METAL-SUPPORTED CERIA ELECTROLYTE-BASED SOFC STACK FOR SCALABLE, LOW COST, HIGH EFFICIENCY AND ROBUST STATIONARY POWER SYSTEMS

Charles Vesely – Cummins Inc
Bal Dosanjh – Ceres Power Ltd
14-June-2018
Agenda

- Cummins’ emerging SOFC strategy
- Ceres SOFC pedigree & sample data
- FE27844 Objectives
- 5kW building block fundamentals
- Acknowledgements
Cummins’ Market Segments aligned to Fuel Cells

- Mining
- Marine
- Oil & Gas
- Rail
- Defense

- Consumer
- Commercial & Industrial
- Mission Critical
- Prime Power
- Components
Cummins Evaluation Of Data Center Applications

- Evaluation of Microsoft’s vision for data centers of the future at small scale
- First phase of evaluation commenced October 2017
- Ceres and Cummins DoE demonstrator engineered for Microsoft’s operational and physical targets
World leading developer of SteelCell® low cost, non combustion power generation technology

- High efficiency distributed generation
- Lowers CO2 emissions
- Improves Air Quality
- Provides energy security
- Enables EV’s and balances renewables
- Uses existing fuel infrastructure today, e.g. Natural Gas, bio fuels and H2 ready

- Unique Fuel Cell Technology
- 50 patent families
- 144 employees
DEVELOPMENT PARTNERS

HONDA

- Honda Power Systems – several applications

NISSAN

- SOFC Stack to Extend Range of Electric Vehicles

CONFIDENTIAL PARTNER 1

- Data Centre & Commercial Scale Opportunity

CONFIDENTIAL PARTNER 2

- Commercial Scale CHP Development with aim to market launch

WEICHAI

- European-based Global OEM co-developing multi-kW prototype for multiple applications

- Strategic collaboration – buses and other China markets - targeting equity investment and JV
Version 5.0 Cell Technology Performance Uplift vs. Current Production Design

- 10.5A, 75% fuel utilization
- Simulated steam reformed natural gas
- Cells running in the same stack

V5.0 R&D cells <0.2%/kh degradation

V4.0 cells <0.3%/kh degradation
Steel Cell Stacks are robust to On-Off thermal cycles

>3600 thermal cycles

- Mean Cell Voltage (V)
- Thermal Cycles
- Fuel: H2/N2
  - dT = 350°C
  - 10 cycles/day
- Fuel: Sim/Ref
  - 7 cycles/day
Robustness to Redox cycles and E-stops demonstrates world class results

10 years life
FE27844 Objectives

- Development of:
  - Complete internal fuel reforming capability
  - Larger active cell area to achieve integrated, compact, low cost 5kW stack
  - Integrated 5 kW modular stack platform scalable from 5 – 100kW
  - 5 kW FCPS demonstrator utilizing integrated 5 kW modular stack platform

- Demonstration of:
  - 5kW FCPS performance through minimum of 1,000 hours of real-time testing:
    - Galvanostatic Degradation: <0.5%/1000hrs
    - Robustness: >10 on/off cycles; >5 emergency stops (e-stops)
  - Cost modelling to show system cost of $1,500/kW (2011 currency basis) achievable at production volumes
  - Predictive modelling using demonstration test results to show system lifetime robustness capability of:
    - Galvanostatic Degradation: <0.1%/1,000hrs
    - Robustness: >2,000 on/off cycles ; >60 e-stops
  - Partnership with PNNL for anode poison sensitivity
  - Partnership with UConn for cathode poison robustness

- Complete
- Complete
- Complete
- Complete
- Dec 2018
- Dec 2018
- In progress
- Complete
- Complete
- In progress
- In progress
Internal Reforming Proven

Simulated 100% Internal reforming

10.5A
75% Fuel utilisation
610°C

9.1A
70% FU
610°C

2.8A
Low FU
500°C

9.1A
70% FU
610°C Low O:C

Bottled methane

De sulphurised natural gas

AOGR reformate

Mean Cell Voltage (mV)

Time Under Load (khrs)
1kW Large Area Cell Prototype Short Stack Built & Tested

- Increase in active area is a factor of ~3 from the cell used in current stacks
- Fluid manifolds are designed for up to 250 cell layers in a stack
- First of a kind developed to prove concept
Larger Cell Area Roadmap

- Ceres plans a step by step approach to deliver larger area cells

Active Area [cm^2]

- **Today's Baseline V4.0 cell**
- **Optimised V4.0 cell**
- **2 x 1 Stack with Optimised V4.0 cell**
- **'Large Area' Cell**
- **2 x 1 Stack with 'Large Area' Cell**

DoE project scope

Next steps & commercialisation
DoE / Cummins Project Demonstrator

- 5kW stacks
- Data Centre compatible
- >60% electrical efficiency
- predicted

- Unit size: Depth 1.25m,
- Width 0.6m, Height 1.9m

- First Unit running Q3 2018
DoE / Cummins Project Demonstrator
Upgrade Path Engineered in from the Get-Go

- Improvement from V5.0 cell technology
- Further improvement expected with system development
Next Gen Stacks Satisfy Microsoft Durability Targets

- Average rated power efficiency through life >50%
- Average end user efficiency through life >55%
Demonstrator System - Top Level Assembly
Hot Balance of Plant – Fuel Cell Module Weldments

- PEKO Precision responsible for execution of detailed design & system build
5kW Stack

- 5kW Stacks now built and on test at CPL
Progress & Accomplishments

- Large area short stack designed, built and tested
- Internal reforming proven
- Demonstrator system detailed design successfully completed with PEKO Precision
- PEKO Precision progressing system build for testing in Q3 2018
- Poison work progressing to plan with UConn & PNNL
- Good team working dynamic
Next Steps

- Complete demonstrator system build and shakedown
- Commission demonstrator system
- Complete demonstrator system evaluation at UConn
- Conclude cathode & anode poison work
- Continue to develop pipeline of activities beyond end of DoE project
Acknowledgements

- The work summarized in this paper was funded by the U.S. Department of Energy’s Solid Oxide Fuel Cell Program.
- NETL: Patcharin Burke, Angela Bosley, Shailesh Vora, Joseph Stoffa
- PNNL: Jeffry Stevenson
- University of Connecticut: Prabhakar Singh