Accelerated Testing Validation

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Objective/Barrier/Target

The objectives of this project are 3-fold

1. Correlation of the component lifetimes measured in an AST to real-world behavior of that component.
2. Validation of existing ASTs for Catalyst layers and Membranes
3. Development of new ASTs for GDLs, bipolar plates and interfaces

Technical Barrier Addressed: A. Durability

- Durability of fuel cell systems operating over automotive drive cycles has not been demonstrated.
- Stationary fuel cells must achieve greater than 40,000 hours durability to compete against other distributed power generation systems.
- Research is also needed to understand failure mechanisms and develop mitigation strategies.

Technical Targets

Automotive : Durability with cycling: 5,000 hours (2010/2015): 2005 Status (2000 hours for stack and 1000 hours for system)

Stationary : Durability: 40,000 hours (2011): 2005 Status = 20,000 hours

Approach

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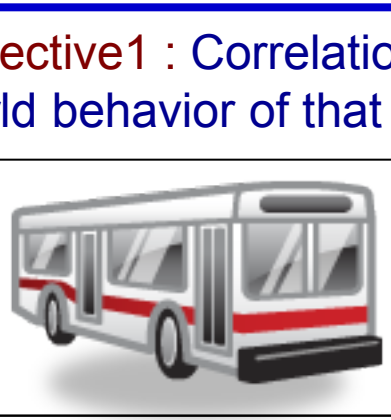
Objective1 : Correlation of the component lifetimes measured in an AST to real-world behavior of that component.

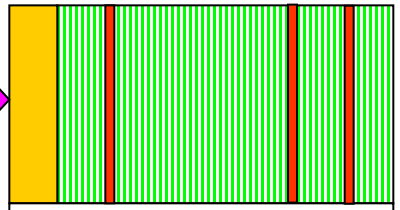


Bus Fleet Data
Provide voltage degradation distribution data from P5 fleet & HD6 Module
Provide detailed degradation data from buses analyzed in detail (4)

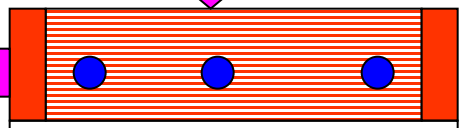
Stack
B.O.P.

BOP/Stack Data (Total 4)
Thermodynamic conditions – Average
Frequency & size of voltage transients

Medium High Low



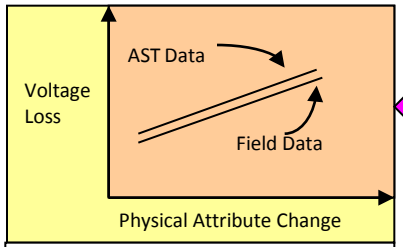
Stack Data (Total 4)
Define distribution of degradation of MEAs
Pick 3 MEAs from each of the highest, lowest & average degradation for further analysis



Cell Data (Total 36 samples)
Perform Cathode CVs (EPSA)
Perform Anode CVs (EPSA)
Global Loss Break Down Test
Local Loss Break Down & Limiting Current Test (3 points)

MEA X-Section (Total 108)
Membrane Thickness change
Platinum layer thickness change
Platinum particle size change
Platinum in the membrane level
Ruthenium concentration on Cathode

LANL



Correlate AST & Field Data Versus Physical Attribute Change
Good correlation if AST slope similar to Field data slope

The Institute for Hydrogen and Fuel Cell Research

Los Alamos

Approach (Objective 1)

BALLARD®

Materials

- New MEAs, and GDLs used in the bus modules for AST analysis

Field data analysis of 3 bus stacks from different locations and routes

- Bus stack(s) are presently in service, or recently returned
- Data analysis from one bus module using a different MEA design
- Bus module data set will be Pareto plots showing importance of operating conditions (Voltage jumps, start/stop, etc.)

Testing of in-service bus stacks/modules in the lab to compare/confirm field results

- Analysis of MEAs selected from stacks
- Global and localized Loss Voltage Breakdown (Kinetic, Ohmic, Mass Transport)
- Localized cathode limiting current
- Global ECSA (anode and cathode)

FA Analysis of cross-sectioned MEAs

Membrane thickness, Pt layer thickness, Pt particle size, Pt in the membrane, Ruthenium on the cathode

Approach (Objective 1)

Test materials with widely varying durability

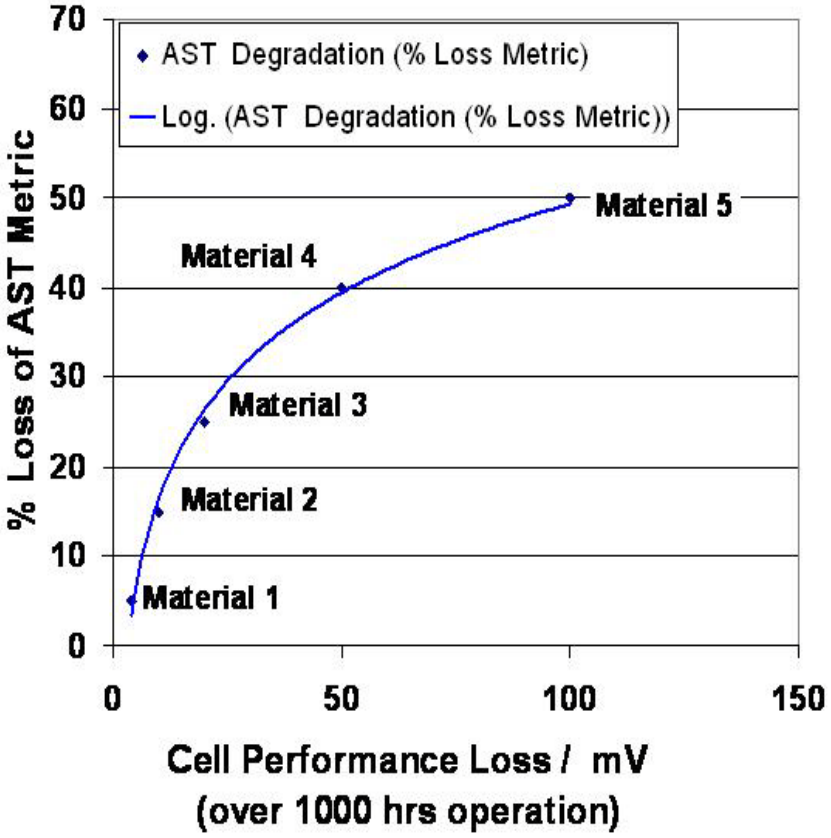
- Custom membranes/MEAs supplied by ion power
- Bus MEAs provided by Ballard Power Systems
- Commercial MEAs obtained from W.L. Gore

Correlate loss in AST metric to cell performance (LBNL)

- ECSA to voltage loss in kinetic region
- Cross-over to OCV

Analyze EOL MEAs

Correlate physical attribute to performance loss



Approach (Objective 2)

Objective 2 : Validation of existing ASTs for Catalyst layers and Membranes

Voltage loss Breakdown

$$V_{cell} = U - \eta_{ORR} - \eta_{HOR} - \eta_{\Omega,HFR} - \eta_{\Omega,elec} - \eta_{tx,H_2,elec} - \eta_{tx,H_2,GDL} - \eta_{tx,O_2,elec} - \eta_{tx,O_2,GDL} - \eta_{tx,H_2O,GDL}$$

Ignore anode kinetics and transport

Membrane degradation $\eta_{\Omega,HFR}$

Pt Catalyst degradation η_{ORR}

Carbon Corrosion $\eta_{tx,O_2,elec}$

GDL degradation $\eta_{tx,O_2,GDL}$

Catalyst layer ionomer degradation $\eta_{\Omega,elec}$

Better understand ionomer degradation and losses due to proton conduction in electrode

$$\eta_{\Omega,cat} = i\frac{R_{sheet}}{3+\zeta}$$

LBNL Porous electrode model

- Verify single component degradation in current ASTs
- Correlate with fuel cell drive cycle data

Approach (Objective 3)

Objective 3 : Development of new ASTs for GDLs, bipolar plates and interfaces

GDL Durability

- Multiple materials supplied by SGL
- Develop an AST for durability of GDL (hydrophobicity loss)
- Test #1: Water Immersion (ex-situ)
- Test #2: Vapor Water in Oxidative Conditions (Air + potential in-situ)
- Test #3: GDL Cycling (T, RH, V in-situ)

Bipolar plate Durability

- Metal and Nitride (ORNL) bipolar plates
- Test #1. Corrosion measurement with simulated fuel cell conditions
- Test #2. Corrosion measurement with applied potential

MEA Interface Durability

- Test #1: Constant current operation at $\leq$-20 ^{o}C
- Test #2: Freeze/thaw cycling of un-purged cells to – 40 ^{o}C

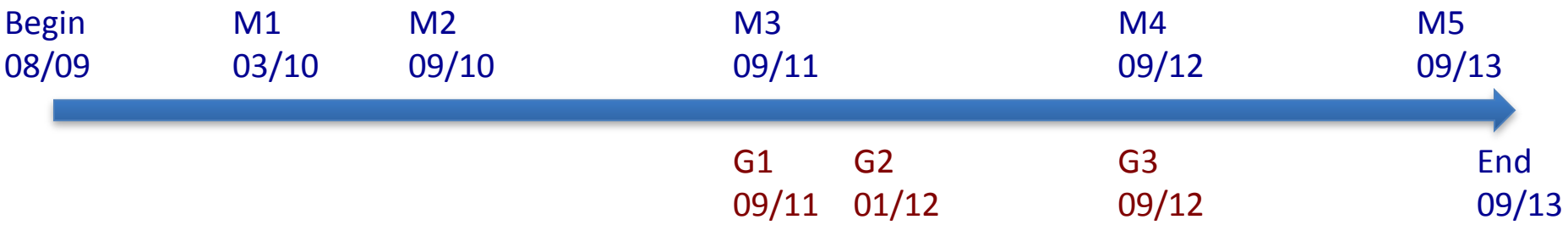
Project Timeline

Task Schedule, by Quarters (Q) with Milestones (M), Decision Points (G), Deliverables (D)

Q Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1a				M1												
1b						M2										
1c						D1		G1 M3								
1d												G2 M4				M5
1e						M6										
1f						D2				M7						
2a(i)						M8										
2a(ii)												M9				
2a(iii)																M10
2a(iv)																
2a(v)					As Needed											
2b(i – ii)		D3 M11		M12		M13				M14		M15				M16
3a								M17								
3b							M18						M19			M20
3c									G3							M21
4a																D4
4b	As needed in support of USFCC AST Durability Round Robin															

Task 1. AST Testing
Task 2: Cell life testing
Task 3: Correlation of AST to Life Data
Task 4: Development of New ASTs / Verification of Existing AST

Project Timeline



Milestones

M1 : Ballard delivers BOL Bus MEAs and initial breakdown analysis

M2 : Develop GDL AST

M3 : Complete initial AST testing

M4 : Complete Drive cycle testing with start up / shut down

M5 : Final Statistical correlation of AST and Bus data to material property and AST lifetimes to drive cycle of materials with varying lifetimes

Co-ordinate with USCar Tech Team and USFCC fuel cell council

Go/No go Decision

G1 : Stop using multiple Membranes and down-select a membrane if degradation mechanism of various initial membranes is identical

G2 : Initial Correlation of AST of life cycle and bus data – Redirect AST based on results

G3 : Go/ No go on Freeze AST for MEA interfaces

Organization

LANL
- Co-ordinate project
- Perform all ASTs and Drive cycle testing
- Materials Analysis of EOL materials

Ballard Power Systems
- Analyze Bus Data
- Deliver BOL MEAs used in Busses
- Analysis of EOL MEAs

Ion Power
Deliver MEAs with varying durability

ORNL
Deliver metal bipolar plates

LBNL
- Detailed Voltage loss break-down
- Statistical correlation of materials properties to lifetimes and AST metric loss of materials with differing durabilities

Budget

DOE Cost Share	Recipient Cost Share	TOTAL
$4,000,000	$159,790	$4,159,790
96%	4%	100%

YR 1	YR 2	YR 3	YR 4	CUMULATIVE
$1023k	$1081k	$1037k	$1020k	$4160k

	FY09-10 (Year 1)
LANL	$550k
Industrial + Univ. Partners (Ballard, Ion Power)	$239k
Other National Labs (LBNL, ORNL)	$234k
FY09-FY10 Total	$1023k

Any Inputs/Needs

Continued feedback from USCAR Tech Team on ASTs

Any additional input from Stationary fuel cell OEMs