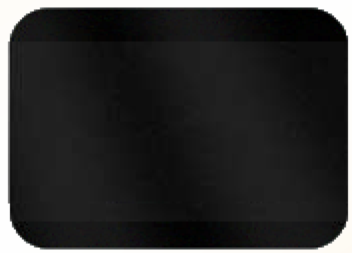
FUEL CELL TECHNOLOGIES

Developing Durable, Cost- Effective MEAs for Automotive Fuel Cells

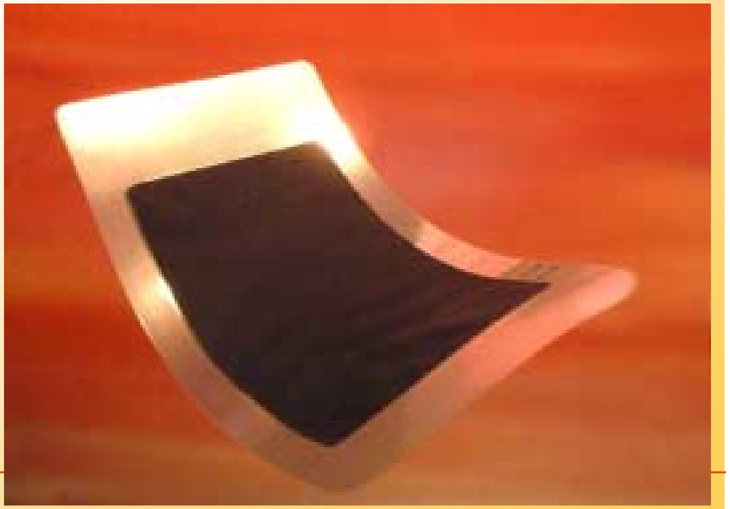


SAE TOPTEC Symposium, Dearborn, MI
(9th April 2003)

S. J. C. Cleghorn

Gore Fuel Cell Technologies

- **Gore Fuel Cell Technologies was established in the early 1990s, and is one of the top investment areas for Gore**
- **A Global Manufacturing & Technology Team** - with sites in the U.S. and Japan, plus sales / technical support teams throughout the world
- **The highest volume MEA supplier in the world**
- **The innovation leader**, redefining MEA performance expectations

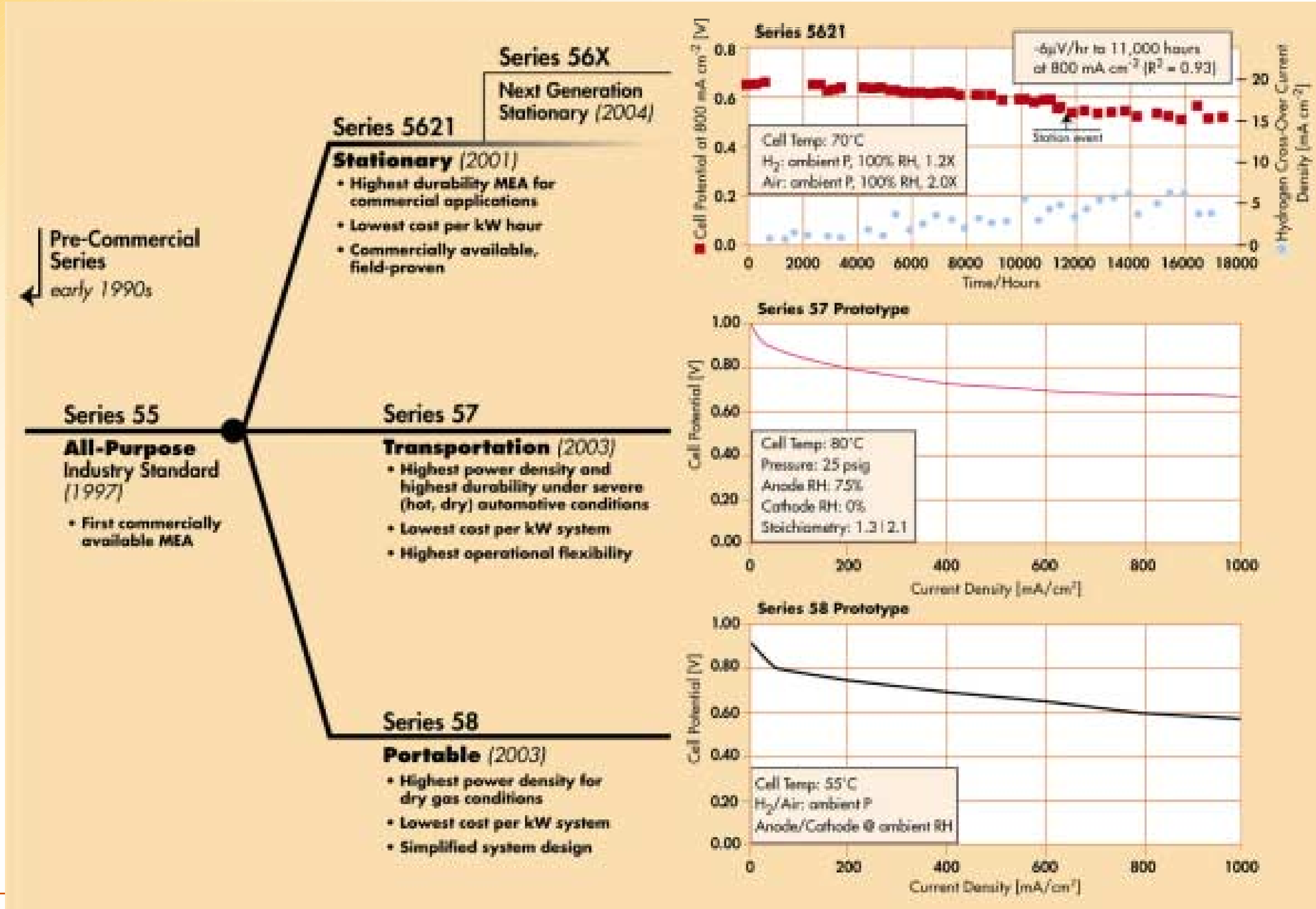


Gore's Vision is to Supply the Most Cost-Effective MEAs for all PEMFC Applications

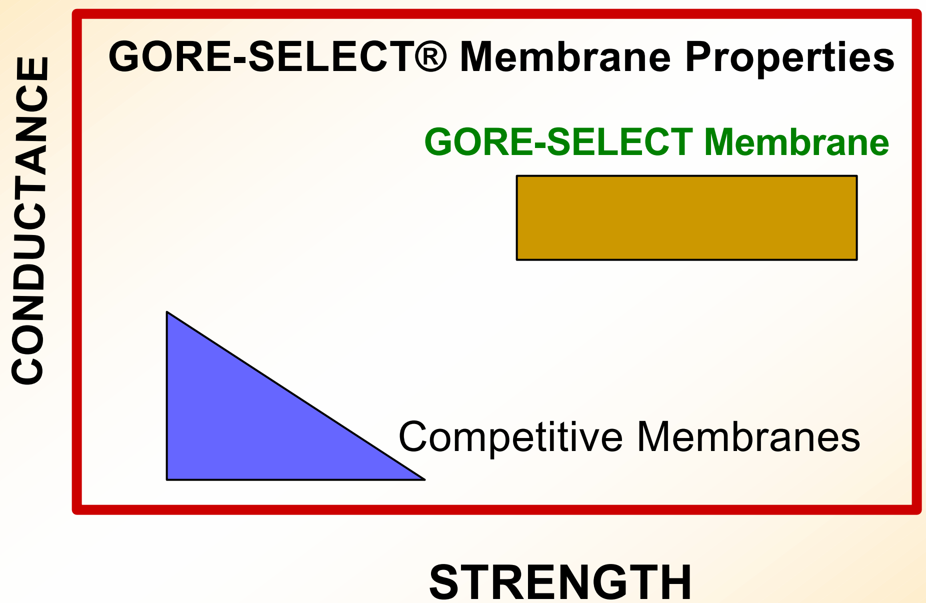
- **Highest Power Density**
  - Reduced stack size
  - Less MEAs, GDMs, seals and bipolar plates
- **Greatest Durability**
  - Least stack changes per power plant life
- **Operational Flexibility**
  - Systems simplification
  - Reduced parasitic power losses
- **Inherent Cost Advantage**
  - Lowest raw material (catalyst / ionomer) content

= Lowest $ / kW-hr system cost

Gore Fuel Cell Technologies PRIMEA® MEA Portfolio



The Composite ePTFE Reinforced GORE-SELECT® Membrane Facilitates Membrane Structures with:

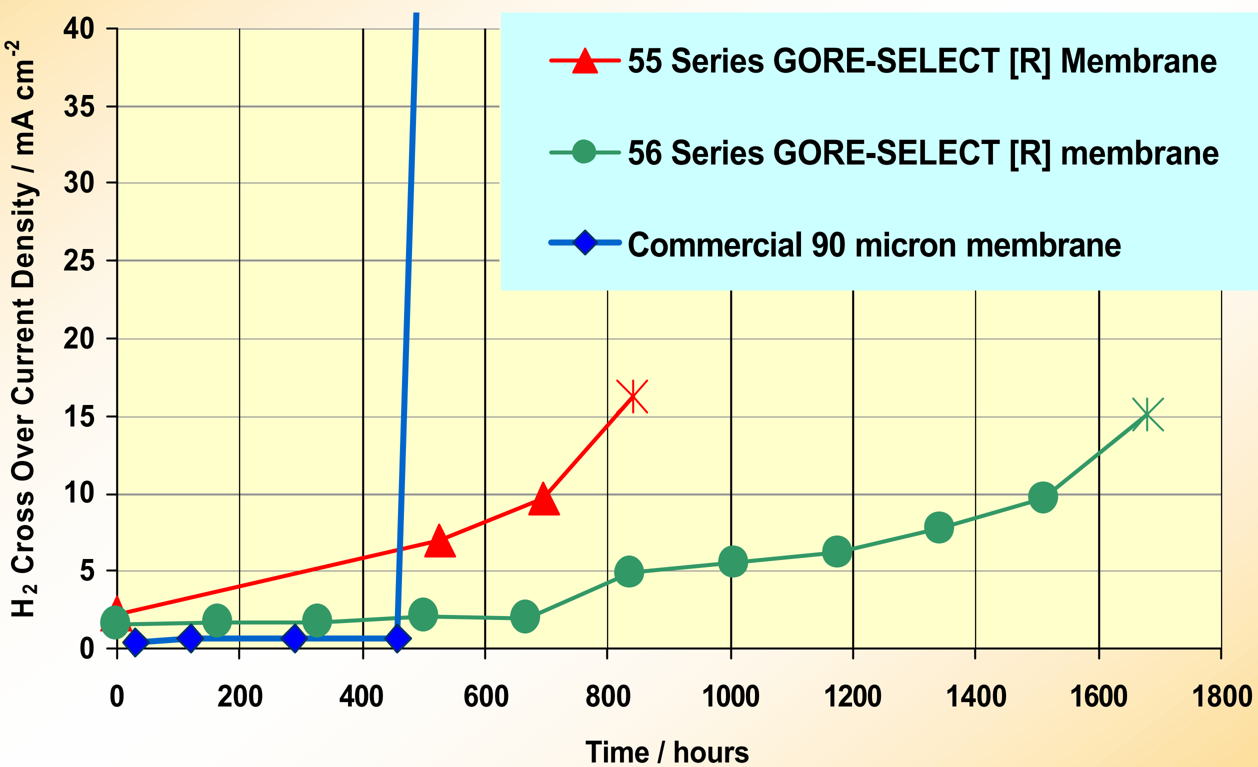


- **High ionic conductance**
- **High strength**
- **Increased hydrational stability**
- **Reduced ionomer materials utilization**
- **Increased durability**

GORE FUEL CELL TECHNOLOGIES

Reinforced and non-reinforced membranes Durability in Accelerated Tests

Accelerated test methods are used to demonstrate new membrane technologies: *See W. Liu et al, J. New Mat. Electrochem. Syst. 4 (2001) 227*



Cell temperature 90 °C

H_2 75 % RH, 15 psig

Air 75 % RH, 15 psig

Automotive MEA Product and Technology Development Road Map

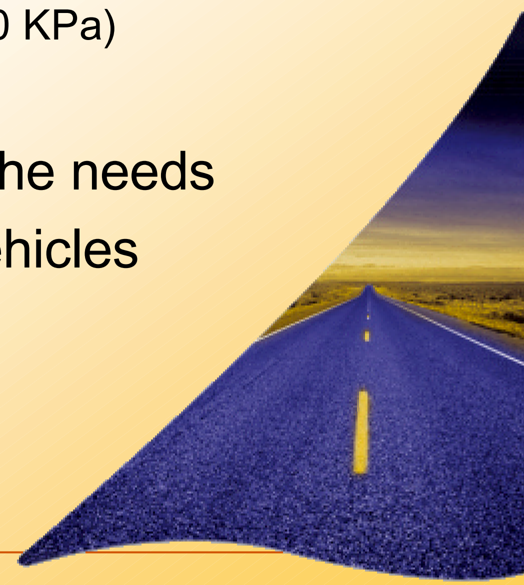
A) Product Development - PRIMEA® Series 57 MEA

Most durable high power density MEAs for current and next generation demonstration fuel cell vehicles

– Target operating conditions: Cell temperature approx 80 °C
  Sub-saturated or dry reactants
  Elevated pressure (up to 300 KPa)

B) MEA Technology Development to support the needs for future wide spread commercialization fuel cell vehicles

– addressing future technology needs of cost, operability and durability / reliability



GORE FUEL CELL TECHNOLOGIES

PRIMEA® Series 57 MEA

The most durable[1] high power density[2] MEA for next generation automotive fuel cells[3]

Now Available

1. Increase MEA life and decreased voltage decay

2. Power density greater than or equivalent to current PRIMEA® Series 55 MEA under automotive conditions.

3. Operating conditions relevant to today's demonstration automotive fuel cell vehicles (Cell temperature approximately 80 °C, sub-saturated or dry reactants and elevated pressure up to 300 KPa)

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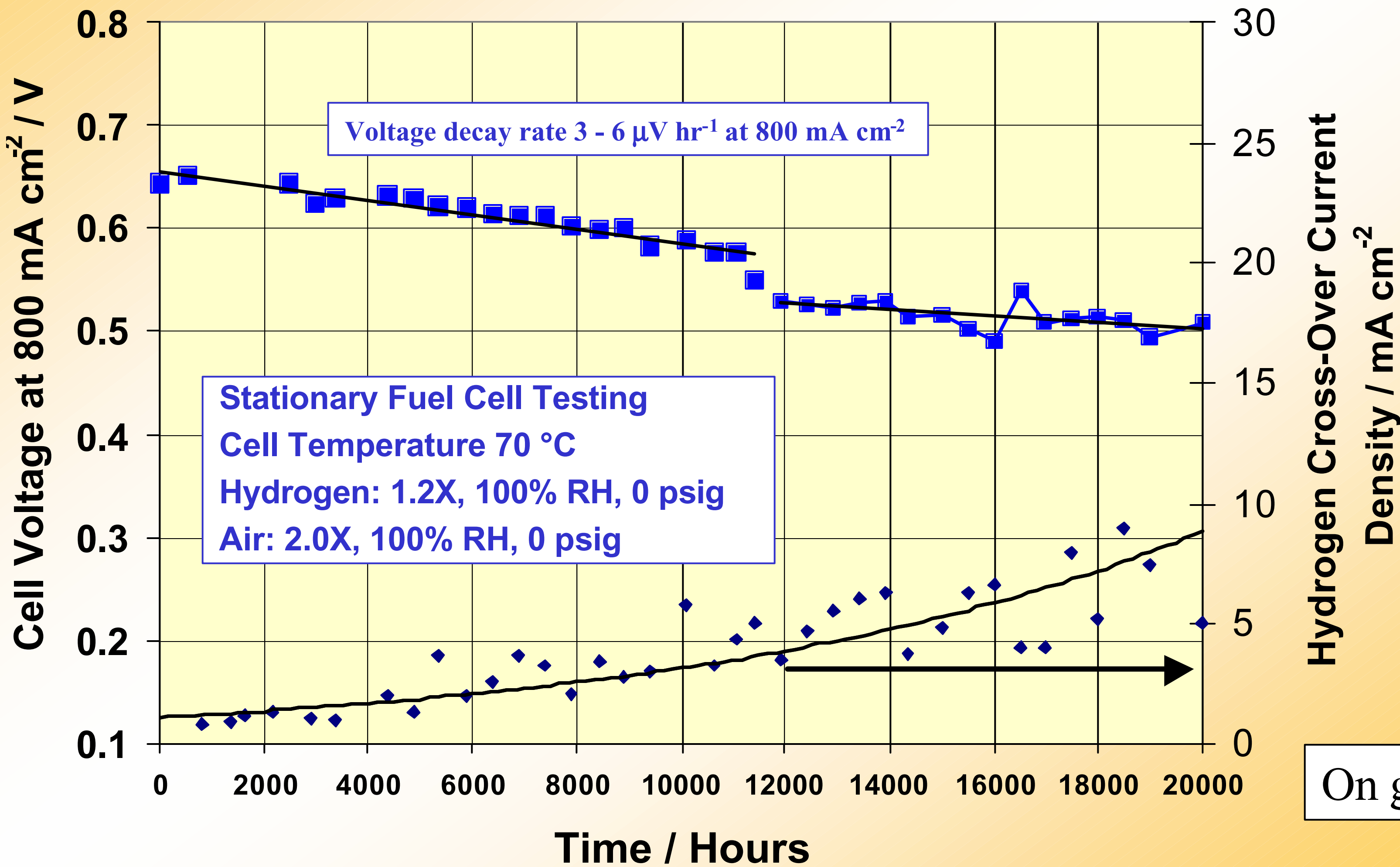
MEA Life Testing at Stationary Fuel Cell Conditions

(PRIMEA® Series 56 MEA - continuous operation at 800 mA cm^{-2} on hydrogen)

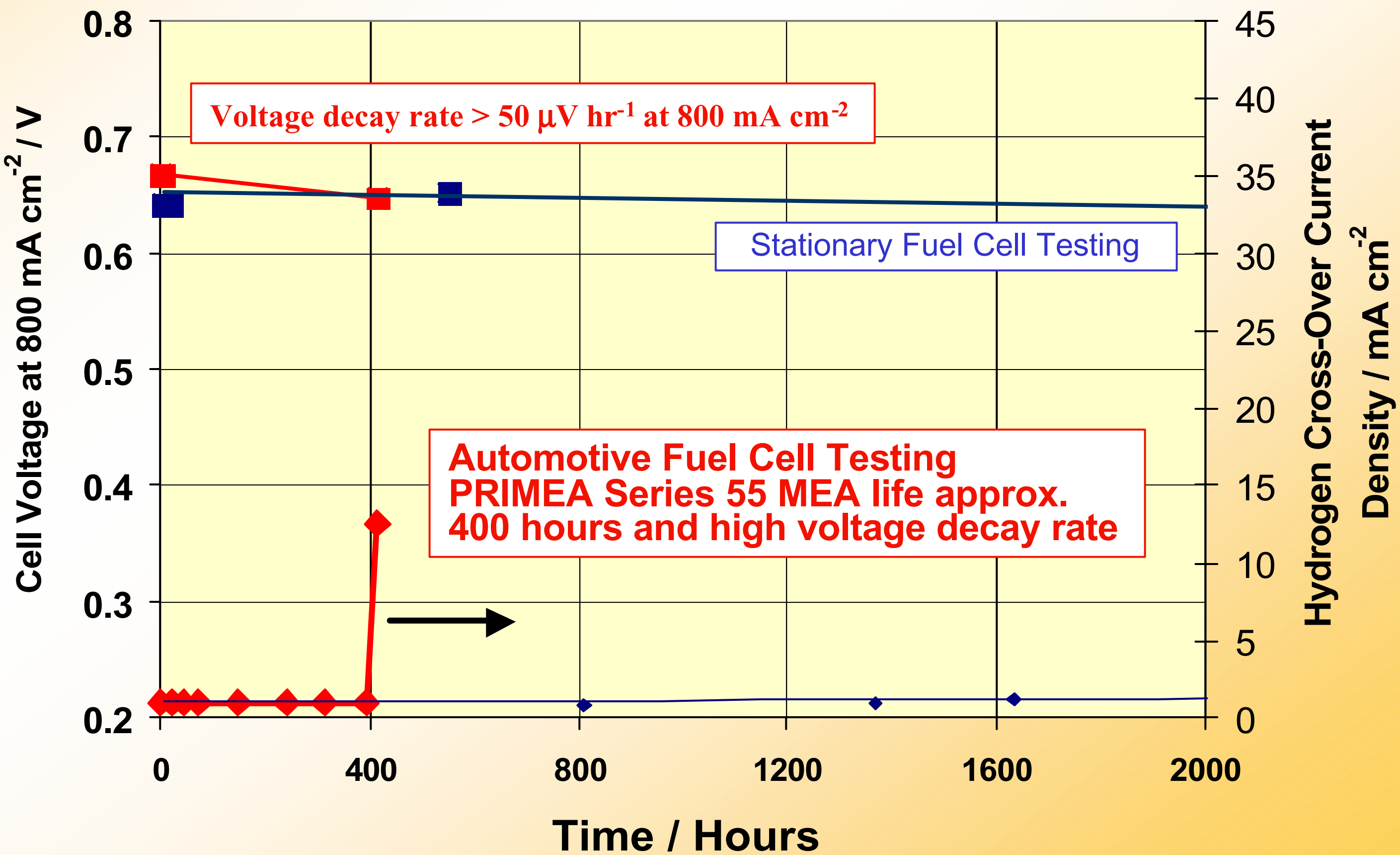


On going Test

FUEL CELL TECHNOLOGIES

MEA Life Testing Automotive Fuel Cell Conditions
(PRIMEA® 55 series MEA)

The operating conditions dictated on the MEA by the automotive system leads to rapid membrane failure and high voltage decay.



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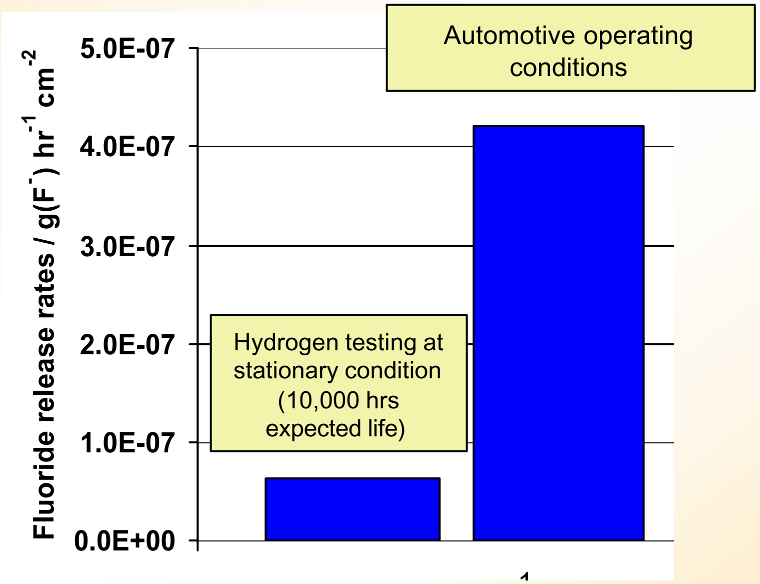
Chemical Degradation

- **Ionomer degradation is thought to occur through peroxide radical attack of the polymer**
- **Fluoride ion decomposition product in the exit water can be used to measure (in-situ) rates ionomer degradation**
- **Automotive fuel cell operating conditions accelerate ionomer degradation**
  - **high temperature, high pressure and low membrane RH**

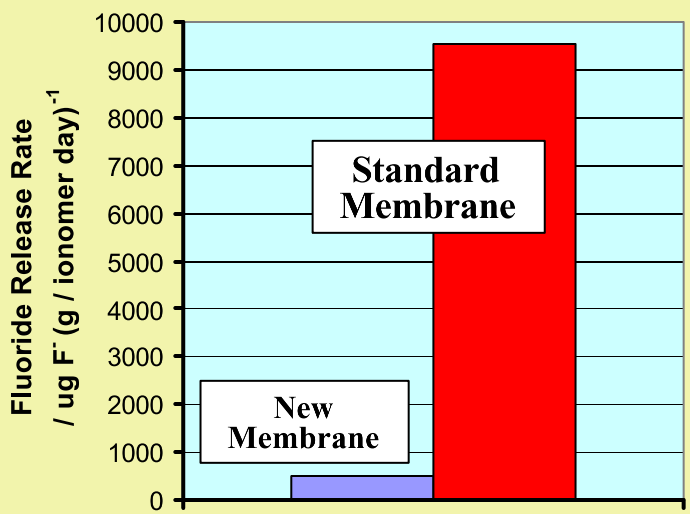


Results for PRIMEA® Series 55 MEA

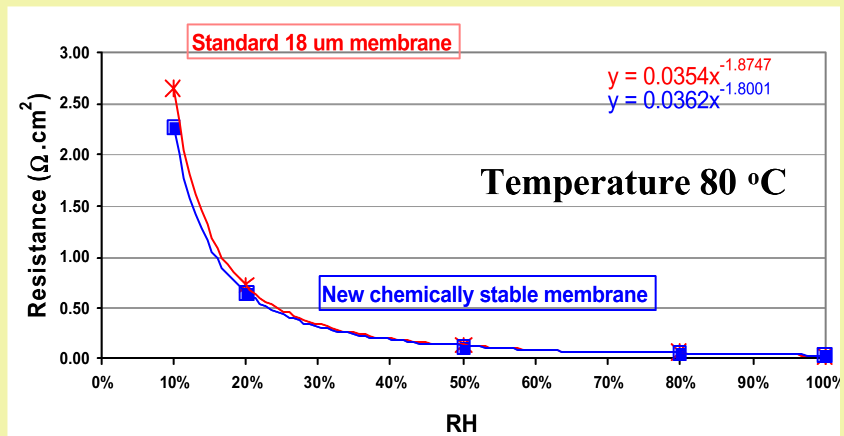
Chemical Degradation

- **An ex-situ peroxide radical challenge test (Fenton's Reagent test) has been developed at Gore to evaluate chemical stability of membranes**
- **With the aid of this test a new more chemically resistant (w.r.t. peroxide radical attack) MEA has been developed**

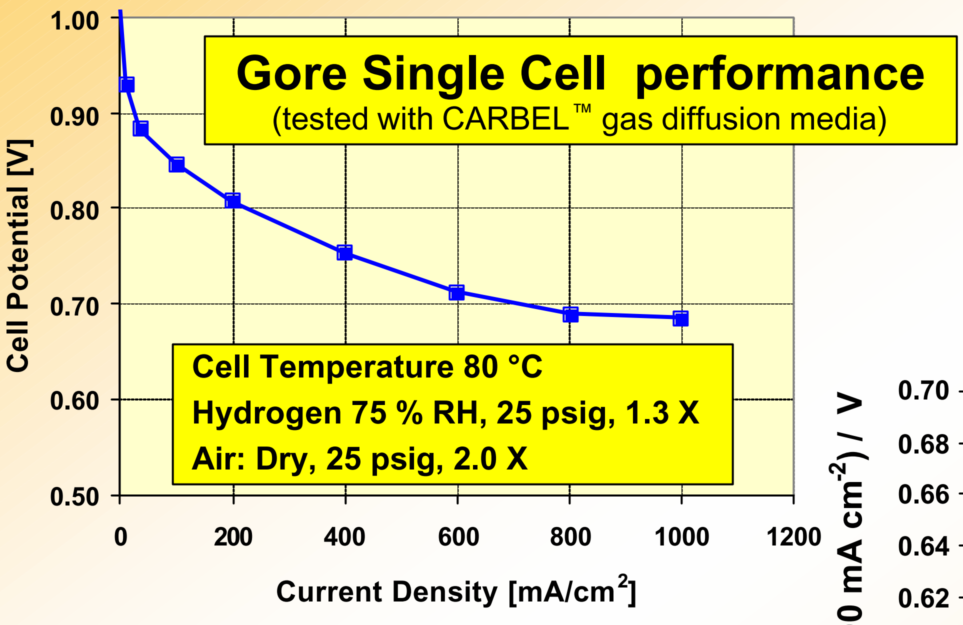
A. 20 X more chemically resistant in Fenton's Reagent tests (cf. existing product)

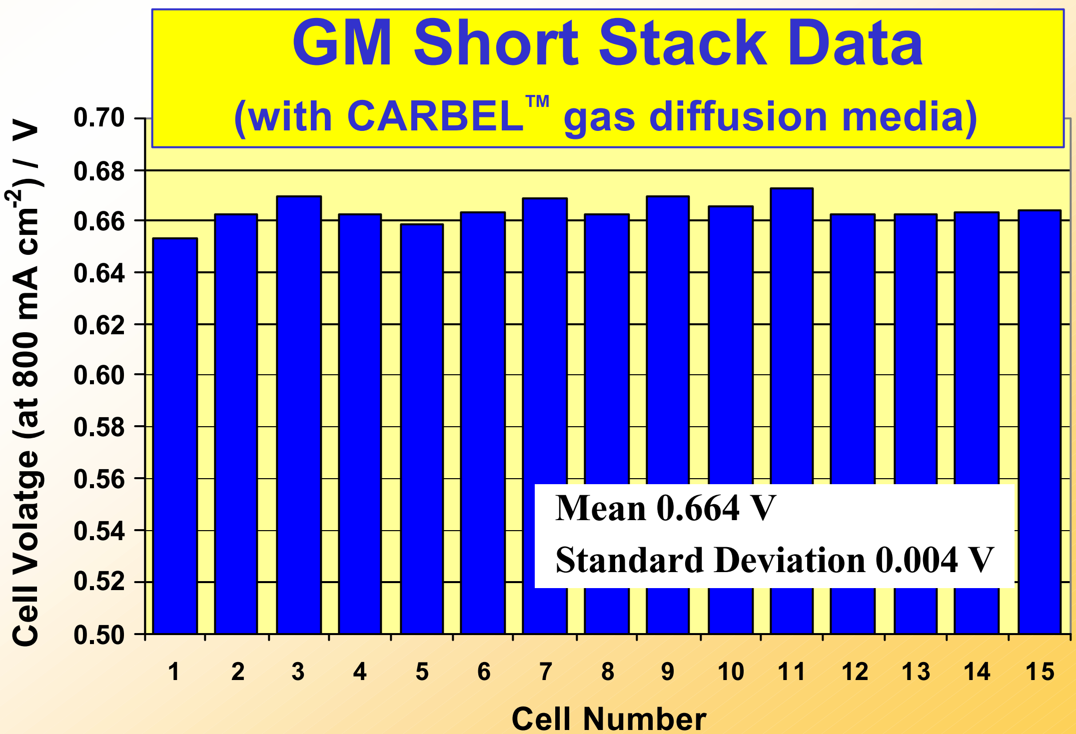


B. Demonstrates no penalty in membrane resistance



PRIMEA® Series 57 MEA - Power Density





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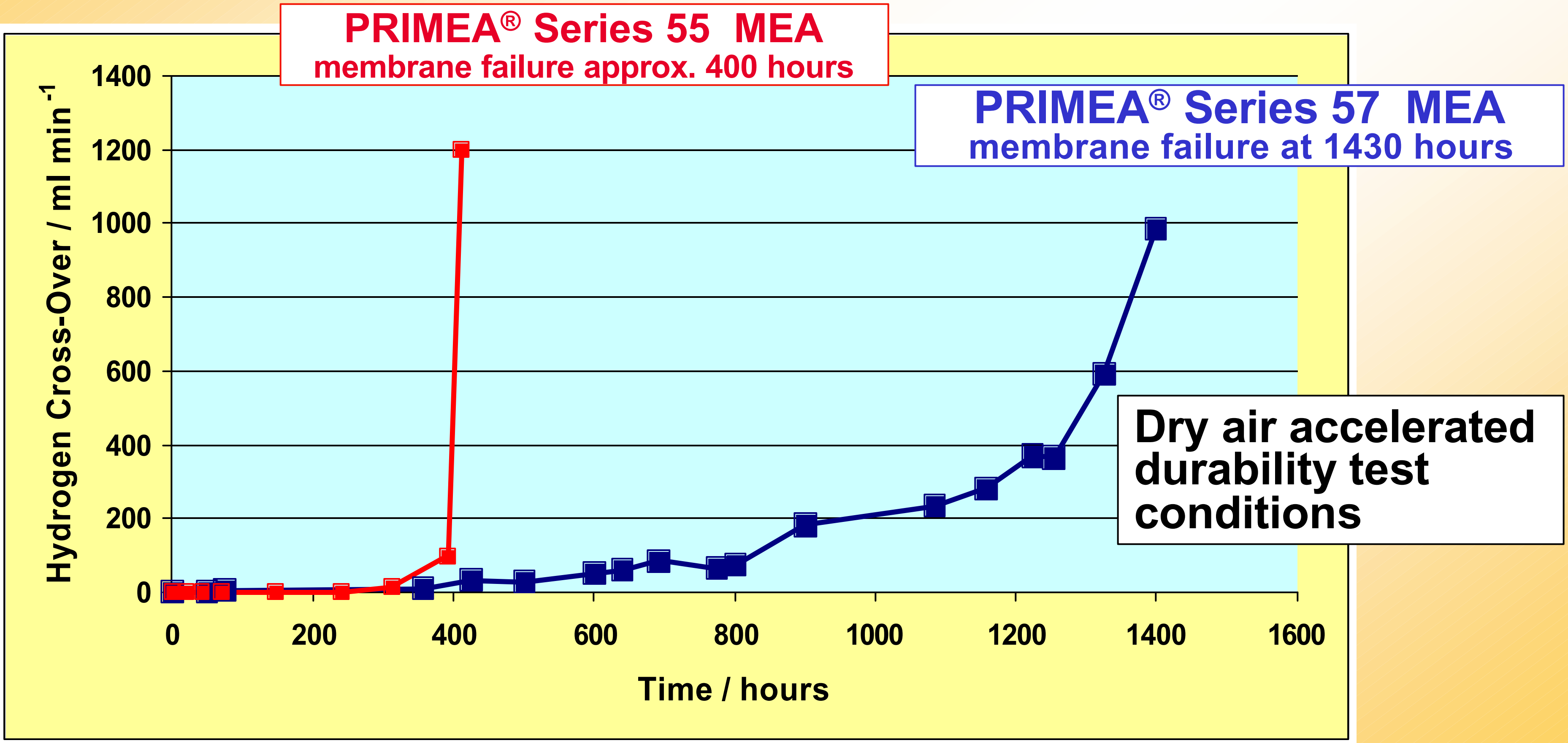
GM Short Stack Durability - Membrane Life

PRIMEA® Series 57 MEA with CARBEL™ gas diffusion media

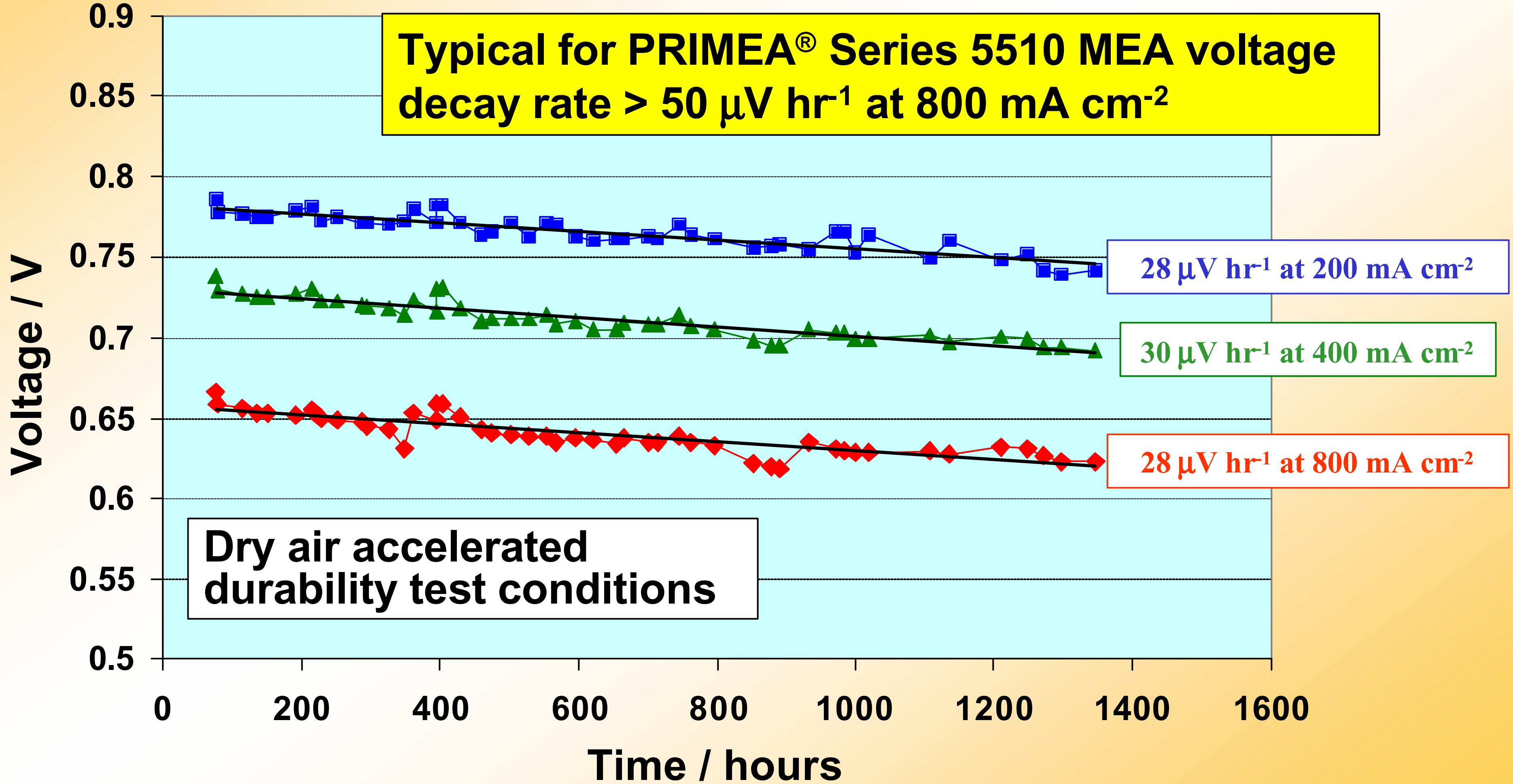


Extended membrane life is consistent with low in fluoride release rate measured (10^{-8} g[F^-] hr^{-1} cm^{-2})

GORE FUEL CELL TECHNOLOGIES

GM Short Stack Durability - Voltage Decay

PRIMEA® Series 57 MEA with CARBEL™ gas diffusion media



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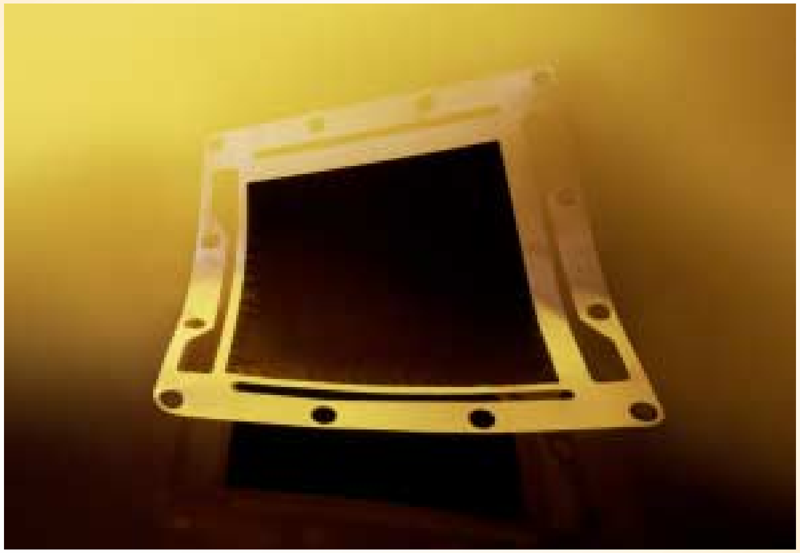
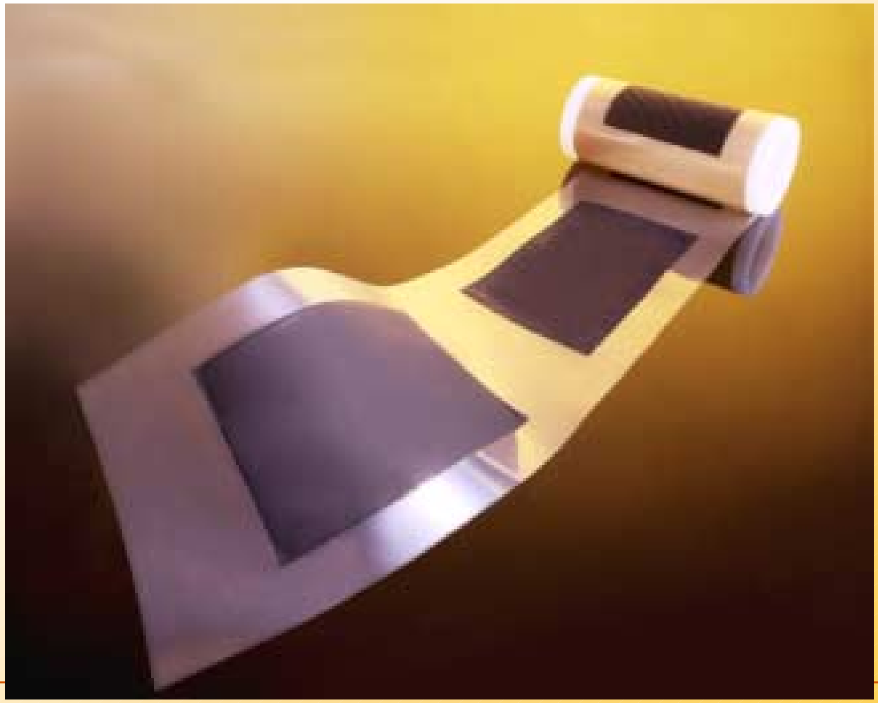
PRIMEA® Series 57 MEA - Product Status

- **Product Development** - technical feasibility demonstrated
- **Manufacturing Scale-Up and Qualification**
- **Commercial Launch**





MEA Requirements for Commercial Fuel Cell Vehicles
- MEA Technology Development Goals

	Current Demonstration Vehicles PRIMEA® Series 57 MEA	MEA Needs for Commercial Fuel Cell Vehicles
Cost (assume dictated by Platinum cost)	**1 g_{pt} / kW** (at 0.6 V) (75 g for a 75 kW engine)	< **0.2 g_{pt} / kW** (> 0.6 V) (15 g for 75 kW engine)
Operating Conditions (temperature)	• **$T_{cell} \approx 80\ ^oC$** • RH < 50 % • Pressure < 270 kPa	• **T_{cell} 110 – 120 ^oC** • RH < 25 % • Pressure < 150 kPa
Durability (membrane life)	MEA life accelerated conditions approximately **1500 hours**, and **< 30 $\mu V\ hr^{-1}$** (voltage decay rate).	MEA life of **5,000 hours**, voltage decay rate TBD. Consider: Freeze/thaw, cold start, stop/start, duty cycle.

Technology Development

Automotive MEA Technology Development at Gore

(focused on developing MEA technologies to meet the needs for future commercial fuel cell vehicles)

A) MEA durability at 95 °C and higher

- Technologies have demonstrate desired power density at 95 °C
- Goal is to understand MEA failure mechanisms at high temperature and discover MEA solutions

B) New membrane materials development for operation up to 120 °C

- Goal is to discover membrane (and MEA) technologies with required conductivity up to 120 °C

C) Advanced electrode development

- Goal is to develop low loading electrodes, and
- understand high temperature, low RH electrode operation

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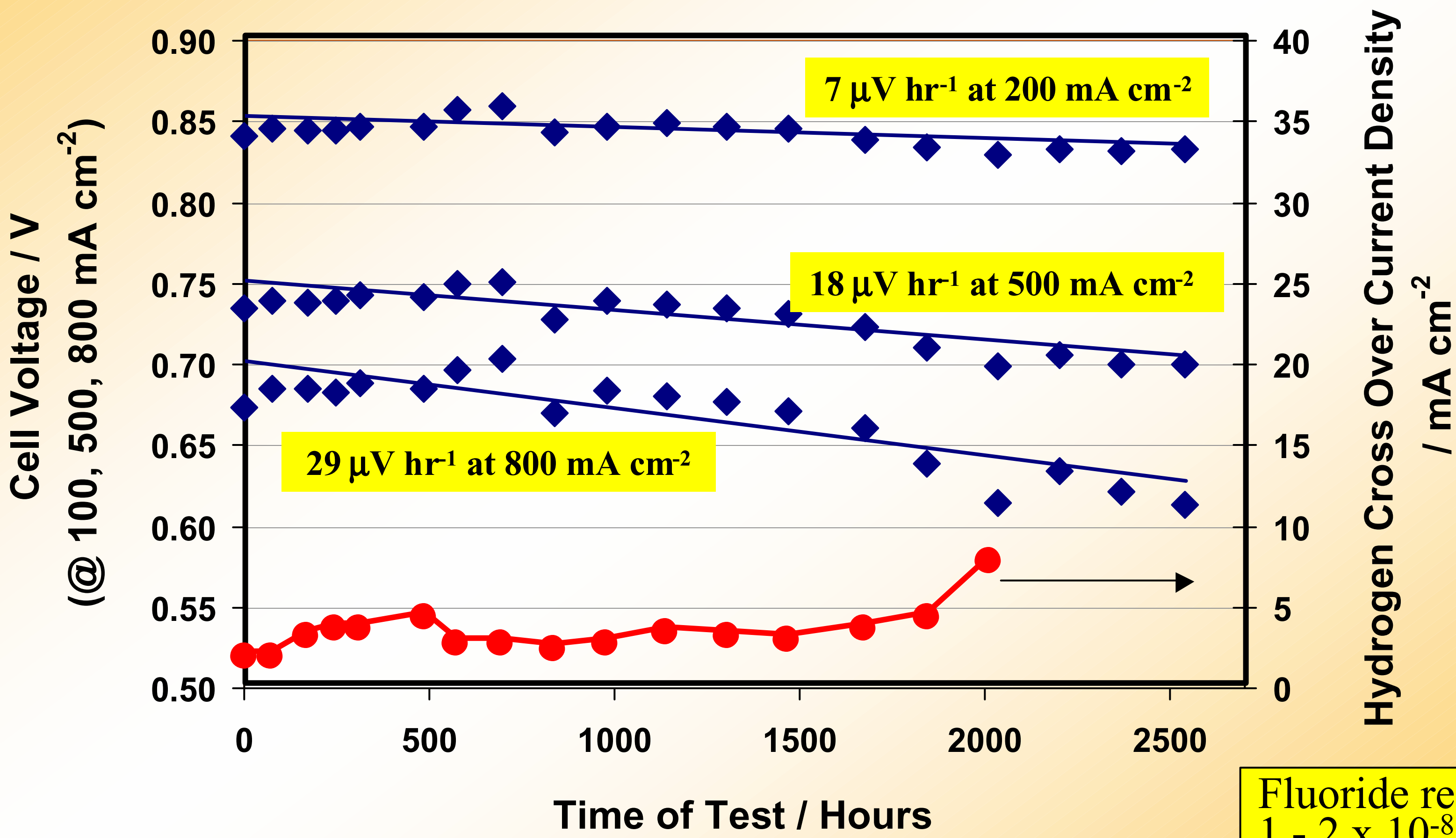
A. Prototype MEA Life Testing at 95 °C

Cell Temperature 95 °C, Hydrogen 1.2 X, 25 psig, 50 % RH, Air: 2.1 X, 25 psig, dry

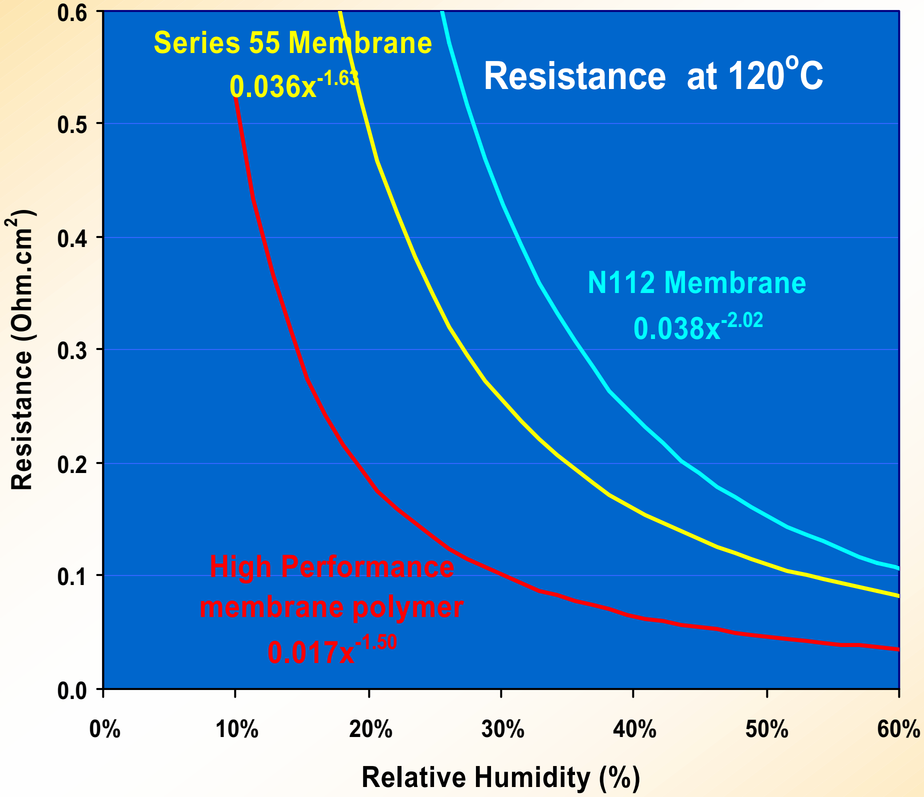


Fluoride release rate
1 - 2 x 10^{-8} g F^- hr^{-1} cm^{-2}

B. Membrane materials for Automotive Operation at 120 °C

Membrane materials with acceptable conductivity at low RH have been demonstrated.

Other critical properties are the mechanical and chemical stability, reactant permeability and water swelling properties acceptable?



Empirically Determined Power Law

$$\text{Resistance, } R = A(RH)^{-b}$$

High performance at automotive membrane require minimum b and minimum A

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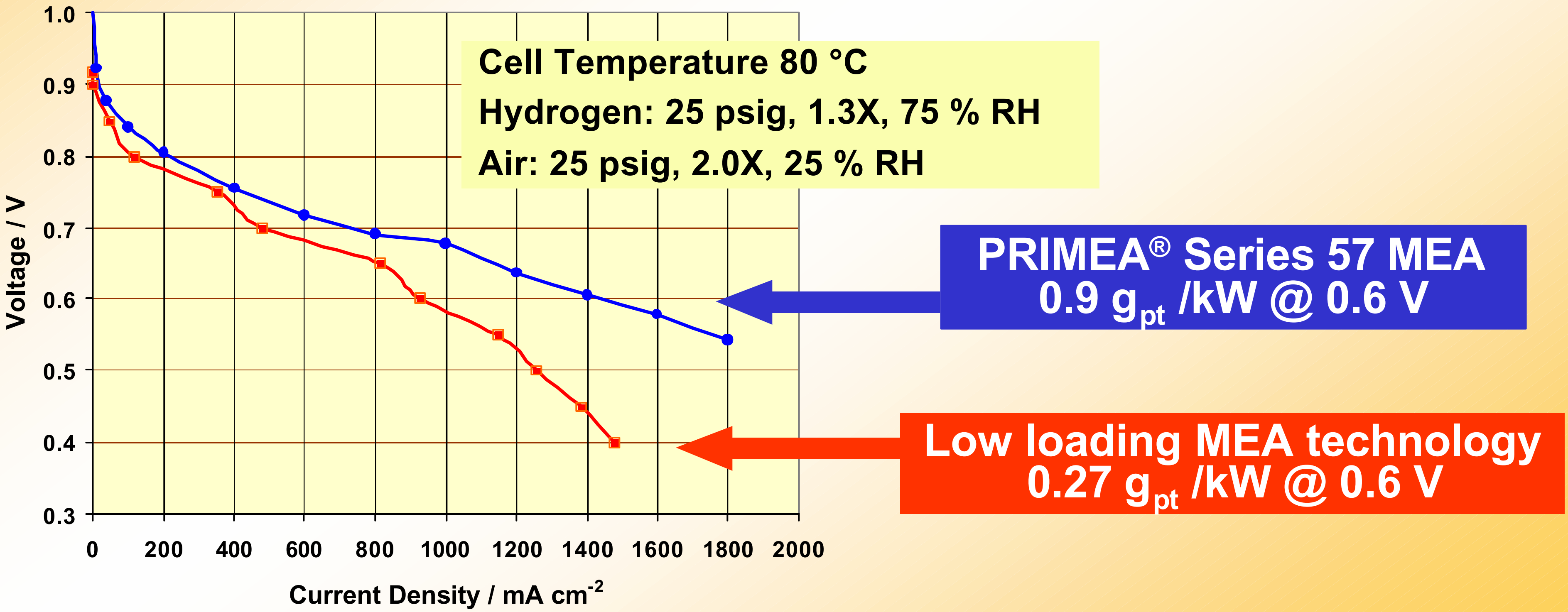
C. Electrode Challenges for Automotive Operation

- High temperature automotive MEAs must provide high power density at low RH and high temperature with decreased platinum loading (cf. today's technology)
- However, at these conditions: 1. Electrode catalytic active area, 2. ORR equilibrium potential and 3. Electrode ionic resistance all decreases in current technology



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www.gore.com/fuelcells