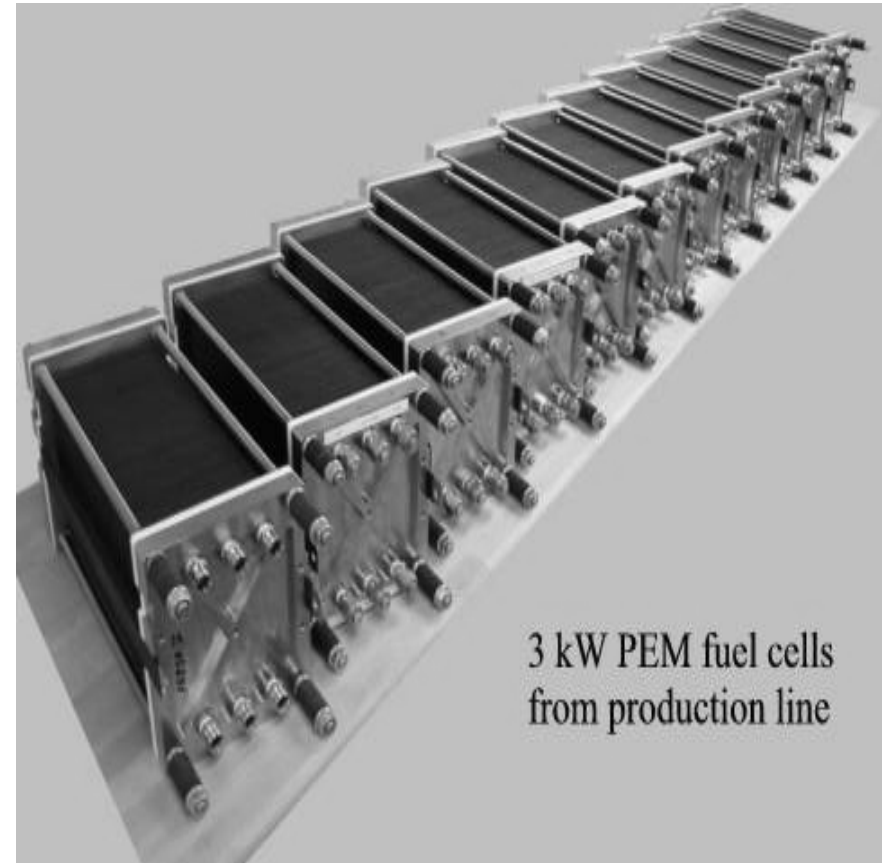
- High Flexural Stiffness
- Corrosion Resistance
- Function as Insulator
- Dimensionally Stable



ESC Application – Pressure Plates

Competing Materials

- Cast Stainless Steel or Anodized Aluminum
- Assemblies of Components
 - Machined rigid plate
 - Load distribution bars
 - Springs
- Engineering Thermoplastics



**QUANTUM
COMPOSITES**

ESC Application – Pressure Plates

Manufacturing Challenges

- Tight Tolerances
- Thick Sections
- Controlling Fiber Volume / Orientation in Molded Part

ESC Advantages

- Design Flexibility / Improved Functionality
- Molded-in Tolerances
- Corrosion Resistant
- Low Creep Characteristics
- Ability to Control Fiber Orientation
- Lower Cost for Endplate Assembly

ESC Corrosion Resistance Data

ESC Creep Performance Data

Development Process

for

**Structural Composite
Applications**

**QUANTUM
COMPOSITES**

Goals

- **Reduce Development Time**
- **Bring Credibility to Design**
- **Reduce Project Risk**
- **Optimize Part Design for...**
 - Parts Consolidation
 - Total Cost
- **Provide “Quick and Low Cost’ Testable Prototype Parts**

Evaluate Program Targets

Material Requirements

- High Strength / Modulus
- Corrosion Resistance, Potential UL Recognitions, etc.

Performance Targets

- Deflection Requirements at Service Loads / Temperature
- Weight Reduction
- Equal or Improved Functionality

Part Costs

- Vs. Incumbent Design and Current / Potential Material(s)

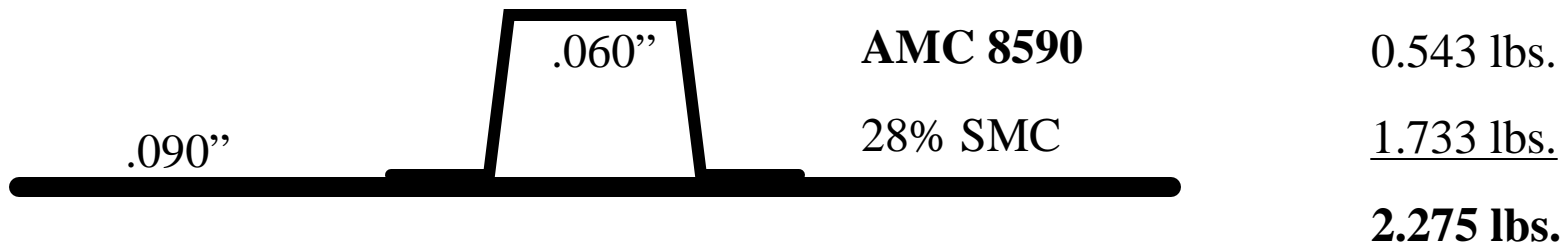
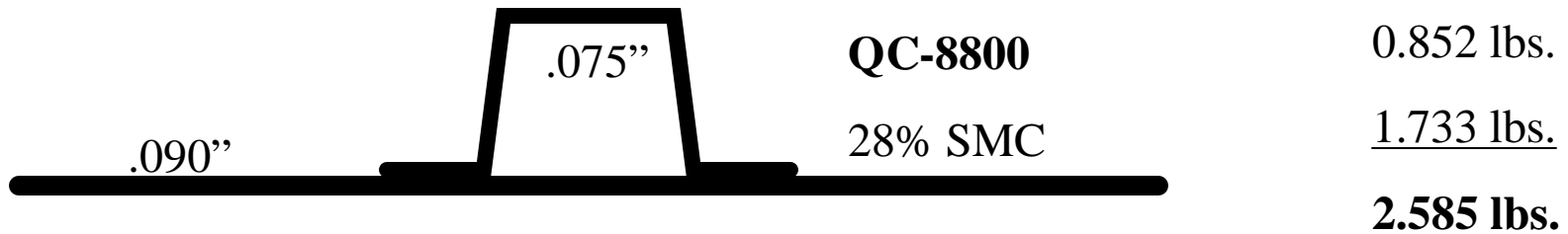
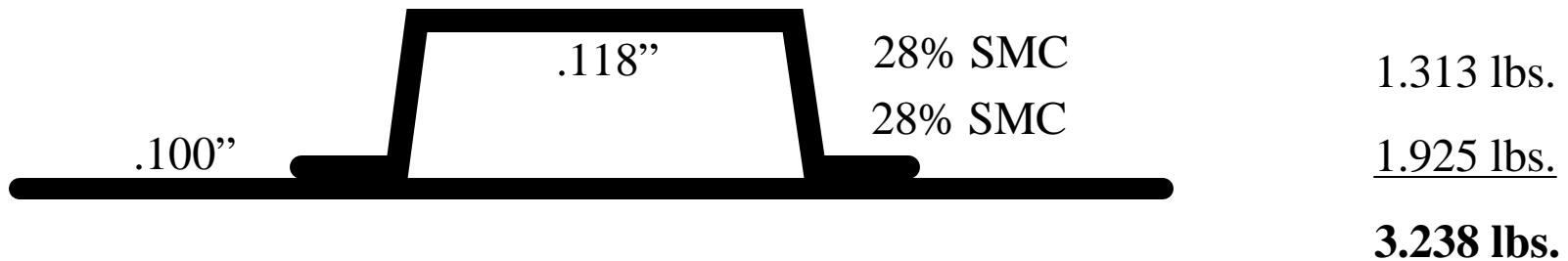
Piece Price Including Mold Costs

- Number of Molds Required to Meet Production

COMPAREM™ Design Tool

- **Determines Optimum Design with Optimum Material Choice**
- **Outputs are ...**
 - Wall Thickness
 - Rib Height
 - Cure Time
 - Part Costs
 - Tonnage
 - Press Size

Assemblies with Similar Strength & Stiffness



**QUANTUM
COMPOSITES**

Review Initial Part Design

- **For ...**
 - Moldability
 - Tooling Issues

- **Use COMPAREM Results to Finalize Design Direction**

Charge & Flow Pattern Analysis

- **Enables Determination of Proper Charge Placement Required to Achieve Flow and Fiber Orientation**
- **Benefits ...**
 - Determine Material Volume Needs
 - Part Strength
 - Shape of Charge
- **Go-no-go Decision Point**

Production Launch

- **Use Engineered Charge Pattern**
- **Obtain Full Parts in 2 – 3 Shots ... Not Days**

Composite Pressure Plate Design Example

Advantages of ESC Materials

- **Design Flexibility**
- **Corrosion Resistance**
- **High Strength**
- **High Impact Resistance**
- **High Strength-to-weight Ratio**
- **Low Coefficient of Thermal Expansion**
- **Electrical Performance – non-conductive**
- **Dimensional Accuracy – Molded-in Tolerances**
- **Improved NVH Characteristics**

Conclusions

Commercialization is Imminent

- Various Demo Programs Underway
- Residential / Portable in '02
- Transit Busses in '03
- Automobiles in '04

Many Segments / Niche Applications

- Initial Penetration into Price Insensitive Segments
- Broaden Commercial Scope / Deepen Penetration
- Increased Demand Will Affect Mass Production

Conclusions

Keys for Fuel Cell Manufacturers

- Demonstrate Success Initially
- Validate Efficiency / Reliability
- Drive Costs Down
- Creative Marketing / Business Strategies to Create Volume

Keys for Component Suppliers

- Material Development / Specification
- Design for Manufacture
- Development of High Performance / Low Cost Components
- Collaboration with OEM's / Key Players