# Characterization of single cell PEFC performances using US/Japan/EU procedures and hardwares

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# Outline

- **Introduction**
- **Procedures and hardwares investigated**
- **General Protocol**
- **Comparison of the results**
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# Introduction

- **PEFC components are presently**
  - **sold by a large number of component manufacturers,**
  - **bought by a large number of stack manufacturers who assemble components**
  - **continuously worldwide investigated by research laboratories.**

↳ **large variety of single cell tests performed by the different players**

- **However, for the promotion of component businesses worldwide, the different published results must be shared, in order to verify consistent and repeatable methods to test the performance of single cells.**

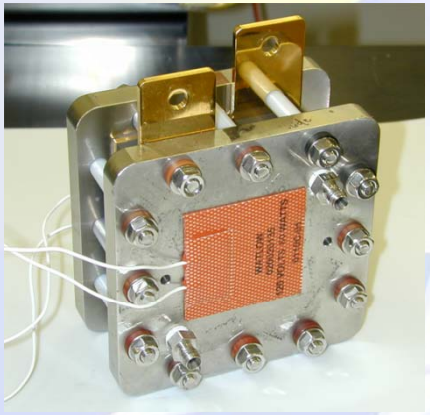
- **Documents related to PEFC single cell test methods have been individually provided by USA (USFCC), Japan (JARI) and EU (FCTestNET)**

↳ **Are the performance results comparable**
**and if not why and what has to be improved?**

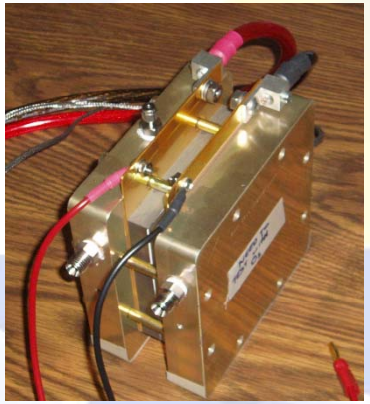
# Procedures & hardwares investigated

- **Partners involved in frame of FCTesQA (6th PCRD)**
  - CEA (EU), DOE/LANL (USA), JARI (Japan)
- **Selection of the objects to be tested**
  - CEA, LANL, JARI "standard hardware" including "standard" MEA (CEA/LANL)

CEA – 25 cm²
1 channel serpentine



JARI – 25 cm²
1 channel serpentine



LANL – 50 cm²
1 channel serpentine

- **Testing procedures**
  - FCTesNet procedure / Test Module PEFC SC 5-2, version 1.2
  - USFCC/DOE/LANL procedure / Doc 05-014B2. Release date July 13, 2006
  - JARI procedure / Document JARI-SSCTP1-005, revised January 12, 2007

# General protocol

- **Nominal Operating conditions**

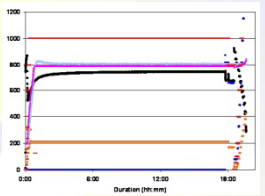
  - Back Pressure: 1 barG (relative) or 15 PSIG
  - Stoechiometry $H_2$= 1.2 and at constant flow for i<0.1 A/cm² (value corresponding to i=0.1 A/cm²)
  - Stoechiometry air= 2.0 and at constant flow for i<0.1 A/cm² (value corresponding to i=0.1 A/cm²)
  - Relative humidity $H_2$: 100%
  - Relative humidity air: 100%
  - Temperatures: 80°C and 60°C

# General protocol

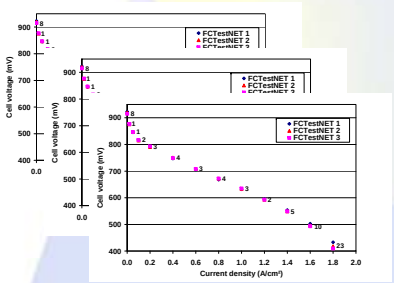
- **Sequence for each i-V curve procedure**

1. Assembly following the given procedure with a new MEA

2. Break-in at 80°C following the given procedure



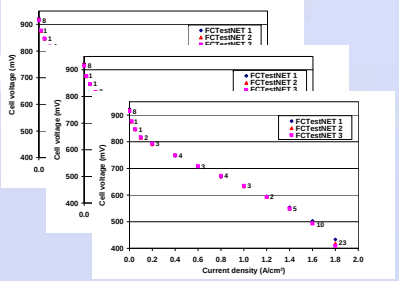
3. 3 i-V curves at 80°C (repeatability), check the stability by $\Delta V$ < +/- 5 mV over the last 15 min




4. Decrease of the temperature to 60°C

5. Check of the achievement of stationary conditions by $\Delta V$ < +/- 5 mV over the last 1 hour

6. 3 i-V curves at 60°C (repeatability) check the stability by $\Delta V$ < +/- 5 mV over the last 15 min




7. Disassemble of the cell

# General protocol

## Testing sequence

### 1. Effect of break-in procedures

break-in: FCTestNet → i-V curves FCTestNet, USFCC/DOE/LANL, JARI procedures

break-in: FCTestNet → i-V curves FCTestNet

break-in: JARI → i-V curves JARI

break-in: USFCC → i-V curves USFCC

### 2. Effect of hardwares

break-in: FCTesNet → i-V curves FCTestNet

break-in: JARI → i-V curves JARI

### 3. Effect of test station and operator

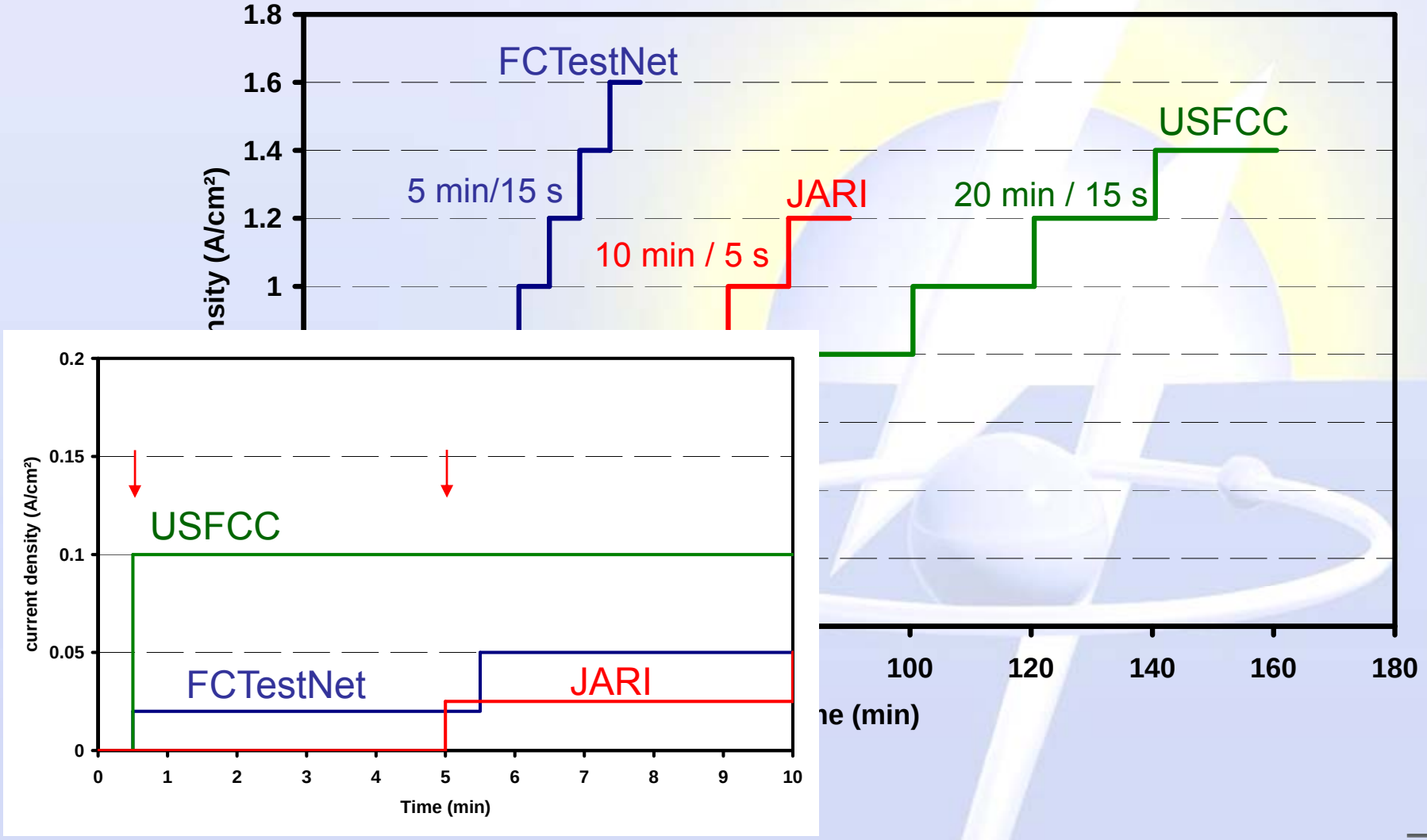
break-in: FCTesNet → i-V curves FCTestNet

break-in: JARI → i-V curves JARI

break-in: USFCC → i-V curves USFCC

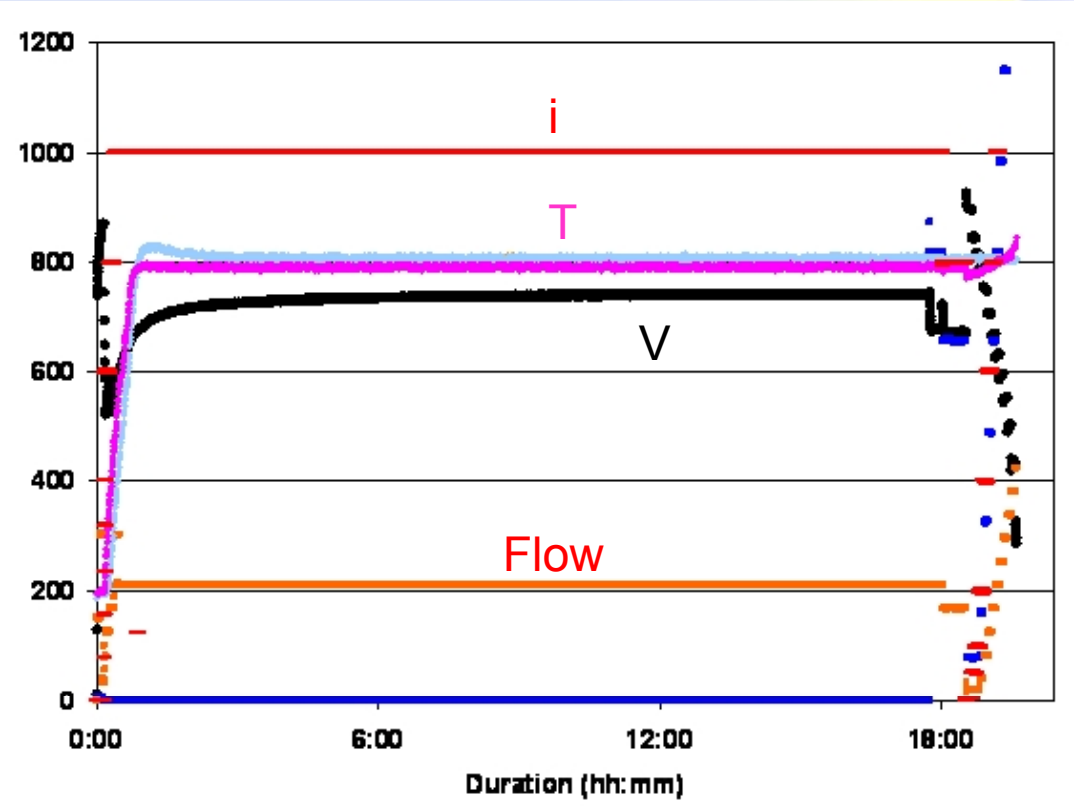
# General protocol

## i-V curve procedures



# Results: Effect of break-in procedures

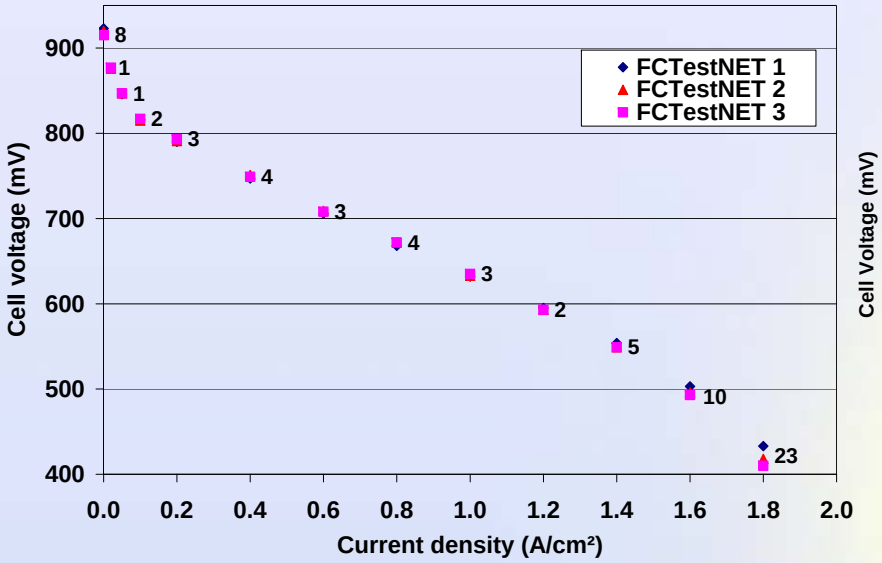
- **FCTestNet Break-in**
  - $H_2/O_2$ ; Back Pressure: 3 barG ; $T_{cell}$ = 80°C ; RH $H_2/O_2$ = 100%/100%
  - St $H_2$ = 1.2 ; St $O_2$ = 1.5
  - Increase of i until 1 A/cm² keeping Cell Voltage V > 500 mV
  - Stabilization during 18h (overnight) at i = 1 A/cm²

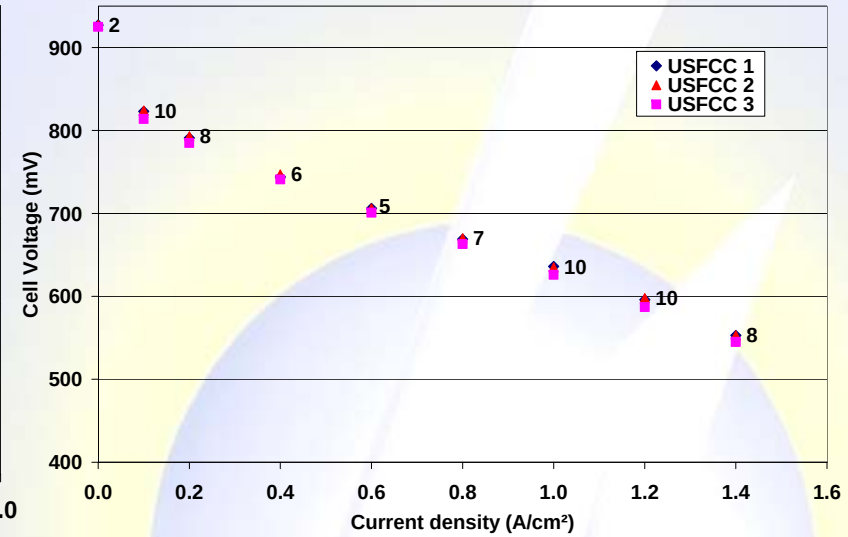


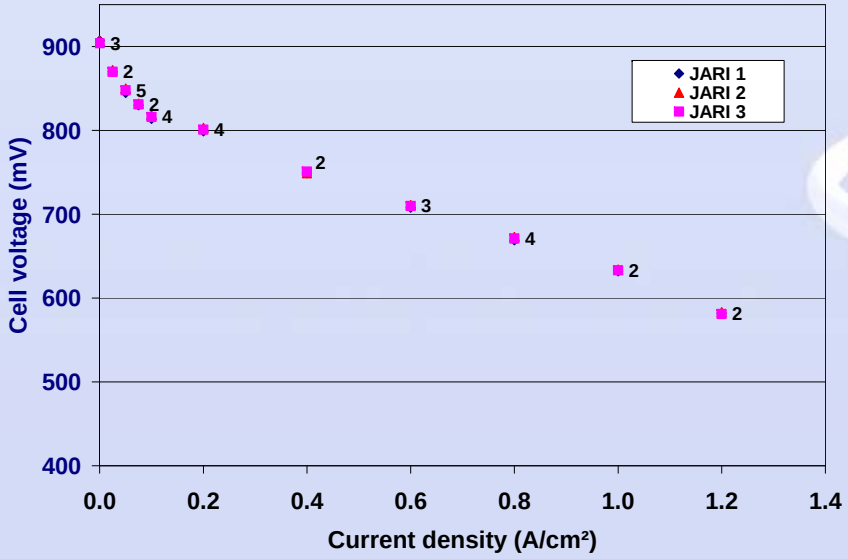

over the last 6 hours

MEA 1 V=740 ± 0.9 mV
MEA 2 V=742 ± 2.1 mV
MEA 3 V=732 ± 1.1 mV

# Results: Effect of break-in procedures i-V curves @ 80°C



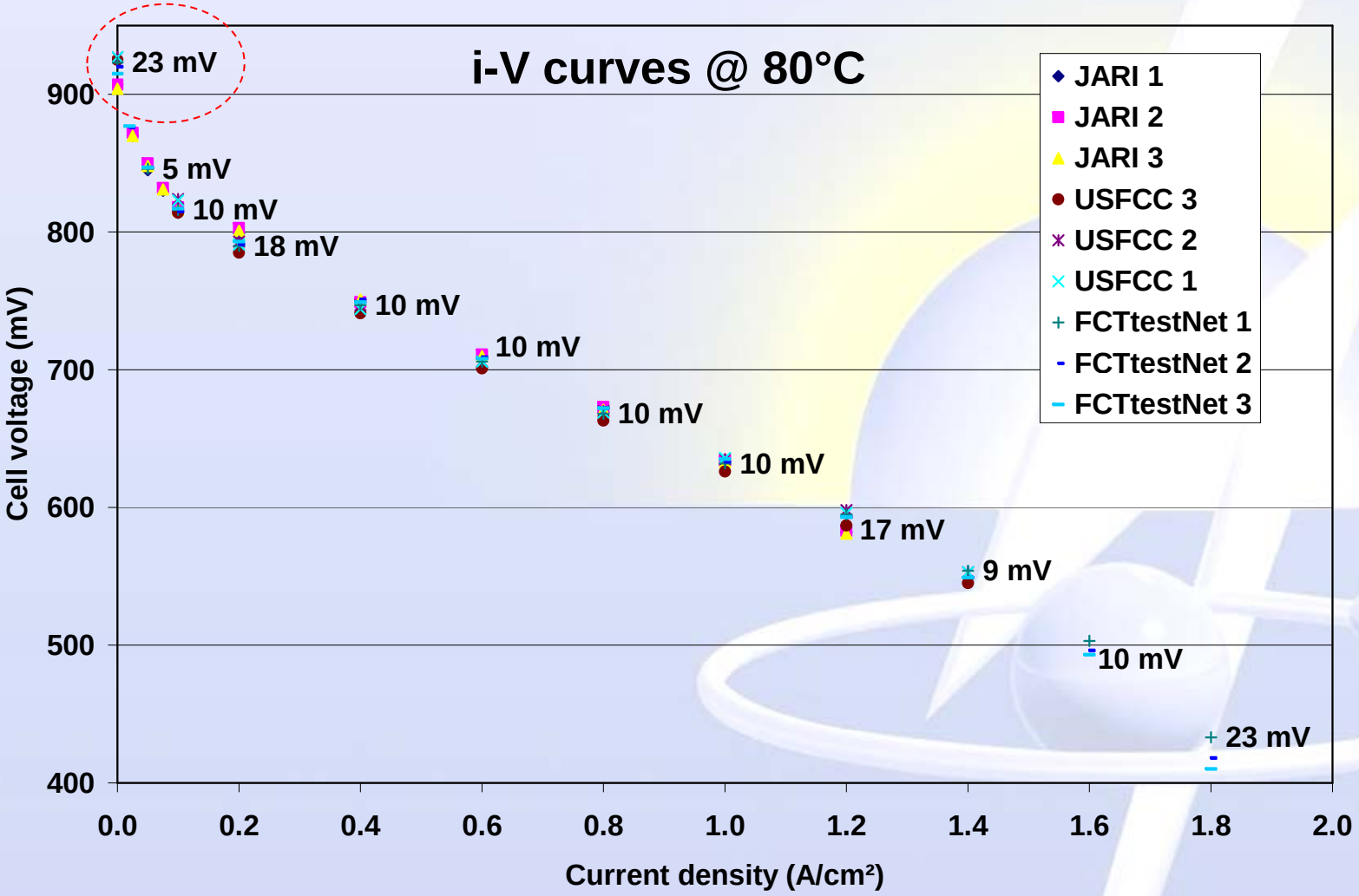




0.02 A/cm² to 1 A/cm²:

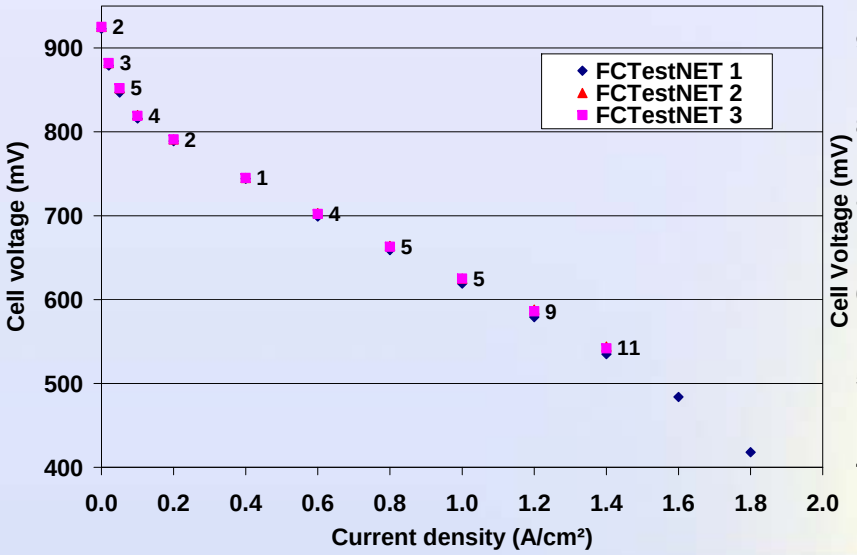
Good repeatability (x3)
for each procedure: $\Delta V \leq 10$ mV

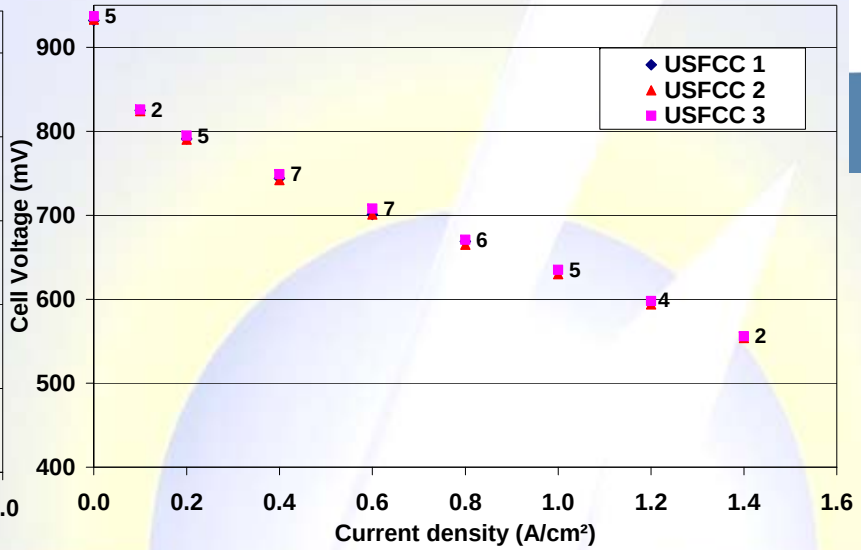
# Results: Effect of break-in procedures

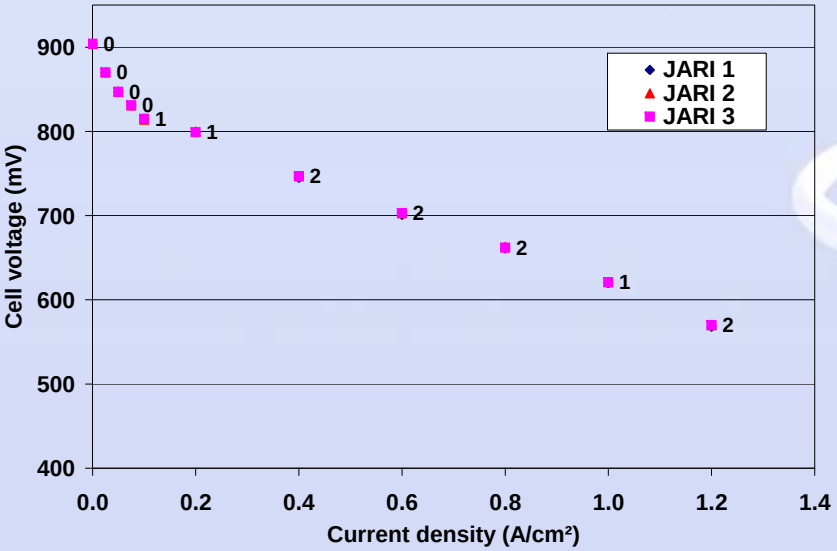



0.02 A/cm² to 1 A/cm²: Comparable results using the 3 procedures: $\Delta V \leq 18$ mV

# Results: Effect of break-in procedures i-V curves @ 60°C



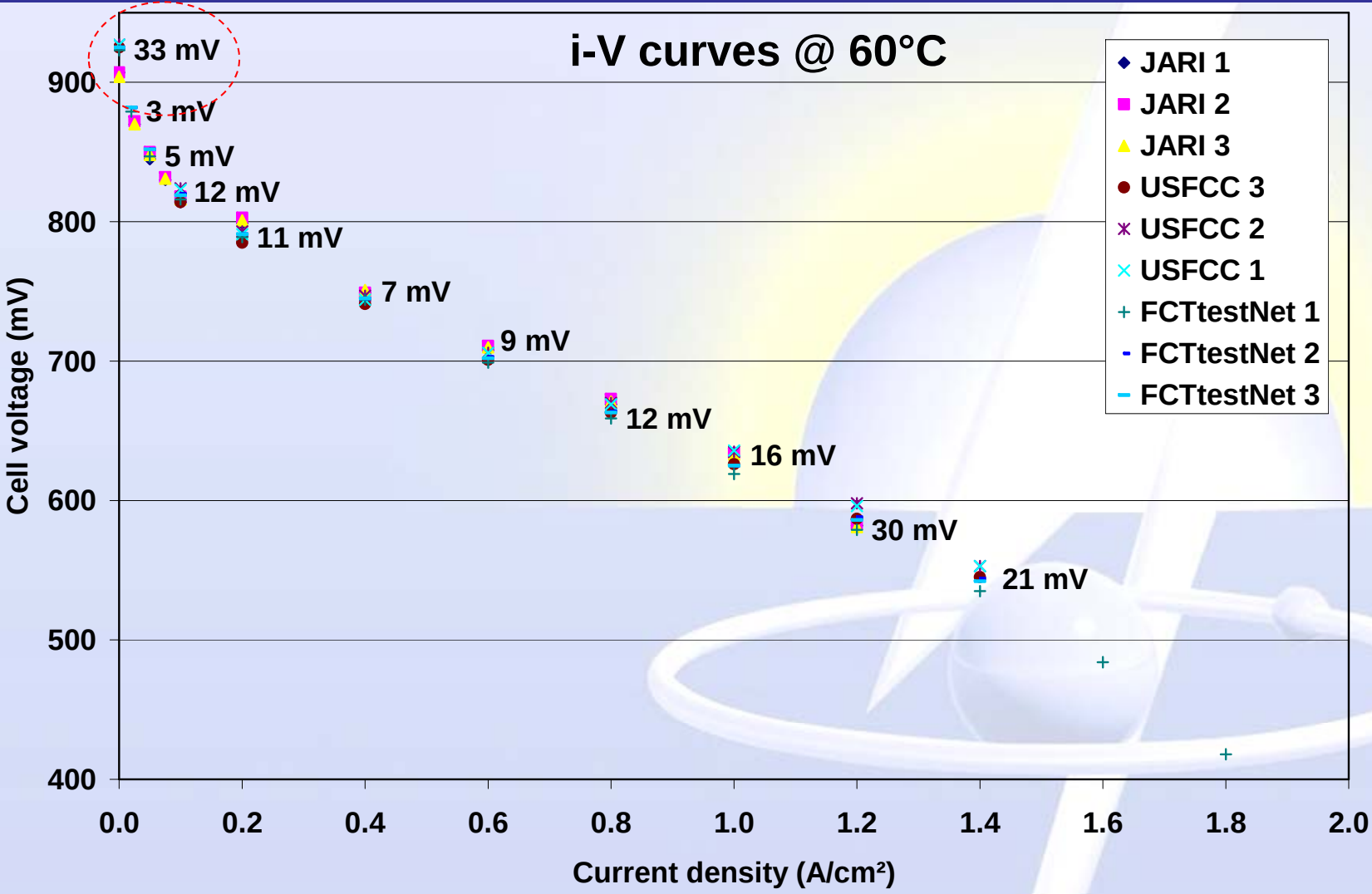




0.02 A/cm² to 1 A/cm²:

Good repeatability (x3)
for each procedure: $\Delta V \leq 7$ mV

# Results: Effect of break-in procedures



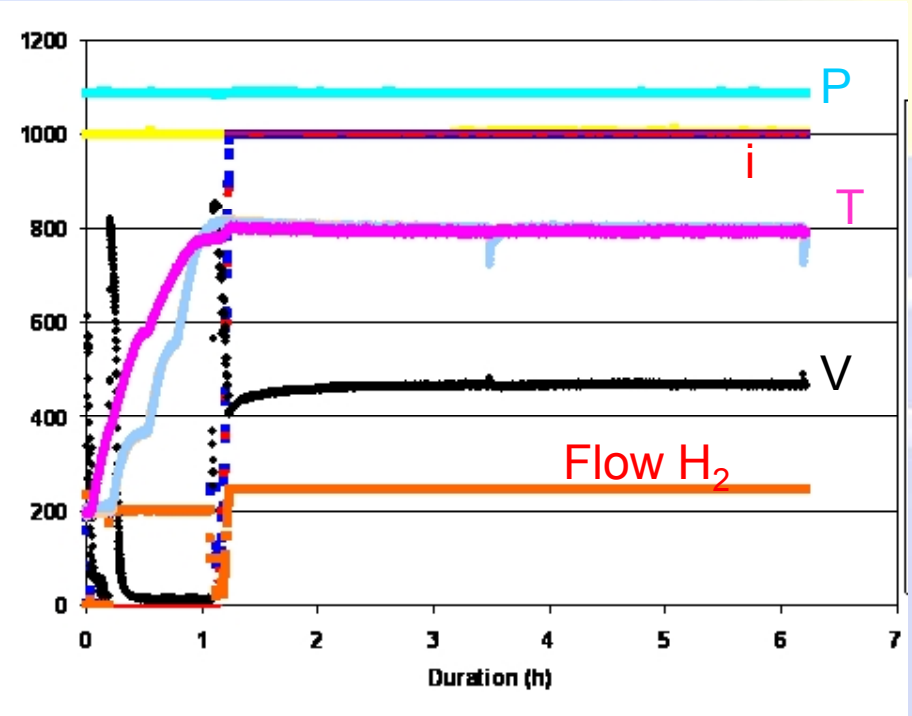

0.02 A/cm² to 1 A/cm²: Comparable results using the 3 procedures: $\Delta V \leq 16$ mV

# Results: Effect of break-in procedures

- Using the same break-in protocol (FCTestNet)
- Good repeatability (x3) for each procedure at 80 and 60°C
  - FCTestNet break-in 80°C: $\Delta V \leq 10$ mV; 60°C: $\Delta V \leq 7$ mV
- Comparable results using the same MEA
  - FCTestNet break-in 80°C: $\Delta V \leq 18$ mV; 60°C: $\Delta V \leq 16$ mV
- Main difference at OCV
  - Dwell time of 30s (FCTestNet, USFCC) vs. 5 min (JARI).

# Results: Effect of break-in procedures

- **JARI Break-in**
  - Dry $N_2$ during 1min 22s at 200 cc/min on both sides
  - Heating of the cell without gases and of the bubblers
  - $H_2$/Air ; Back Pressure: $P_{atm}$ ; $T_{cell}$ = 80°C ; RH $H_2$/Air = 100%/100%
  - St $H_2$ = 1.4 ; St Air = 5.5
  - Increase of i until 1 A/cm² and stabilization

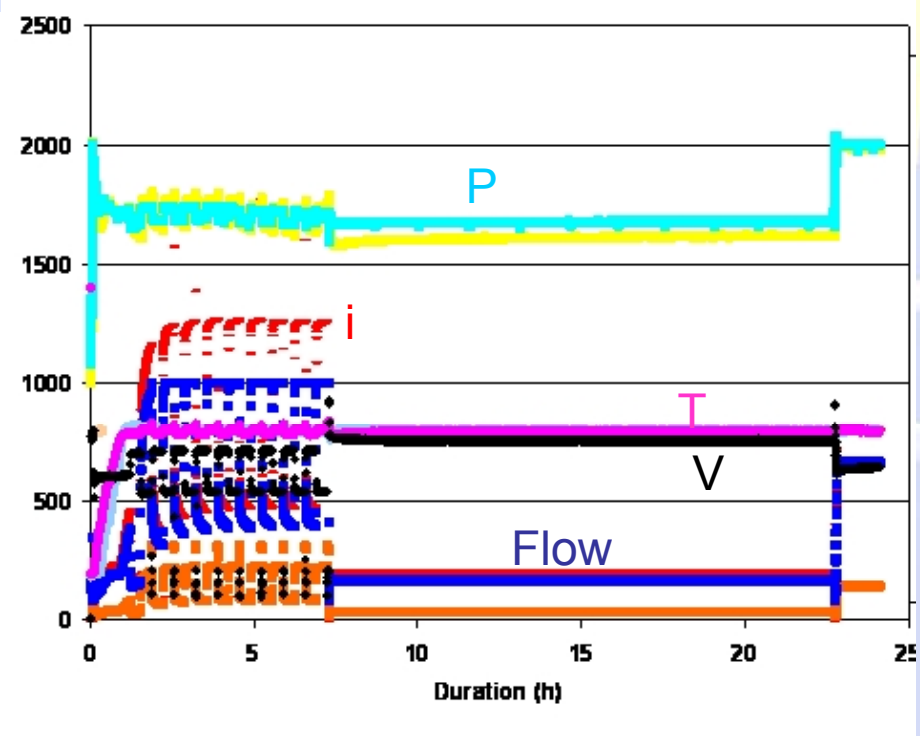



over the last hour

MEA 1 V=469 ± 1.2 mV

# Results: Effect of break-in procedures

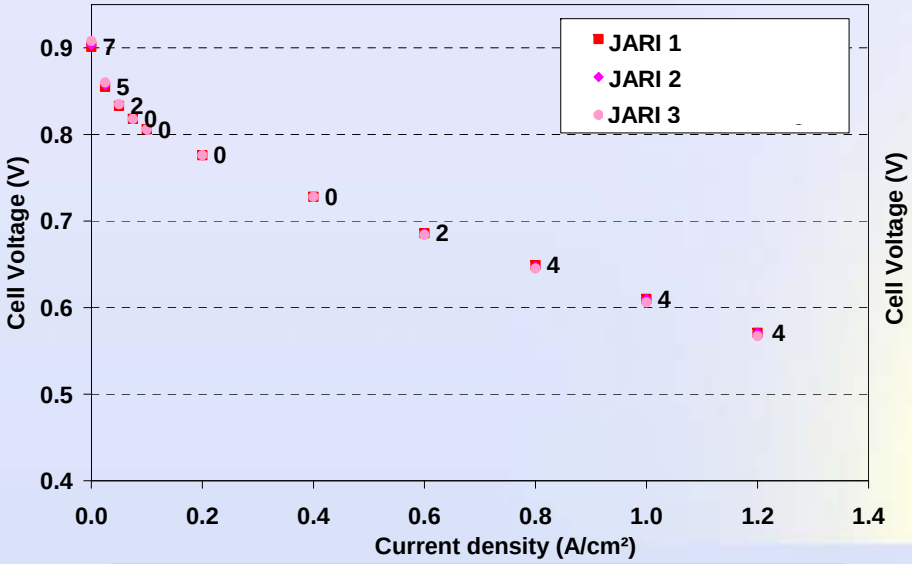
- **USFCC Break-in**
  - $H_2$/air ; Back Pressure: 1.7 barG ; $T_{cell}$ = 80°C ; RH $H_2$/Air = 100%/100%
  - St $H_2$ = 1.2 ; St Air = 1.5
  - Decrease of V until keeping Cell Voltage = 600 mV for 1h
  - Voltage cycles during 6 h: 0.5/0.7V with 20 min dwell time
  - Stabilization during 18h (overnight) at i = 0.2 A/cm² (5A)

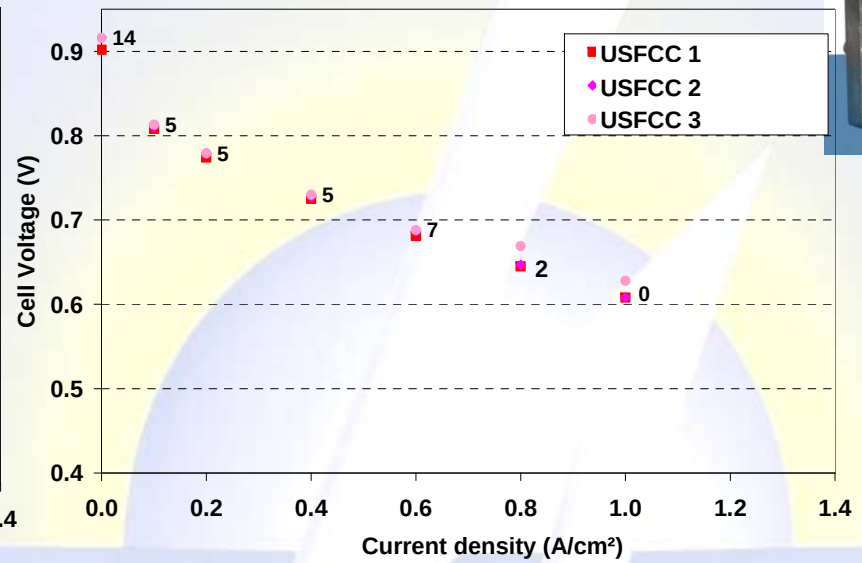


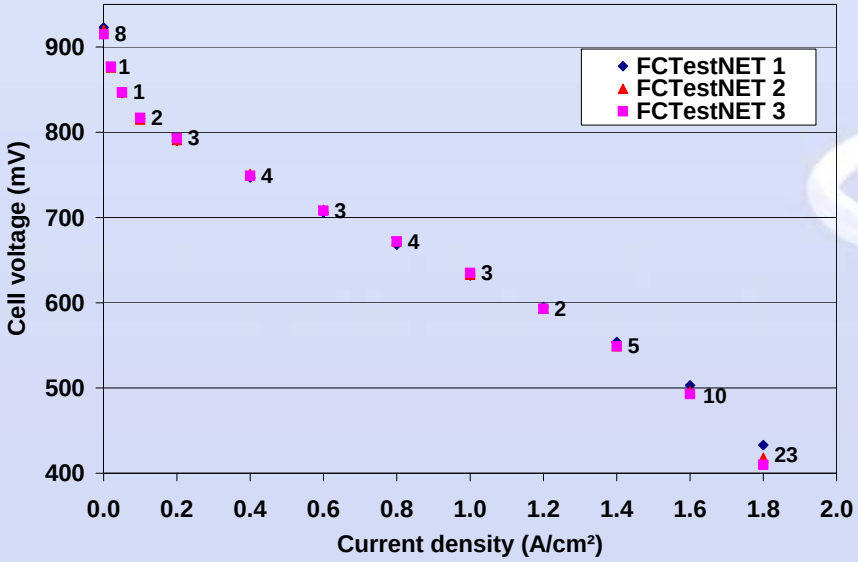

over the last hour

MEA 1 V=755 ± 1.5 mV

# Results: Effect of break-in procedures i-V curves @ 80°C



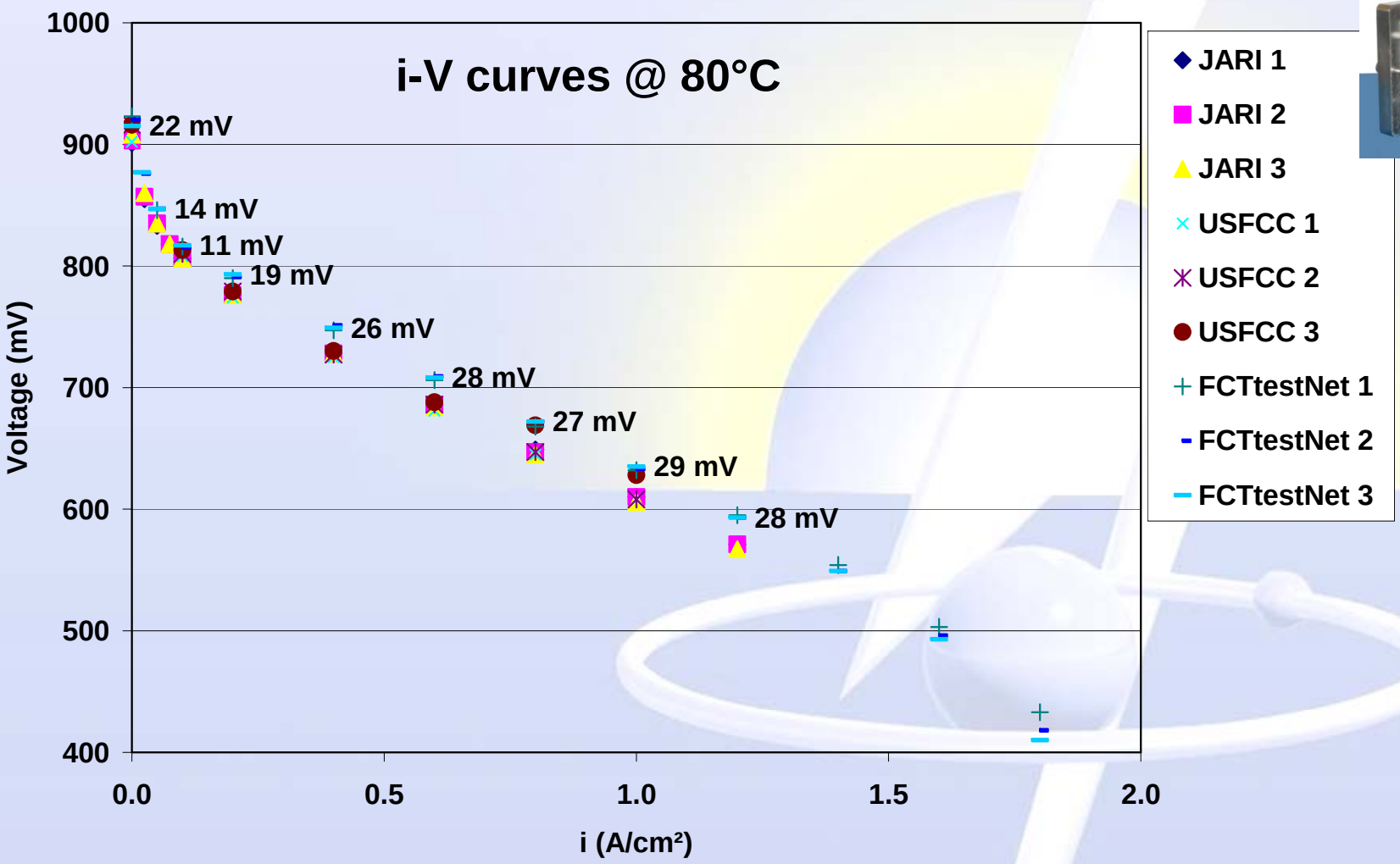




0.02 A/cm² to 1 A/cm²:

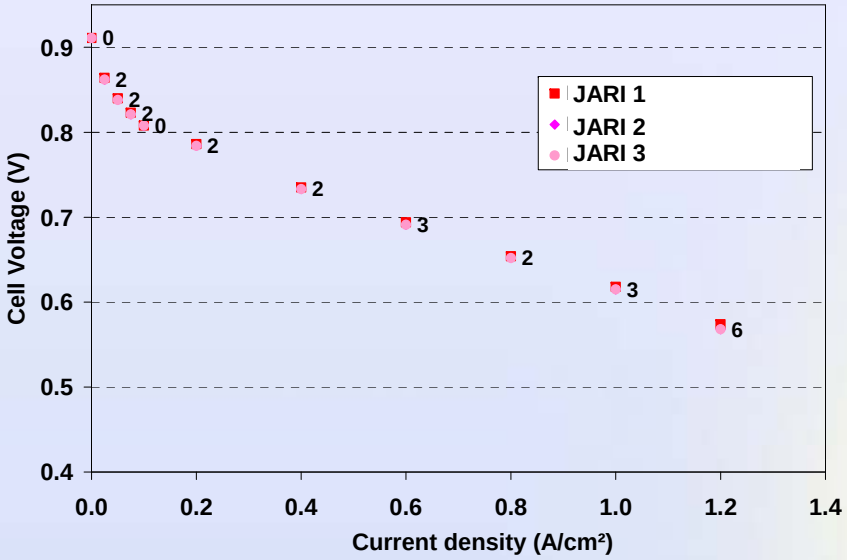
Good repeatability (x3) for each procedure: $\Delta V \leq 7$ mV

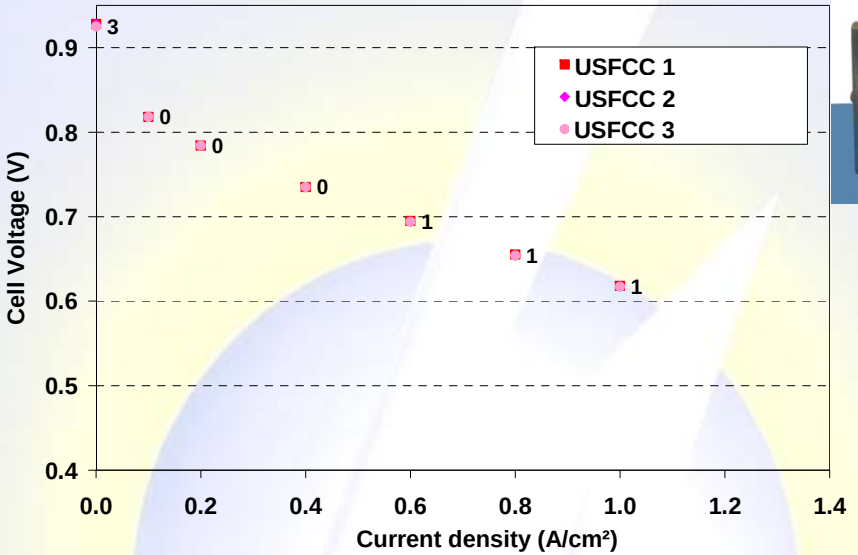
# Results: Effect of break-in procedures

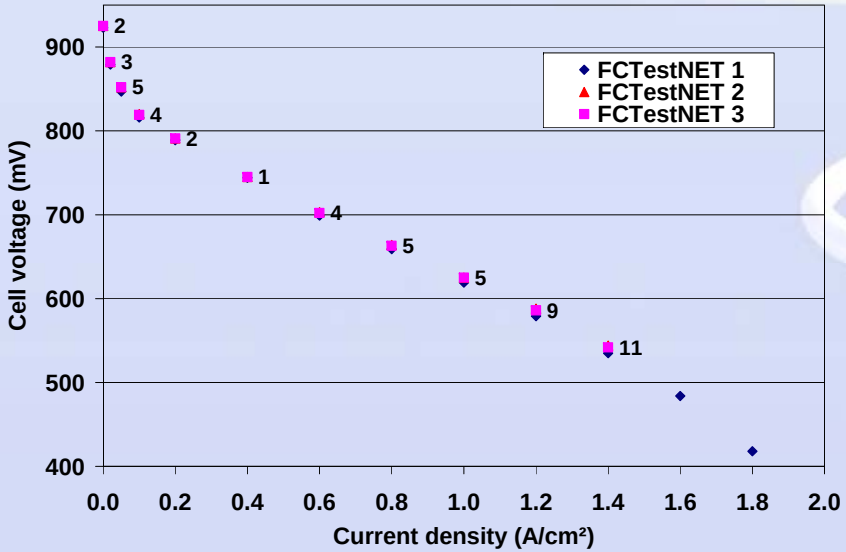



0.02 A/cm² to 1 A/cm²: Comparable results using the 3 procedures: $\Delta V \leq 29$ mV

# Results: Effect of break-in procedures i-V curves @ 60°C



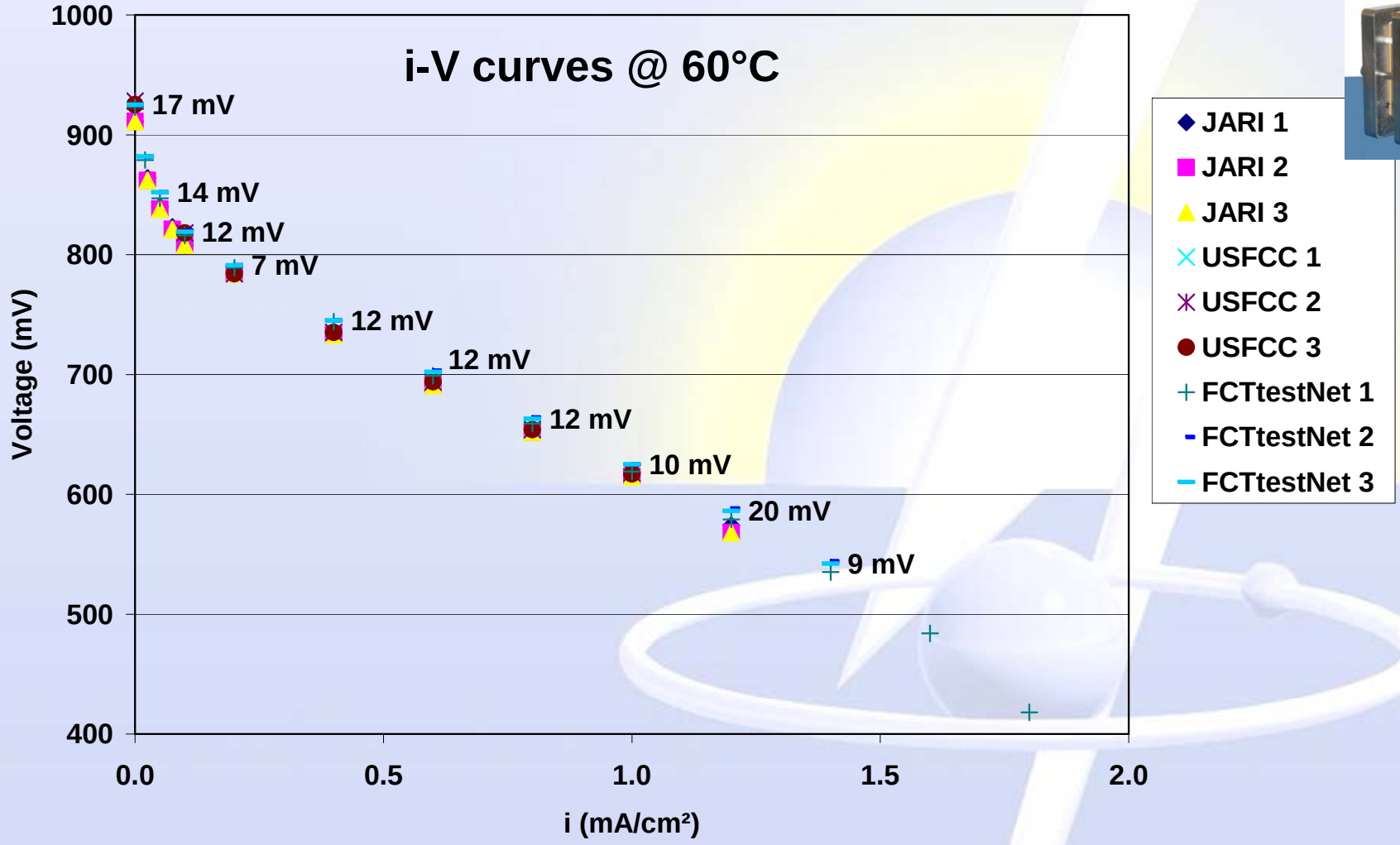




0.02 A/cm² to 1 A/cm²:

Good repeatability (x3) for each procedure: $\Delta V \leq 5$ mV

# Results: Effect of break-in procedures




0.02 A/cm² to 1 A/cm²: Comparable results using the 3 procedures: $\Delta V \leq 14$ mV

# Results: Effect of break-in procedures

- Good repeatability (x3) for each procedure at 80 and 60°C regardless the break-in procedure using the same MEA
  - FCTestNet break-in 80°C: $\Delta V \leq 10$ mV; 60°C: $\Delta V \leq 7$ mV
  - Standard break-in 80°C: $\Delta V \leq 7$ mV; 60°C: $\Delta V \leq 5$ mV
- Comparable results using the same MEA regardless the break-in procedure
  - FCTestNet break-in 80°C: $\Delta V \leq 18$ mV; 60°C: $\Delta V \leq 16$ mV
  - Standard break-in 80°C: $\Delta V \leq 29$ mV; 60°C: $\Delta V \leq 14$ mV
- Main difference at OCV
  - Dwell time of 30s (FCTestNet, USFCC) vs. 5 min (JARI).

# General protocol

## Testing sequence

### 1. Effect of break-in procedures

break-in: FCTesNet → i-V curves FCTestNet, USFCC/DOE/LANL and JARI procedures

break-in: FCTesNet → i-V curves FCTestNet

break-in: JARI → i-V curves JARI

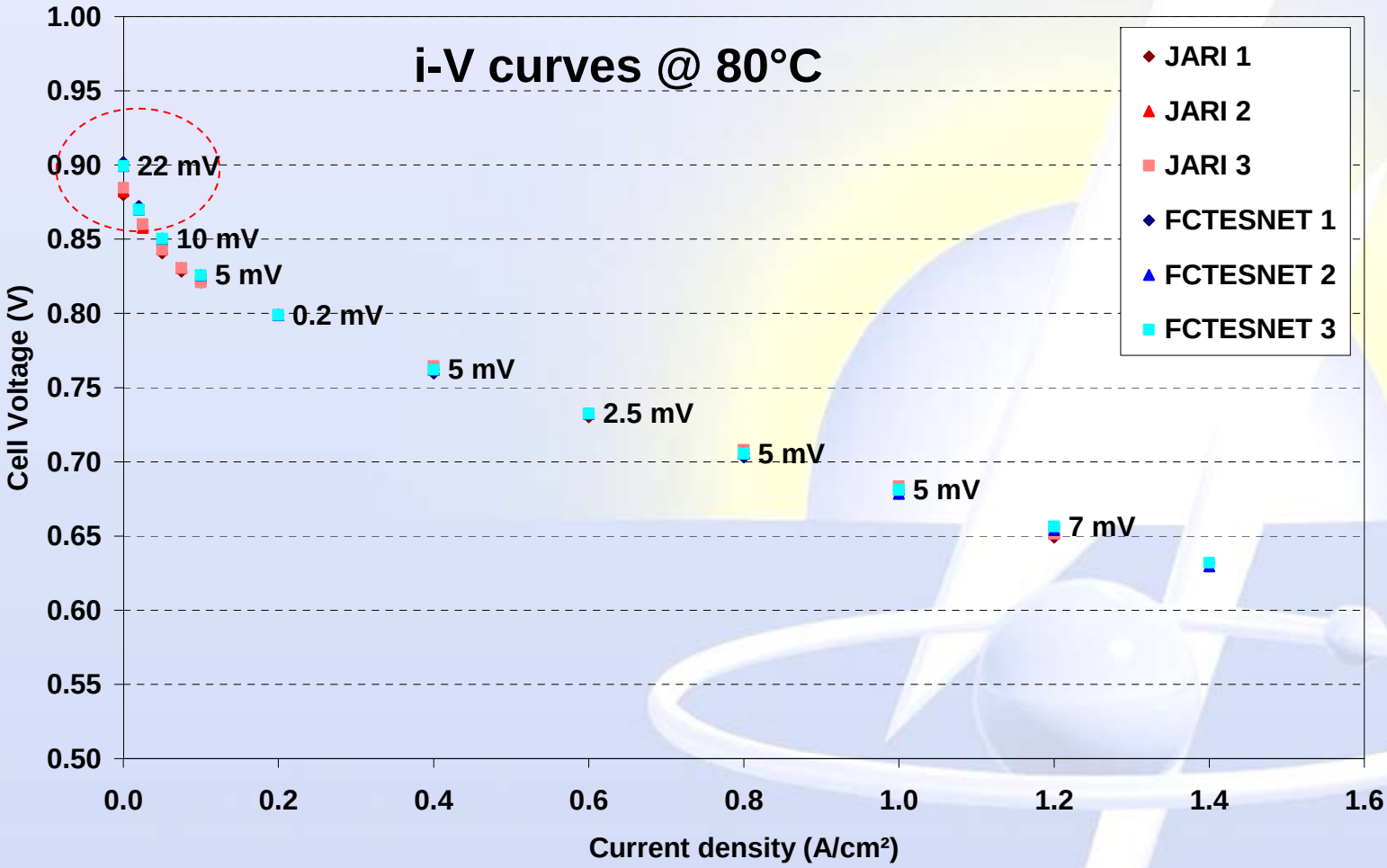
break-in: USFCC → i-V curves USFCC

### 2. Effect of hardwares

break-in: FCTesNet → i-V curves FCTestNet

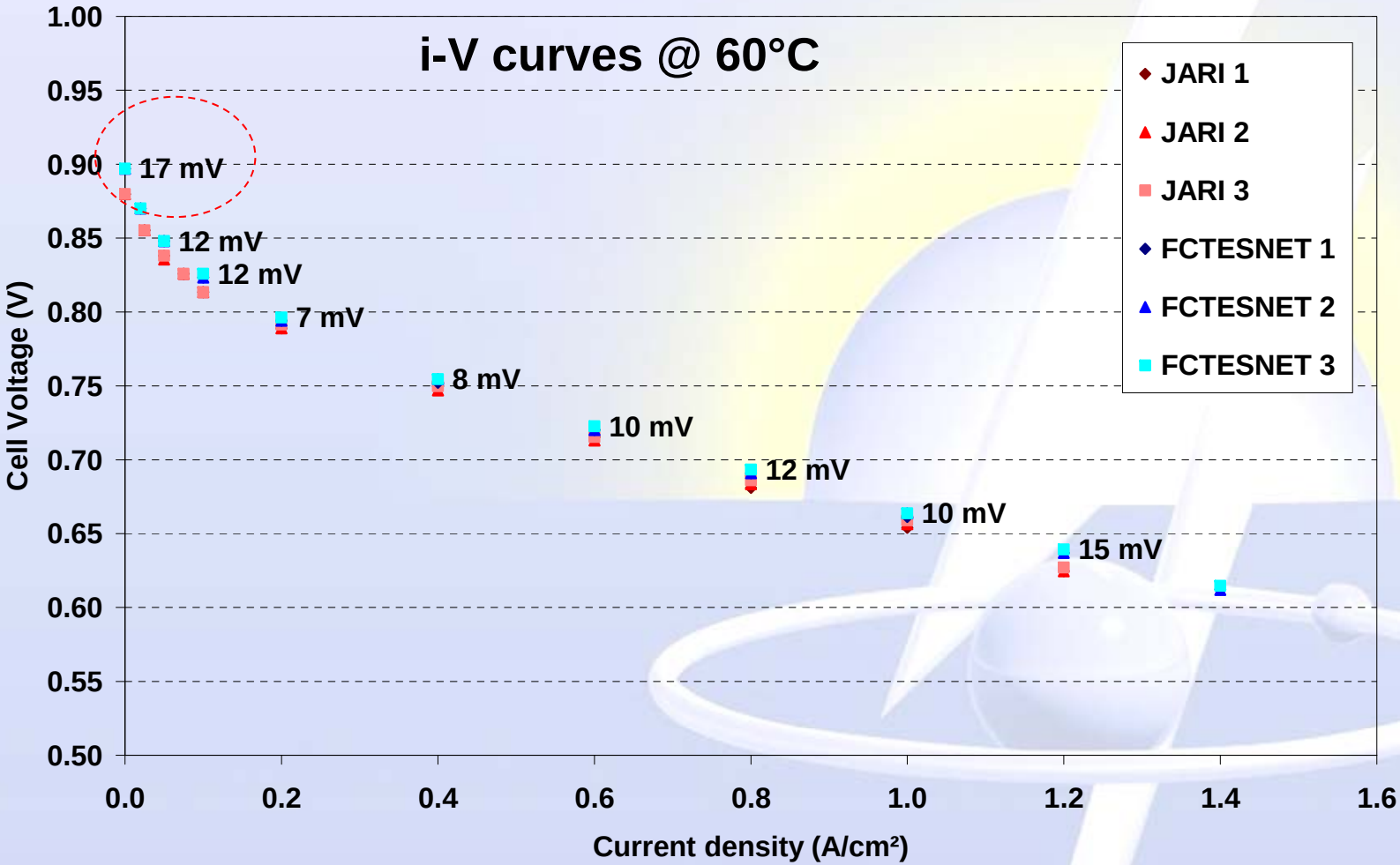
break-in: JARI → i-V curves JARI

# Results: Effect of hardware




0.02 A/cm² to 1 A/cm²: Very good repeatability (x3) for each procedure: $\Delta V \leq 2.6$ mV
Comparable results using the 2 procedures: $\Delta V \leq 10$ mV
$\Delta V_{max}$ @ OCV

# Results: Effect of hardware




0.02 A/cm² to 1 A/cm²: Good repeatability (x3) for each procedure: $\Delta V \leq 5$ mV
Comparable results using the 2 procedures: $\Delta V \leq 12$ mV
$\Delta V_{max}$ @ OCV

# General protocol

## Testing sequence

### 1. Effect of break-in procedures

break-in: FCTesNet → i-V curves FCTestNet, USFCC/DOE/LANL and JARI procedures

break-in: FCTesNet → i-V curves FCTestNet

break-in: JARI → i-V curves JARI

break-in: USFCC → i-V curves USFCC

### 2. Effect of hardwares

break-in: FCTesNet → i-V curves FCTestNet

break-in: JARI → i-V curves JARI

### 3. Effect of test station and operator

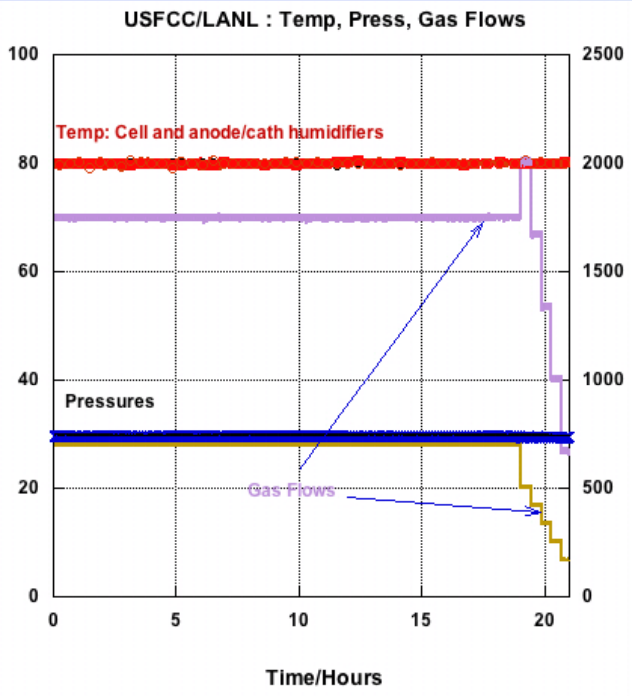
break-in: FCTesNet → i-V curves FCTestNet

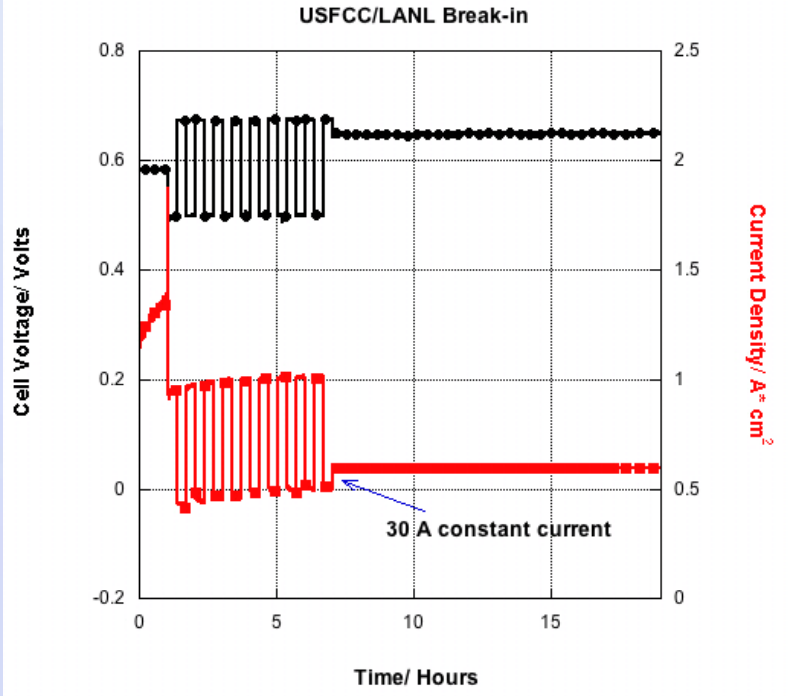
break-in: JARI → i-V curves JARI

break-in: USFCC → i-V curves USFCC

# Results: Effect of break-in procedures

- **USFCC/DOE/LANL Break-in**
  - $H_2$/air ; Back Pressure: 25 psig (sea-level); $T_{cell}$ = 80° C ; $H_2$/Air @ 100%RH
  - Constant Flows $H_2$/Air: 696/1740 sccm
  - Constant Cell Voltage = 600 mV for 1 hour (note: conditions are reached)
  - Voltage cycles during 6 h: 0.5/0.7V with 20 min dwell time
  - Stabilization during ~12h (overnight) at i = 0.6 A/cm² (30A)

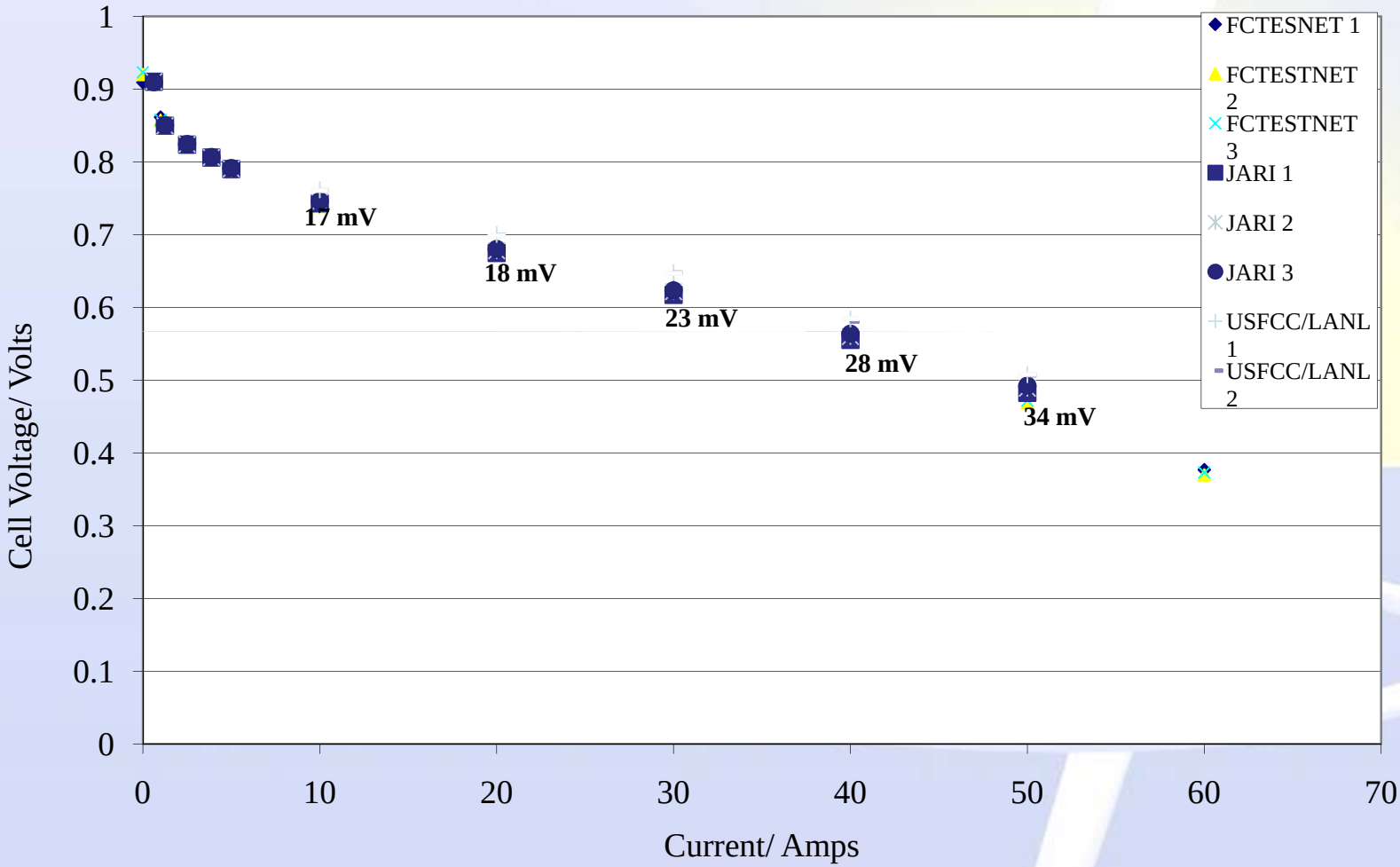



over the last hour
V= 0.649 ± 1.5 mV

# Results: Effect of of break-in procedures

## i-V curves @ 80°C

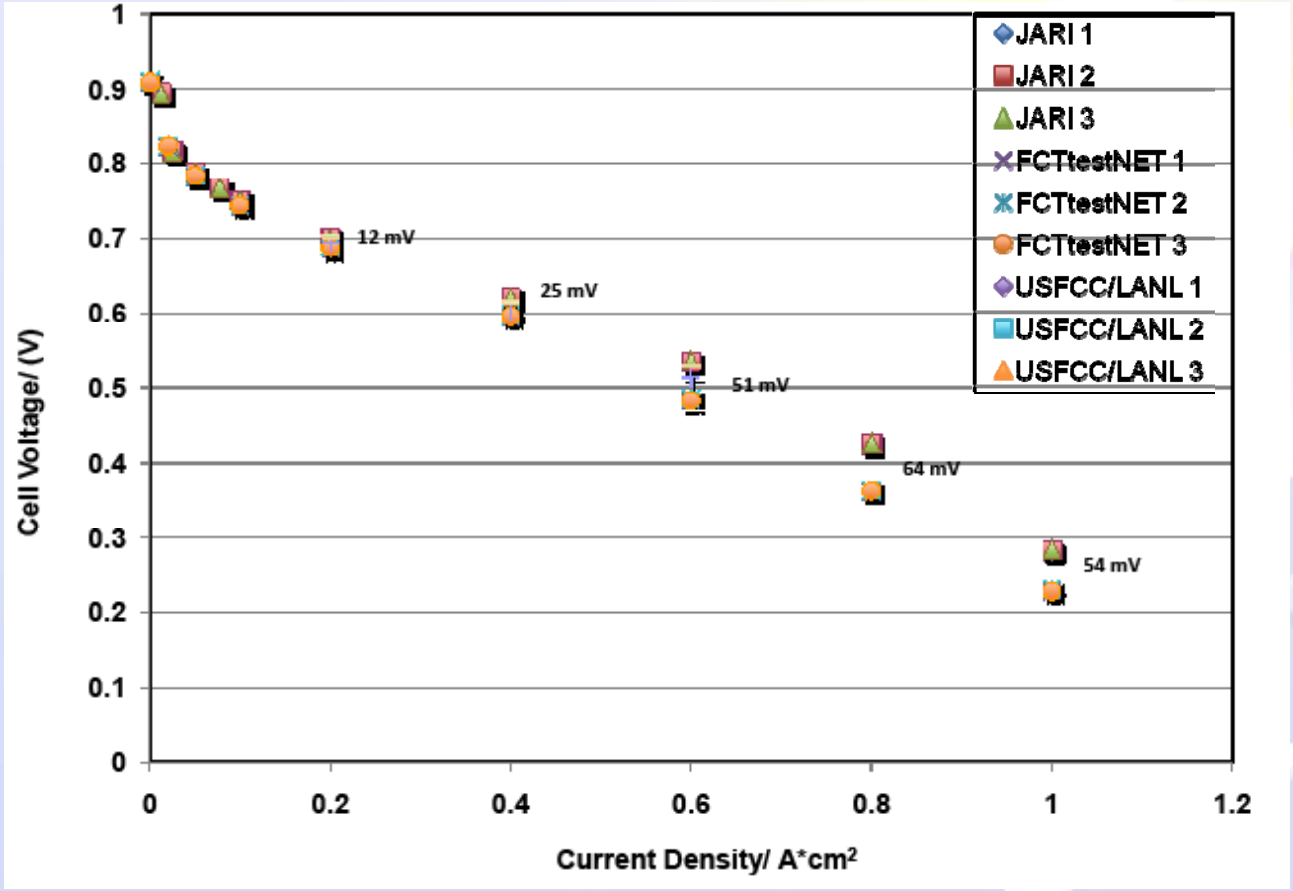



0.2 A/cm² to 1 A/cm²: Good repeatability (x3) for each procedure: $\Delta V \leq 7$ mV

Comparable results using the 3 procedures: $\Delta V \leq 34$ mV

# Results: Effect of of break-in procedures

## i-V curves @ 60°C, back pressure = $p_{atm}$




0.2 A/cm² to 1 A/cm²: Good repeatability (x3) for each procedure: $\Delta V \leq$ 4 mV

Results less comparable using the 3 procedures: $\Delta V \leq$ 64 mV

# Conclusions

- First comparison of 3 i-V curve procedures for single cells provided by USA (USFCC/DOE/LANL), Japan (JARI) and EU (FCTestNET)
- Good repeatability (x3) for each procedure at 80 and 60°C regardless the hardware and the break-in procedure (0 mV ≤ ΔV ≤ 7 mV)
- Comparable results using the same MEA
  - 80°C: ΔV ≤ 29 mV in the range 0.02 A/cm² to 1 A/cm²
  - 60°C: ΔV ≤ 17 mV in the range 0.02 A/cm² to 1 A/cm²
  - Main differences at OCV and at $P_{atm}$@ 60°C
    - Dwell time of 30s (FCTestNet, USFCC) vs. 5 min (JARI).

⇒repeatable and reproducible results can be achieved by using different testing protocols as long as the protocol clearly defines the accuracy of the parameters to ensure a stable criterion before performing the measurements (e.g. ΔV ≤ ± 5 mV).

This study fully supports the technical specification (IEC62282-7-1) in preparation in the working group 11 of the ISO TC105 “Fuel Cell Technologies” on “Single Cell Test Methods for Polymer Electrolyte Fuel Cell (PEFC)”.

# Conclusions



Thank you for your attention!

# Back-up

## *Test hardware and MEA*

- Cell assembly procedure:
  - Alignment fixtures: The clamping plates are equipped of TEFLON centrings to align the flow plates. Two PEEK centrings allow to the alignment of the flow plates, the gaskets and the membrane.
  - Tightening procedure: The six bolts are tightened progressively first by hand and then in three steps: 5 N.m / 8N.m/10N.m (final torque).

- MEA:
  - Gas diffusion layers: Woven type + MPL (ELAT SS)
  - Catalyst layers: ELAT SS ~ 0.5mgPt/cm² (cathode and anode)
  - Membrane: NAFION® NRE212