

# Automotive PEM Stack Freeze Requirements & Suggested Fundamental Studies

*Fuel Cell Activities*

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01FEB05



# Conundrum

One of the most attractive attributes of a hydrogen fuel cell is that it makes pure water

One of the most challenging attributes of a hydrogen fuel cell is that it makes pure water

# Agenda

## Minimum Temperatures

Startability

Freeze Related Degradation

Suggested Fundamental Studies

# Minimum Ambient Temperatures

Minimum start temperature*	-40°C
Vehicle able to start unassisted	
Minimum non-start temperature*	-48°C

\*From GM Vehicle Technical Specifications

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# Startability Targets

## Start Time

- A competitive FCV must be able to start unassisted from  $-30^{\circ}\text{C}$  and drive away at 70% power within 30 seconds

## Start Energy

- Total vehicle fuel consumption should not increase more than 75% when comparing Phase 1 (Cold Start) of a  $-25^{\circ}\text{C}$  EPA City test vs. Phase 3 (hot start) of  $20^{\circ}\text{C}$  EPA-City test\*
- For an 'average' hydrogen FCV this translates to roughly 5MJ of additional energy allowed for  $-25^{\circ}\text{C}$  startup and drive (including shutdown)

\*Derived from SAE paper 2001-01-0221 "Cold Start Impact on Vehicle Energy Use", Gordon W. R. Taylor, Steve Stewart



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**Freeze Related Degradation**

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# Freeze Related Degradation Targets

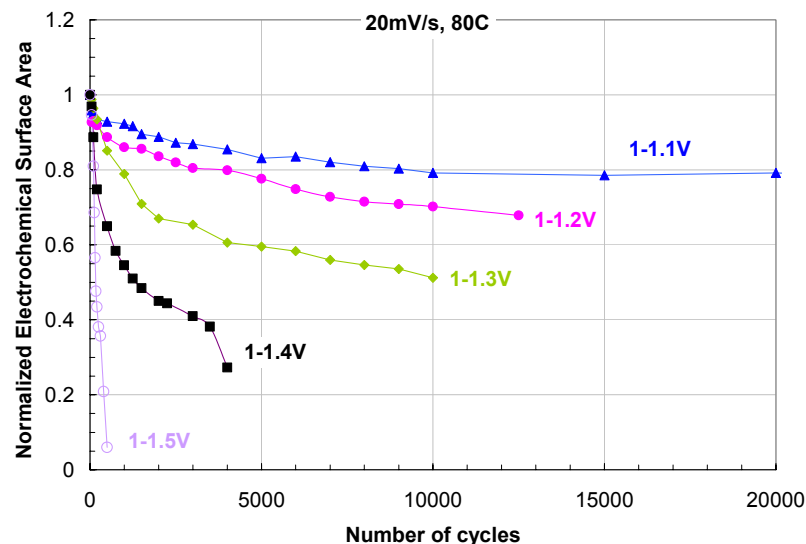
- Up to 30 millivolts of cell voltage degradation (at max current) is allowed over the life of the stack (5500 operating hours)
  - There are multiple sources of stack voltage degradation
  - The vehicle is expected to startup about 40,000 times during its 5500 hour operating life
  - 1000 to 1500 of these starts are expected to be frozen



# Freeze Related Degradation Targets

- The mix of voltage degradation requirements results in the following:
  - Allowable freeze related voltage degradation can be as high as 20 to 30 microvolts per frozen start if all other sources are zero (highly unlikely)
  - Considering the other sources of voltage degradation today, freeze related voltage degradation is a relatively minor issue

Effect of voltage range on  
Electrochemical surface area



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# Suggested Fundamental Studies

Considering the wide variety of fuel cell stack designs and system approaches it seems that the common ground for freeze related studies lies in the MEA/GDL (softgoods) arena

- Suggestions for fundamental studies include the following:
  - Better understanding of the state of water and proton conductivity in PFSA membranes (and others?) at freezing temperatures down to  $-40^{\circ}\text{C}$
  - Develop low cost catalyst systems and/or electrodes that are resistant to corrosion, platinum sintering and platinum dissolution.
  - Develop coolants with lower slush points that meet or exceed cost, performance, environmental and safety requirements



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