DOE Hydrogen Program

# 2007 DOE Hydrogen Program

## Subfreezing Start/Stop Protocol for an Advanced Metallic Open-Flowfield Fuel Cell Stack

Nuvera Fuel Cells

16th of May 2007

**Project ID #**
**FCP21**

NUVERA

# Overview

## Timeline

- Start - May 2007
- Finish - April 2010
- Project not started yet

## Budget

- Total project funding
  - DOE ≈ 4,970 k$
  - Partners ≈ 2,124 k$
- Funding for FY07
  - 529 k$

## Barriers

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A. Water Transport within the Stack.

B. Start-up and Shut-down Time and Energy/Transient Operation

### Targets

| Characteristic | Units | 2003 Status | 2005 Status | 2010 | 2015 |
|---|---|---|---|---|---|
| Cold start-up time to 50% of rated power | | | | | |
| @-20°C ambient temp | sec | 120 | 20 | 30 | 30 |
| @+20°C ambient temp | sec | 60 | <10 | 5 | 5 |
| Start up and shut down energy[1] | | | | | |
| from -20°C ambient temp | MJ | na | 7.5 | 5 | 5 |
| from +20°C ambient temp | MJ | na | na | 1 | 1 |

## Partners

- University of Delaware
- SGL Carbon
- W.L. Gore & Associates

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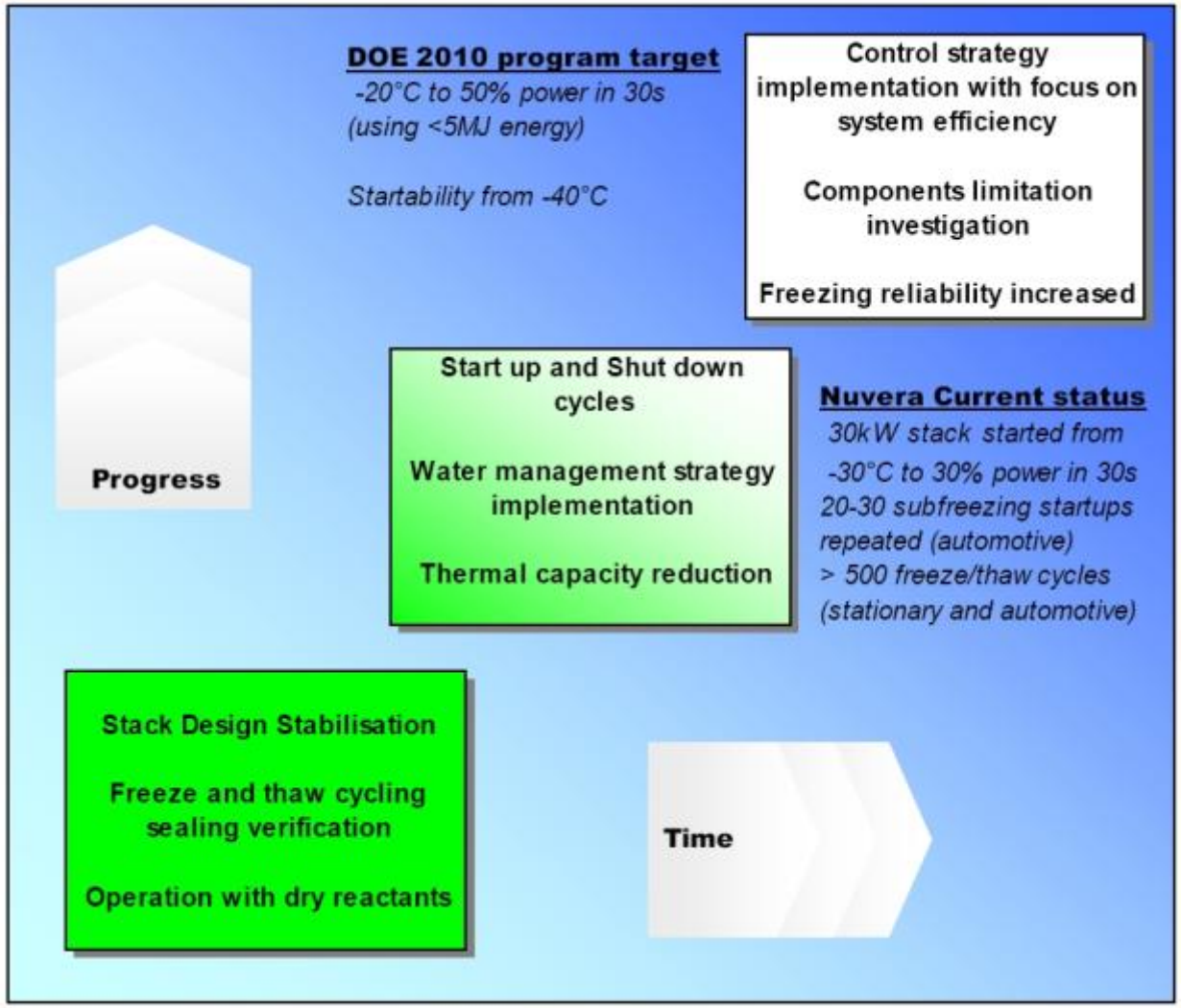
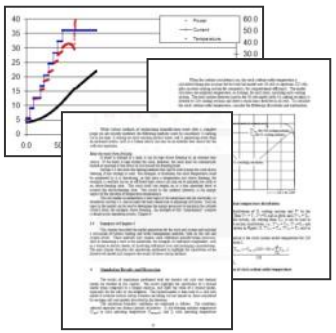
# Objectives



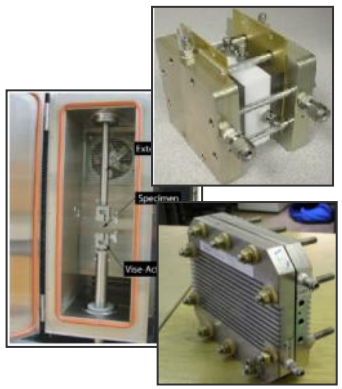
# Approach

**INVESTIGATION** → **SELECTION** → **QUALIFICATION** → **VALIDATION**

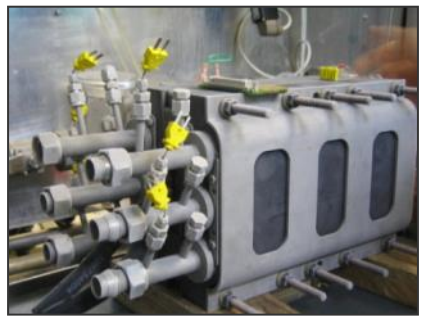
- Literature investigation (constraints, procedures, materials)
- Status of the art data collection (tests, strategies, materials)
- Test protocol definition (MEA, GDL, Stack Architecture)
- Dynamic thermo electric model construction



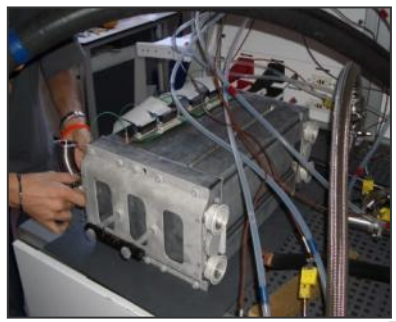
- Ex-situ & in-situ tests on components and procedures
- Startup/shutdown strategies selection
- Compatible materials selection (1st version)
- Model tuning through experimental tests



- Tests on new components (performances, endurance, postmortem)
- Improvements evaluation (tests and model)
- Components optimization through iterations



- Construction of a stack using final components
- Testing on DOE required conditions
- Repeated cold startups



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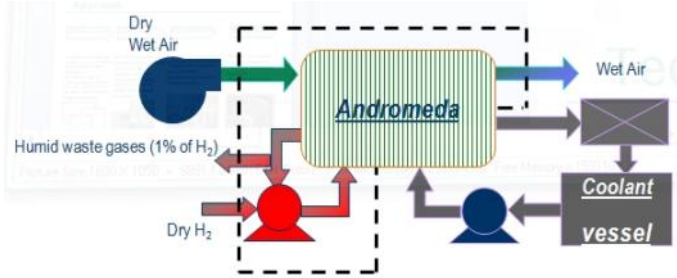
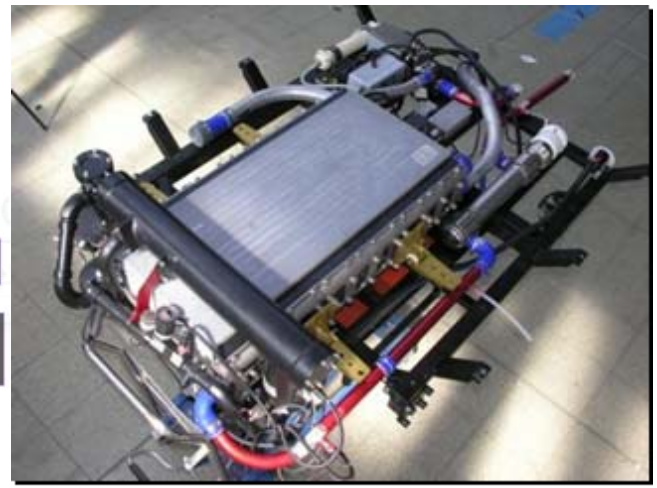
# Approach

## ANDROMEDA STACK

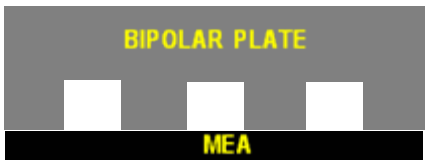
### Open flow field structure

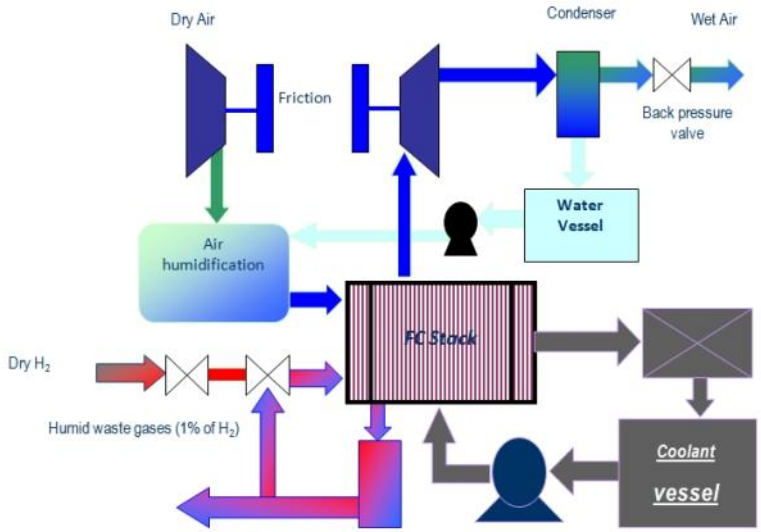

### System with no external humidification



## COMPETITORS STACK

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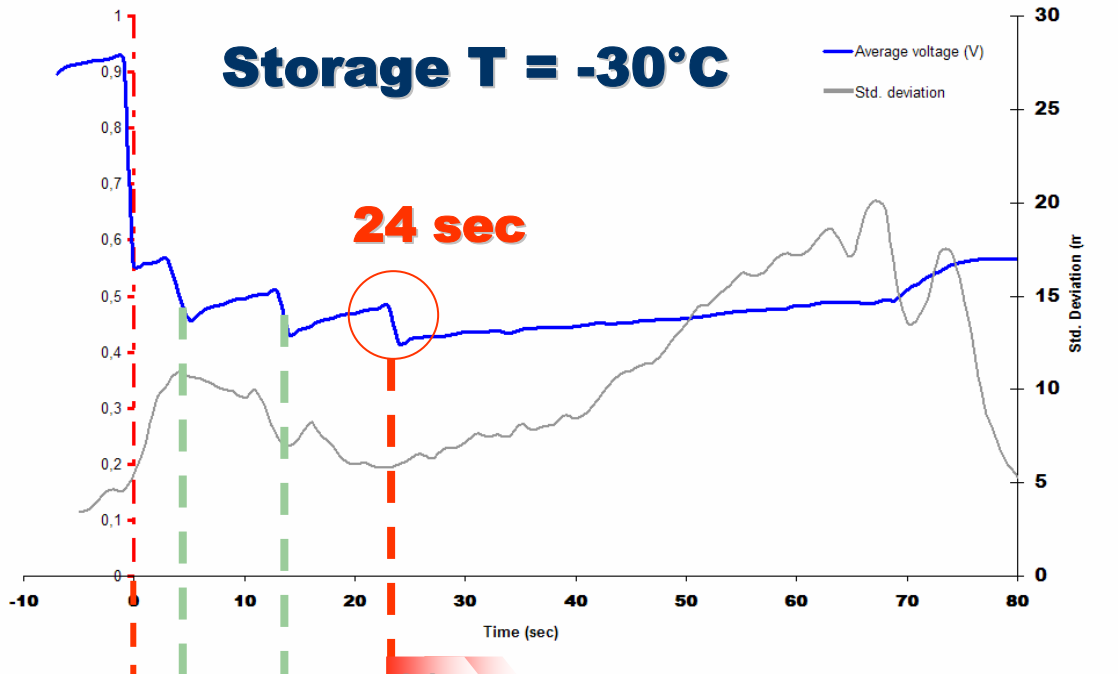
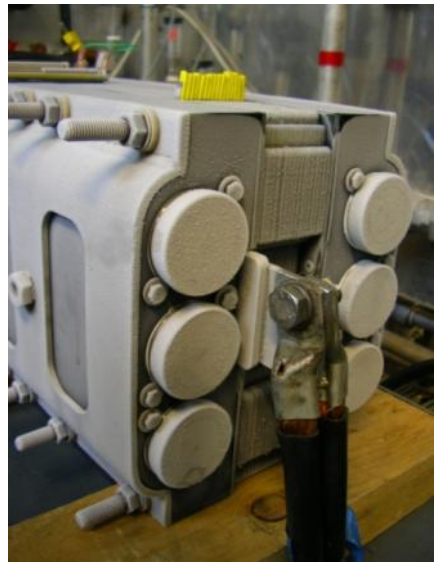
# Technical Accomplishments/Progress

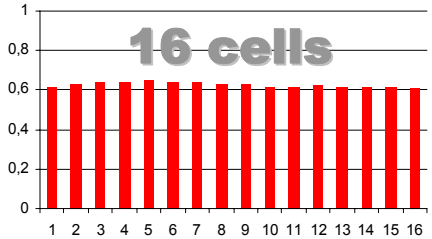
## NUVERA PAST PROGRAM: Tests on small scale stack focused on procedure



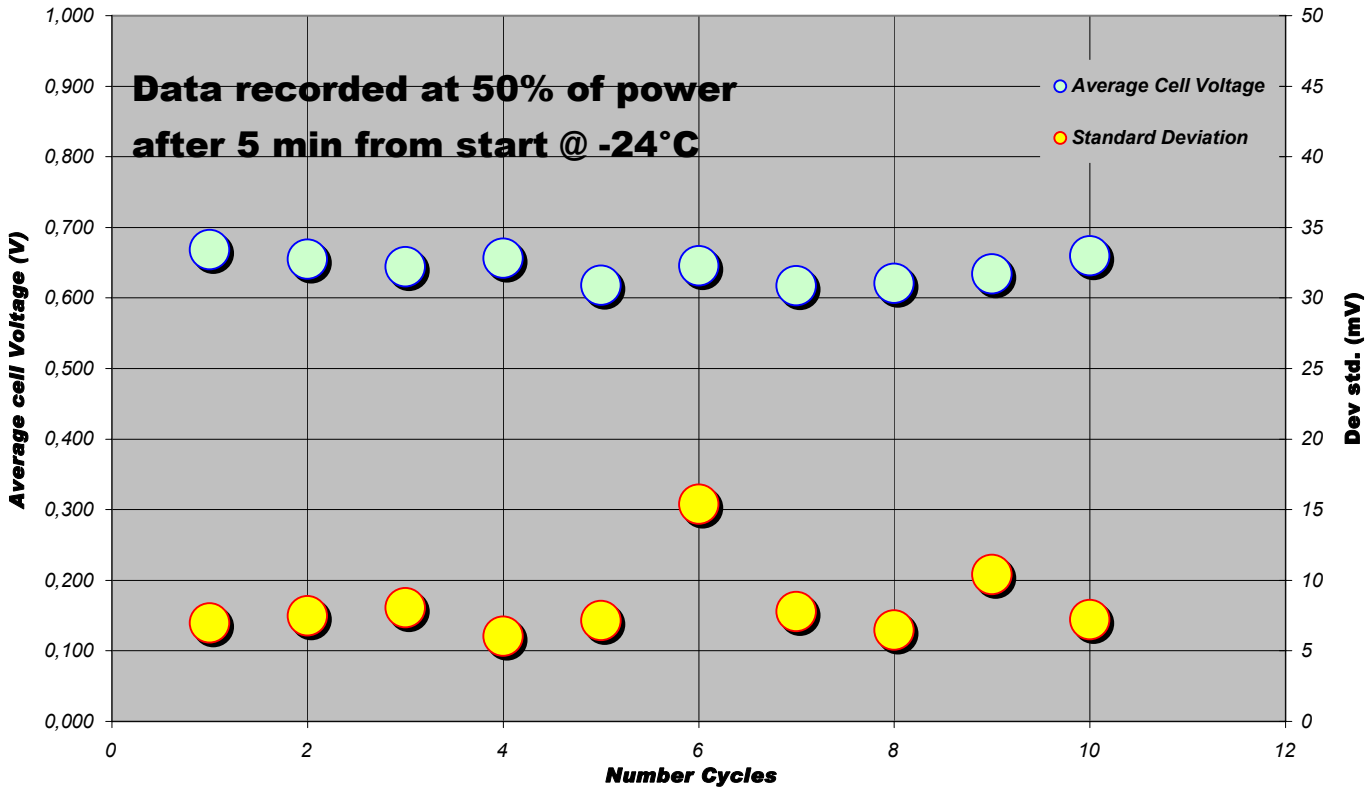



# Technical Accomplishments/Progress

## NUVERA PAST PROGRAM: Performance decay rate evaluation

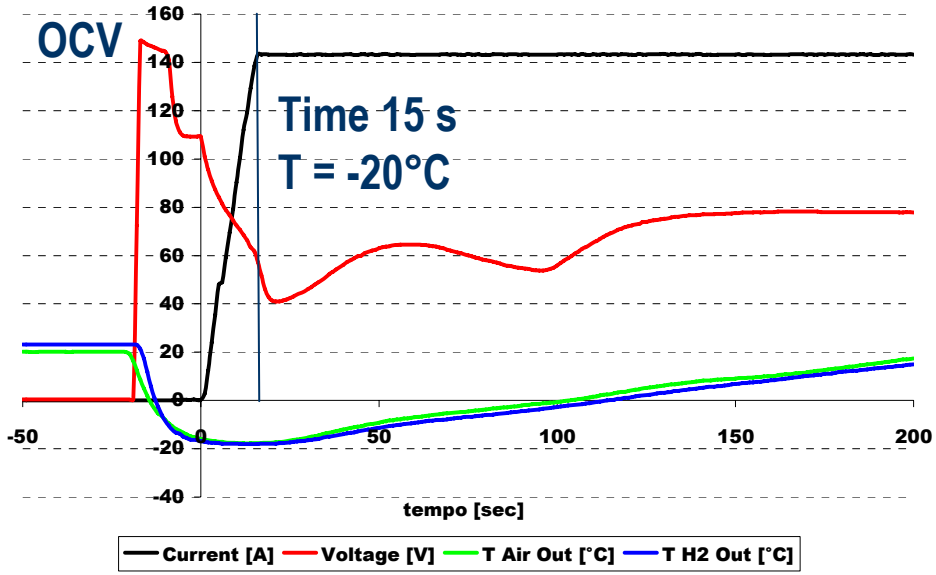



- High cell stability over start up cycles
- No decay rate recorded after 10 cycles



# Technical Accomplishments/Progress

## NUVERA PAST PROGRAM: 27kW Stack Time to ½ Power at -20°C

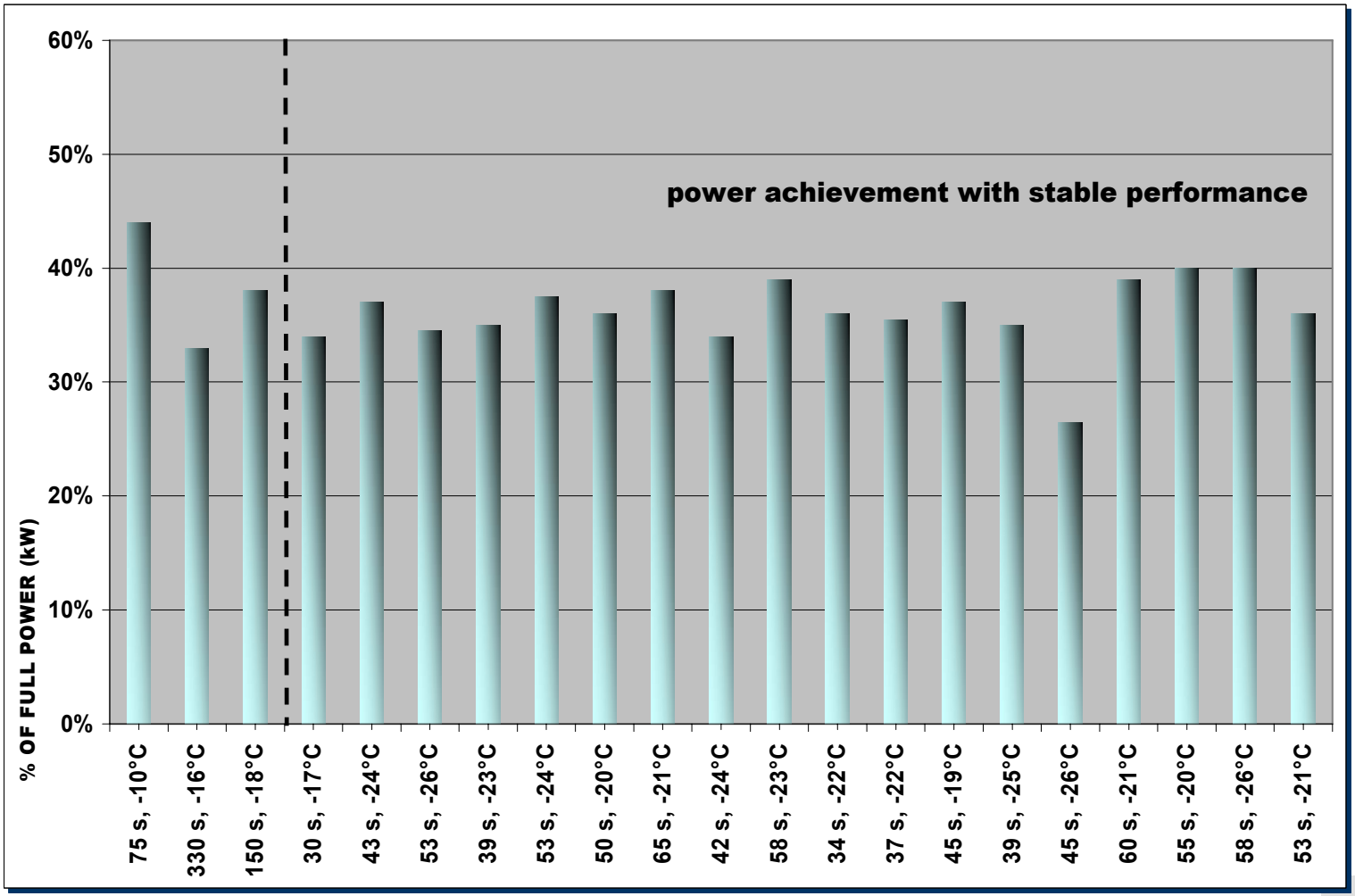



- Cold start up tests have been carried out on 128 cells stack (27 kW) in multiple test (40 starts) showing progress in getting the process reliable

- The cold start up procedure have been studied in compliance with the capability of the stack, and allows the stack to be started at temperature down to -30°C.

# Technical Accomplishments/Progress

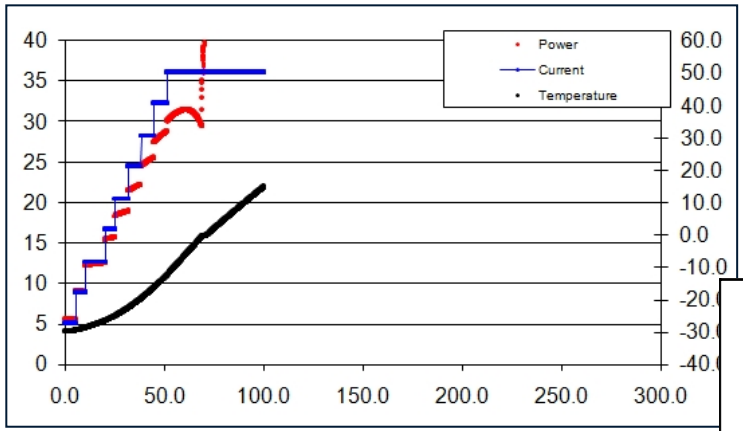
## NUVERA PAST PROGRAM: Repeated cycles on 27kW Stack



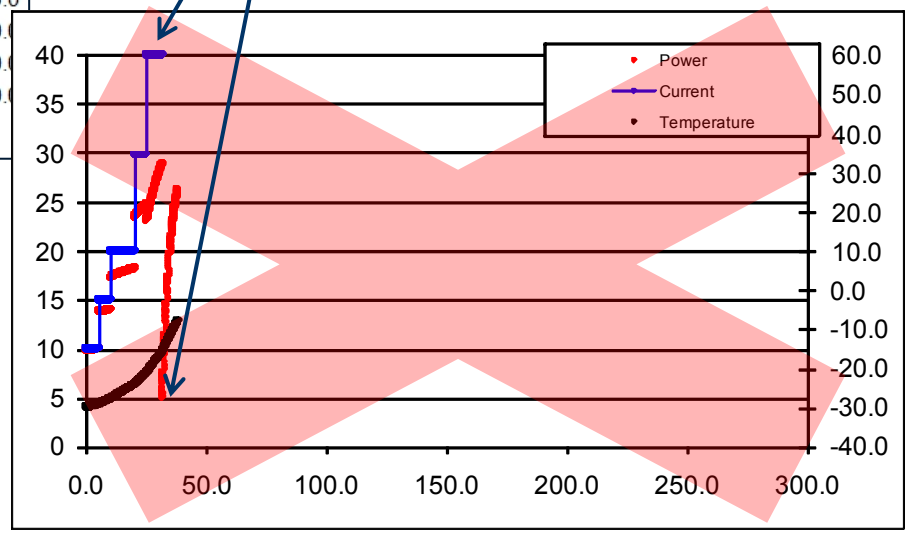
# Technical Accomplishments/Progress

## DOE PREPARATORY ACTIVITIES:

**Draft of dynamic model to make forecasts on stack response to different startup strategies**




**Current ramp too fast brings to ice formation and blocking with following drops of power produced**

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# Future work - FY 2007

**SELECTION**

- **Literature investigation**

List constraints typical of Automotive context, collect cold start procedures, assess materials behavior in freezing conditions.

- **Status of the art data collection**

Study test results in past Nuvera program including strategies tried with relative degree of success and energy associated, collect data from partners about GDLs and MEAs, determine possible modifications to improve low T tolerance and performances.

- **Test protocol definition**

Define protocol for freezing tests and water content estimation over MEAs and GDLs, ex-situ mechanical tests, MEA conductivity tests.

- **Dynamic thermo electric model construction**

Build a model to evaluate thermal mass of the stack as function of water content to determine stack response to startup procedures.
Build a model to evaluate the water evacuation efficiency of different techniques.
Preliminary tests on thermal exchange and water evacuation on small scale stack or single cell fixture to tune model parameters.

# Future work – FY 2008

**INVESTIGATION**

- **Ex-situ & in-situ tests on components and procedures**

**Component evaluation: decay under repeated freeze-thaw cycles, water transport analysis, loss of mechanical properties due freezing, MEA conductivity as function of T and RH.**
**Procedures evaluation: tests on visualization cells to estimate water distribution and evacuation, mass balance tecniques to understand water distribution among components.**
**Startup tests with current ramps and external heating techniques.**

**Startup/shutdown strategies selection**

**Identification of best procedure coming out from tests cross-referenced with model previsions and constraint analysis.**

- **Compatible materials selection (1st version)**

**Selection of promising materials considering tests, compatibility with procedure, future possible modifications.**

- **Models tuning through experimental tests**

**Models adjustment through iterations to match experimental results and evaluate peculiar materials parameters.**