

# PEM Fuel Cell Accelerated Stress Tests and Durability Test Protocols

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# Membrane – Chemical Stability

	Kunz & Fenton (UConn)	USFCC (DuPont)	U.S. Drive Fuel Cell Tech Team	W.L. Gore & Associates
<b>Test Condition</b>	Steady state OCV	Steady state OCV	Steady state OCV	Steady state OCV
<b>Cell area, cm<sup>2</sup></b>	5		25 or 50	25
<b>Duration, hr</b>	Up to 200	Up to 250	Up to 500	
<b>Temperature, °C</b>	90	90	90	95
<b>RH, Anode / Cathode (A/C)</b>	30% / 30%	30% / 30%	30% / 30%	50% / 50%
<b>Inlet DP, A/C °C</b>	61 / 61	61 / 61	61 / 61	77 / 77
<b>Fuel / Oxidant</b>	H <sub>2</sub> / O <sub>2</sub>	H <sub>2</sub> / O <sub>2</sub> or 40% O <sub>2</sub>	H <sub>2</sub> / Air	H <sub>2</sub> / Air
<b>Flow / Stoich, A/C sccm</b>	200 / 200	240 / 250	10x / 10x @ 0.2 A/cm <sup>2</sup> equiv. flow (350 / 835 @ 25 cm <sup>2</sup> )	100 / 200
<b>Pressure, A/C kPa<sub>a</sub></b>	101 / 101		150 / 150	273 / 273
<b>Metric – Target; Frequency</b>				
<b>F<sup>-</sup> release or equivalent for non-fluorine membranes</b>	Every 10-20 hr	at least every 24 hr	No target – for monitoring; at least every 24 hr	
<b>H<sub>2</sub> x-over, mA/cm<sup>2</sup></b>			≤ 2; every 24 hr	< 14: freq ?
<b>OCV</b>		< 0.8 V; continuous	≤ 20% loss in OCV; continuous	
<b>HFR</b>			No target; every 24 hr @ 0.2 A/cm <sup>2</sup>	
<b>Shorting resistance</b>			> 1,000 Ω-cm <sup>2</sup> ; every 24 hr	
<b>Source</b>	JES 154(7) B652 (2007)	2007 FC testing workshop	[1] Drive Fuel Cell Tech Team Roadmap, 2013	2007 FC testing workshop

\* Measured at 0.5 V applied potential, 80 °C and 100% RH N<sub>2</sub> / N<sub>2</sub>. Compression to 20% strain on GDL

# Membrane – Mechanical Stability

	USFCC (GM)	U.S. Drive Fuel Cell Tech Team
<b>Test Condition</b>	RH cycling	RH cycling
<b>RH cycle conditions</b>	2 min 0% RH; 2 min 150% RH (90 °C) A/C	2 min 0% RH; 2 min 90 °C DP A/C
<b>Cell area, cm<sup>2</sup></b>		25 or 50
<b>Duration, hr</b>		EOL or up to 20,000
<b>Temperature, °C</b>	80	80
<b>Fuel / Oxidant</b>	Air / Air	Air / Air
<b>Flow / Stoich, A/C sccm</b>		2,000 / 2,000
<b>Pressure, A/C kPa<sub>a</sub></b>	$\Delta P = 20$ kPa	101 / 101
<b>Metric – Target; Frequency</b>		
<b>Total time or EOL criteria</b>	10 sccm (1.4 mA/cm <sup>2</sup> ) H <sub>2</sub> x-over	Until H <sub>2</sub> crossover > 2 mA/cm <sup>2</sup> or 20,000 cycles
<b>Frequency</b>	Every 24 hrs	Every 24 hrs
<b>Shorting resistance*</b>		> 1,000 $\Omega$ -cm <sup>2</sup> ; Every 24 hrs
<b>Source</b>	2007 FC testing workshop	[1] Drive Fuel Cell Tech Team Roadmap, 2013

\* Measured at 0.5 V applied potential, 80 °C and 100% RH N<sub>2</sub> / N<sub>2</sub>. Compression to 20% strain on GDL

# Membrane – Mechanical + Chemical

	USFCC (GM)
<b>Test Condition</b>	RH cycle (0 to 100% RH, every 30 min for 24 hr) + Load cycle (10 to 800 mA/cm <sup>2</sup> , 7/3min, @ 50% RH for 24 hr)
<b>Cell area, cm<sup>2</sup></b>	
<b>Temperature, °C</b>	80
<b>Fuel / Oxidant</b>	N <sub>2</sub> / N <sub>2</sub> for RH cycle, H <sub>2</sub> / Air for load cycle
<b>Flow / Stoich, A/C sccm</b>	
<b>Pressure, A/C kPa<sub>a</sub></b>	
<b>Metric – Target</b>	
<b>EOL criteria</b>	10 mA/cm <sup>2</sup> H <sub>2</sub> x-over
<b>frequency</b>	periodic
<b>Source</b>	2007 FC testing workshop

# Electrocatalyst Stability

	Kocha et. al.	USFCC (DuPont)	U.S. Drive Fuel Cell Tech Team	W.L. Gore & Associates
<b>Test Condition</b>	V cycling	V sweeping	Triangle voltage sweeping	V cycling
<b>Cell area, cm<sup>2</sup></b>	25		25 – 50	25
<b>Voltage and duration</b>	0.6 to 0.95 V various (step-step; step-sweep; etc.)	Sweep: 0.6 to 1.2 V; 20 mV/s (60 s/cycle)	Sweep: 0.6 to 1.0 V, 50 mV/s (16 s/cycle)	Step: 0.7 V, 30 s; OCV 30 s
<b>Duration / cycles</b>	< 20,000	6,000 (~ 100 h)	30,000	19,800 (~330 h)
<b>Temperature, °C</b>	80	80	80	80
<b>RH, A/C</b>	100% / 100%	100% / 100%	100% / 100%	100% / 100%
<b>Inlet DP, A/C °C</b>	80 / 80	80 / 80	80 / 80	80 / 80
<b>Fuel / Oxidant</b>	H <sub>2</sub> / Air or H <sub>2</sub> / N <sub>2</sub>	H <sub>2</sub> / N <sub>2</sub>	H <sub>2</sub> / N <sub>2</sub>	H <sub>2</sub> / Air
<b>Flow / Stoich, A/C sccm</b>		Equiv. to 1.2x H <sub>2</sub> / 2x air @ 0.6 V @ BOL	200 / 75 for 50 cm <sup>2</sup> cell	2x / 2x, min 225 / 525 sccm
<b>Pressure, A/C kPa<sub>a</sub></b>		270 / 270	101 / 101	150 / 150
<b>Metric – Target; Frequency</b>				
<b>ESCA*</b>	BOL, EOT, periodic	BOL, EOT, periodic	≤ 40% loss of initial area; After 10, 100, 1k, 3k, 10k, 20k, 30k cycles	BOL, EOT; periodic
<b>Pol curves</b>	BOL, EOT	BOL, EOT	≤ 30 mV loss at 0.8 A/cm <sup>2</sup> ; After 0, 1k, 5k, 10k, 30k cycles	H <sub>2</sub> / Air (990, 1980, ...); H <sub>2</sub> / O <sub>2</sub> BOL, EOT
<b>Other</b>		TEM, XRD	Catalytic mass activity** ≤ 40% loss of initial catalytic activity; BOL, EOL at minimum	
<b>Source</b>	PEMFC-7 (ECS), p 1215	2007 FC testing workshop	[1] Drive Fuel Cell Tech Team Roadmap, 2013	2007 FC testing workshop

\* Sweep @ 20 mV/s, 0.05 to 0.6 V, 80 °C, 100% RH

\*\* Mass activity in A/mg, 150 kPa<sub>a</sub> @ 857 mV iR-corrected on 6% H<sub>2</sub> (bal N<sub>2</sub>)/O<sub>2</sub> (or equivalent thermodynamic potential), 100% RH, 80 °C normalized to initial mass of catalyst and measured before and after test.

# Catalyst Support Stability (Carbon Corrosion)

	USFCC (DuPont)	U.S. Drive Fuel Cell Tech Team	W.L. Gore & Associates
Test Condition	Hold @ 1.2 or 1.5 V	Triangle voltage sweeping	Start/Stop - Anode at OCV exposed alternately to H <sub>2</sub> & Air
Cell area, cm <sup>2</sup>		25 – 50	25
Voltage and duration		Sweep: 1.0 - 1.5 V, 500 mV/s	30 s H <sub>2</sub> / Air (45 / 100 sccm), 20 s Air / Air (45 / 0? sccm)
Duration / cycles		Up to 400 hr	100
Temperature, °C	80	80	80
RH, A/C	100% / 100%	80% / 80%	66% / 66%
Inlet DP, A/C °C	80 / 80	80 / 80	70 / 70
Fuel / Oxidant	H <sub>2</sub> / N <sub>2</sub>	H <sub>2</sub> / N <sub>2</sub>	H <sub>2</sub> / Air; Air / Air
Flow / Stoich, A/C sccm		?	2x / 2x, min 225 / 525 sccm
Pressure, A/C kPa <sub>a</sub>		150 / 150	101 / 101
<b>Metric – Target; freq</b>			
ECSA*		≤ 40% loss of initial area; after 0, 10, 100, 200, 500, 1k, 2k, 5k cycles	BOL, EOT
Pol curves		≤ 30 mV loss at 0.8 A/cm <sup>2</sup> ; after 0, 10, 100, 200, 500, 1k, 2k, 5k cycles	H <sub>2</sub> / Air every 20 cycles
Catalytic activity**		≤ 40% loss of initial catalytic activity; at beginning and end of test, minimum	
Source	2007 FC testing workshop	[1] Drive Fuel Cell Tech Team Roadmap, 2013	2007 FC testing workshop

\* Sweep @ 20 mV/s, 0.05 to 0.6 V, 80 °C, 100% RH

\*\* Mass activity in A/mg, 150 kPa<sub>a</sub> @ 857 mV iR-corrected on 6% H<sub>2</sub> (bal N<sub>2</sub>)/O<sub>2</sub> (or equivalent thermodynamic potential), 100% RH, 80 °C normalized to initial mass of catalyst and measured before and after test.

# Definitions & Abbreviations

BOL	beginning of life
EOT	end of test
A/C	anode / cathode
DP	dew point (°C)
RH	relative humidity (%)
Stoich	stoichiometry
ECSA	electrochemical surface area (by cyclic voltammetry)
sccm	standard cubic centimeter per minute
USFCC	U.S. Fuel Cell Council ( <a href="http://www.usfcc.com/">www.usfcc.com/</a> )
x-over	cross-over (usually H <sub>2</sub> )

## References:

1. Fuel Cell Technical Team Roadmap June 2013 Report  
[http://energy.gov/sites/prod/files/2014/02/f8/fctt\\_roadmap\\_june2013.pdf](http://energy.gov/sites/prod/files/2014/02/f8/fctt_roadmap_june2013.pdf)