“Scaling Up WATT Fuel Cell’s Additive Manufacturing Process (AMP)”

connect with us
wattfuelcell.com  info@wattfuelcell.com  516.621.0047

NETL
July 14-16 2015
16th Annual Solid Oxide Fuel Cell (SOFC) Workshop
Agenda

- Overview of WATT Fuel Cell Corp
- Progress on WATT’s RIF 2013 Contract – AMP Scale Up
- WATT’s Commercial Portable Fuel Cell Technology
- Development of portable SOFC liquid-fueled systems for the US military
Overview

Who is WATT Fuel Cell?
Who is WATT Fuel Cell?

- Tubular SOFC Technology Manufacturer
- Manufacturing and Operations Plant in Mount Pleasant, PA (With offices in Port Washington and the Hampton Bays, NY)
- Marketed towards portable, military and small Distributed Grid (DG) power applications
- 13 filed patents and 23 active patent applications
- Business Model based upon Direct Customer or Strategic Partnership
- Multi-Fuel Processing Flexibility
**Technology**

- Large format - tubular
- Air electrode supported
- 37,000h of test time
  - Stable Operation
- Robust current collection
  - Reliability
- Extrusion based manufacturing
  - Can be manufactured utilizing WATT’s AMP process
- Interfaces well with WATT’s modular approach
- 40k sq. ft. of lab and office space between WATT and PEEI
- Full in-house capability
  - Synthesis of materials
  - Cell and stack production
  - Fuel processing
  - Construction of complete fuel cell systems
- State-of-the-art clean room for WATT’s AMP (printing multilayered, ceramic and cermet tubular cells)
- Full range of liquid and gaseous fuels testing capabilities
On Site - Analysis and Evaluation Packages

Analytical
- Thermo-gravimetric Analysis
- Laser Diffraction PSD
- Acoustic PSD
- Zeta Potentiometric Analysis
- B.E.T. Surface Area Analysis
- Multiple GC/MS
- Rheometry

Electrochemical Evaluation
- Impedance Spectroscopy
- Custom Fuel Cell Test Stands
- Custom Fuel Cell Stack Test Stands
- Custom Fuel Cell System Test Stands

Imaging and Detection
- SEM with EDS
- Video-based microscopes
World Class Manufacturer - WATT
Fuel Cell

**Cell**
- Additive Manufacturing Process (AMP)
- Automated Cell Production – PROCESS CONTROL
- Rapid Deployment of Modified Designs
- Capacity to support high volume batch or continuous production
- Cost Reduction ↔ Waste Reduction ↔ Recipe Flexibility ↔ Repeatability
- Alternative Geometries

**Stack**
- Expandable Modular Format
- “Seal-less Stack” allows for a range of compliant materials in assembly (i.e. Plastic Manifold)
- Cost Reduction ↔ Weight and Size Optimization ↔ Quality/Integrity
- High Volume Batch Production enables application flexibility
- The benefit of high volume production without the capital outlay typically incurred by an inflexible mass production process

**BoP and System**
- BoP is the “Foundation of the WATT Stack”
- Design for Manufacturing and Assembly (DFM&A)
- Enhanced Reliability and Performance Predictability
- Modular Design

Proprietary & Confidential
WATT’s RIF 2013 Contract

Scale-Up
RIF2013 – Limitation in the Conventional SOFC Manufacturing Process

Conventional SOFC Tubular Manufacturing

- Paste Preparation
- Extrusion
- Drying and Tube Preparation
- Burn-out and Pre-fire

Separate support formation and coating technologies require more than 300 hours of processing time!
Adapt **WATT’s** AMP commercial printing process to scale production of micro-tubular SOFC suitable for military operations.

**Tasks Include:**
- Design and fabricate optimized rack-mount cartridge
- Design and fabricate auto-loader equipment
- Design and Optimize software for integrated systems
- Evaluate the efficiency of manufacturing SOFC technology
- Design and Validate Mfg. Process to Support 2000+systems/year
- Build and deliver a TRL-5 SOFC liquid-fueled system
RIF2013 – WATT’s Solution for Manufacturing SOFCs

WATT’s patented Additive Manufacturing Technology

One technology to manufacture multiple layered ceramic tubes with varying densities

- 60% less energy consumption to create SOFC products
- Precise, repeatable, low cost deposition of layers
- Raw material waste is highly controlled (reduced by 42% to-date!)
  - Increased Recycle
- Low Cost vs. High Energy Density
- Modular Scalability
  - Decreased capital cost in machine set-up and commissioning
- Tailored structures using automated controls
- Intrinsically higher part quality
- Increased production rate by ~400%
Case Study: Improvement (performance and cycle time) of Anode Support Manufacturing Process (Cost and Efficiency Opportunities)

- Decrease cycle time (capacity)
- Improve Cell Performance
- Stable Operations
- Reduce Variability

- Physical measurements (length, wall thickness, mass, etc)
- Structure
- Cell Performance (Power, OCV)

- Variability in physical measurements
- Variability in performance
- Manufacturing process steps
- Machine Configurations
- Identify root causes

- Machine configurations
- Process Documentation
- Handling Steps
- Material Sets
- Recipes

- Process Control Cards (Machine Recipes)
- Ink Recipes
- Process Documentation
- Testing Procedures
- Process Automation

Outcome: 62.5% decrease in cycle time
6% increase in overall First Pass Yield (FPY)
7% and 9% increase in performance (Power and OCV, respectively)
Cell Performance using AMP

WATT’s AMP Cell

Conventional SOFC using Extrusion Method, with many different process steps

Increased power density. Less mass, time to manufacture, handling, energy consumed in manufacturing, and reduced Cost of Goods (COGs)
Sample Performance Metrics - WATT SOFC

1. Cell Production Rate: 3,128 per Q
2. Controllable layer thickness: 0.5 μm
3. Average OCV: 1.185 Volts
4. Low Standard Deviation, OCV
5. Max power per cell ~ 15 Watts
Demonstrated Feasibility of AMP

Open Circuit Voltage (V)/Cell

Averaged OCV measured, made with different stages of AMP

Results from feasibility study showing comparing OCVs, QC Check
Preliminary Results – 1,000+ Samples, SOFC Performance Data
Preliminary Results – 2015 SOFC Production

Watt Fuel Cell Quarterly SOFC Production Projections with Annual System Capacity Projections

Q1: 2880 (3128 Actual)
Q2: 4800
Q3: 7200
Q4: 14400

Annual SOFC System Production Rate:
- Q1: 350
- Q2: 650
- Q3: 1000
- Q4: 2050

Quarterly SOFC Production Rate:
- Q1: 4800
- Q2: 7200
- Q4: 14400

SOFC Production Projection/Target
SOFC YTD Production Actual
Projected WFC Power System Mfg. Totals (Annual)
Project Status

Summary:

- Project is 39% complete and is progressing on-schedule
- Commercial Printer 1 and 2 Tested and Commissioned
- 24/7 SOFC production commissioning in Q3 2015
- Manufacturing Cycle Time successfully reduced by ~400%
- New printing cartridge, enabling a 2x increase in capacity, is designed.
- On/under budget for each reporting period
- Power and OCV ‘pass’ metric exceeded (with stability and repeatability) by ~7% and ~9%, respectively
- Environmental controls are being developed to decrease variability
  - Implementation Q3 2015
Overview

WATT’s Commercial Portable Fuel Cell Technology
Portable Alpha System

Automated Battery Tender System Specs:
- 220W (expandable to 440W)
- 12 or 24 VDC
- < 20 lbs
- Propane fueled
- Startup time – 25 min to nominal run
- Fuel Consumption – 6 hrs per lb.
- Over 850 Wh/kg wet based on 20lb fuel tank
Portable Alpha System

**Functionality:**
- Capable of charging dead battery bank
- Maintains charge level of bank, switching on automatically as State of Charge (SOC) drops to preset threshold
- System warns user and shuts down safely if battery disconnected
- Targeted to serve:
  - Marine
  - RV
  - Emergency Backup
  - Remote Power
Reforming - LOGISTICS FUELS

Modified NETL catalyst stable on liquid fuels
Tested > 1000 hrs
Increased thermal stability
Increased fuel processing capacity
Reduced coke formation
Higher tolerance to redox
Improved light-off of NETL catalyst (consistent after cycling)
CONCLUSION

- Commissioning of State-of-the-Art Manufacturing Facility is Complete
  - Stable Operations
  - Process Optimization
- Scale-up Stage 1 Successful
  - High Volume Batch Production
  - Advanced Manufacturing Process Tested and Implemented
- Scale-up Stage 2 Begins Q3 2015
  - Increased capacity
    - >2x per production run
  - Continuous (24/7 capability) Operation and Production Pilot

WATT has designed a modular manufacturing process. Stage 3 of scale up is an expansion of the modular system.

Each module is designed to optimize demand capability while reducing inventories.