Commercial NiMH Cells in LEO Cycling

Thermal Vacuum Life Test Performed for the Floating Potential Probe (FPP)

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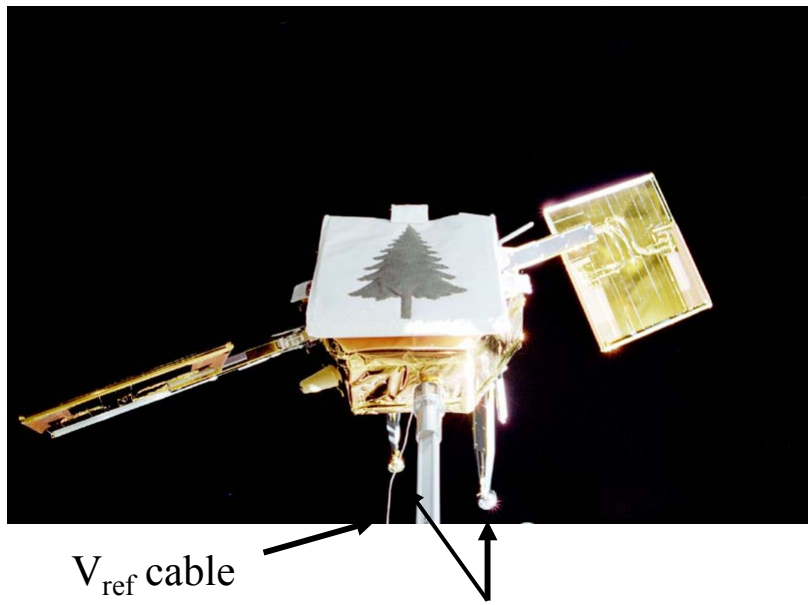
Outline

- Introduction
  - What is the (Floating Potential Probe) FPP?
  - Why was a NiMH battery selected?
  - How well would crimped seal cells performed in long term vacuum exposure?
- Verification Tests
  - Battery description
  - Test Methods
  - Results
  - Main Findings
  - FPP Status

Introduction

- Purpose of FPP
  - Determine the bonding effectiveness of the Plasma Contacting Unit (PCU) to mitigated large electrical fields that could induce a hazardous plasma environment for EVAs (spacewalks) on the international Space Station (ISS)
  - Essentially, it is a fancy voltmeter powered by solar arrays and a 12V battery

Floating Potential Probe



Introduction (cont.)

- Selected Battery
  - Schedule pressure precluded any battery development
  - EVA Helmet Interchangeable Portable (EHIP) light battery was best match
  - 3P-5S array of 4/3A NiMH cells (3.5Ah nameplate) from Toshiba and Sanyo
  - Using only two 5S strings in series to get 12V output, leaving the middle string unused

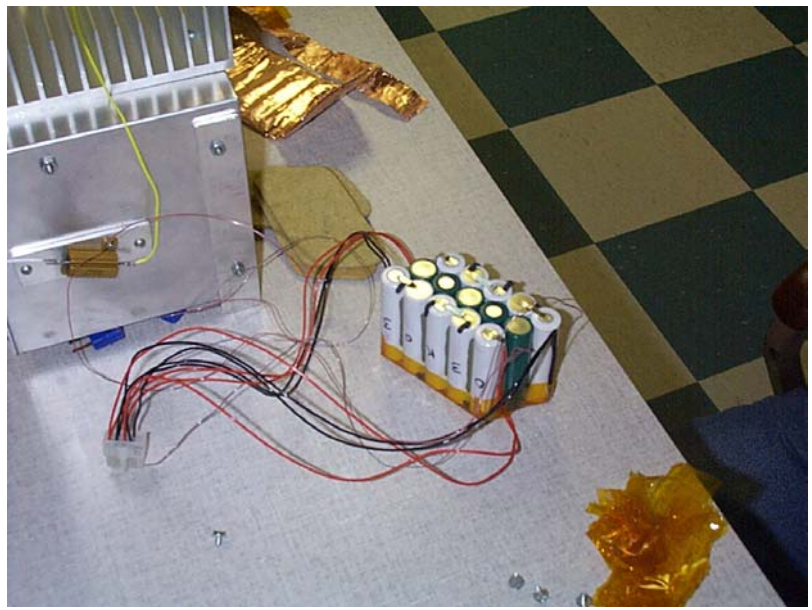
EVA Helmet Interchangeable Portable (EHIP) Battery Brick Assembly SEG39130224

Introduction (cont.)

- Problem
  - FPP needed a battery with 2-year LEO cycle
  - That's >17,520 hours of vacuum exposure
  - EHIP light battery was certified for 260 spacewalks (or 1820 hours of vacuum) over 5 years
  - Would the crimp seal be compatible with vacuum LEO cycling?
  - Seal must hold hydrogen partial pressure and some water vapor pressure

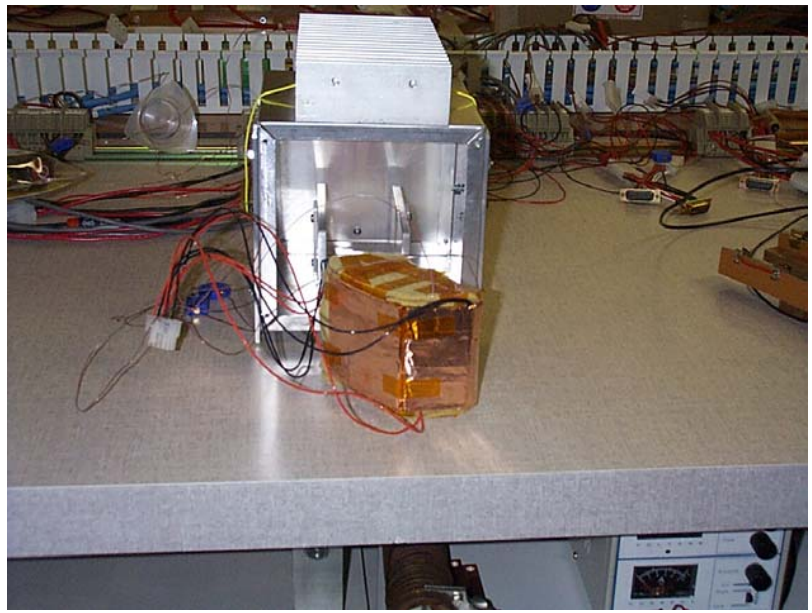
Verification Test Program

- Performed by Symmetry Resources, Inc., in Arab, AL
- Cell Acceptance
  - Cells were spares from EHIP flight lots that had passed all acceptance tests
  - Pre-Test - 2 charge/discharge cycles for capacity and resistance measurements, phenolphthalein leak test, and weighing
- Test Battery Assembly
  - 2 prototype EHIP light battery bricks assembled
  - In each battery, one string of Toshiba and one string of Sanyo
  - Bricks insulated in Durrette felt



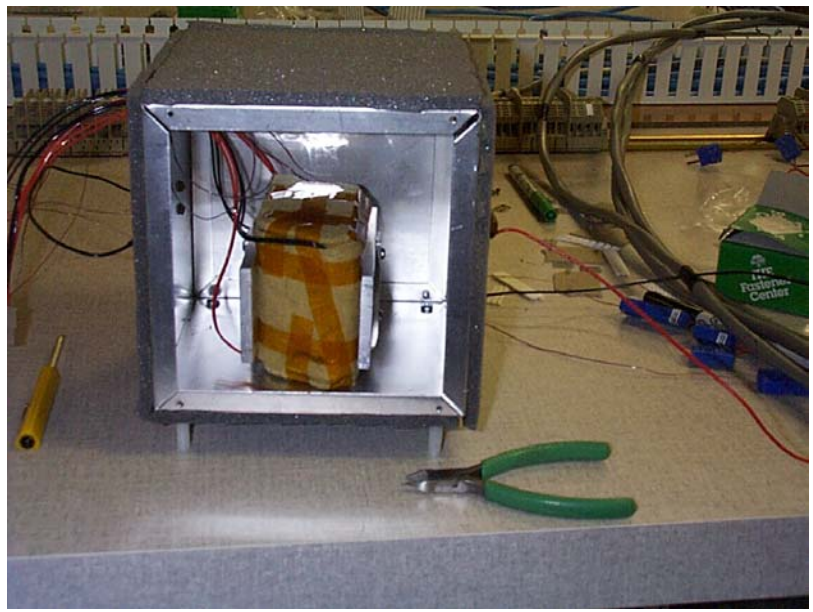
Test Method

- Battery Assembly
  - No EHIP battery housing available
  - Test bricks were modified to include copper tape to encapsulate the felt and provide better thermal conduction after 66 cycles
  - Same configuration for both batteries
  - One thermocouple and one voltage sense per string



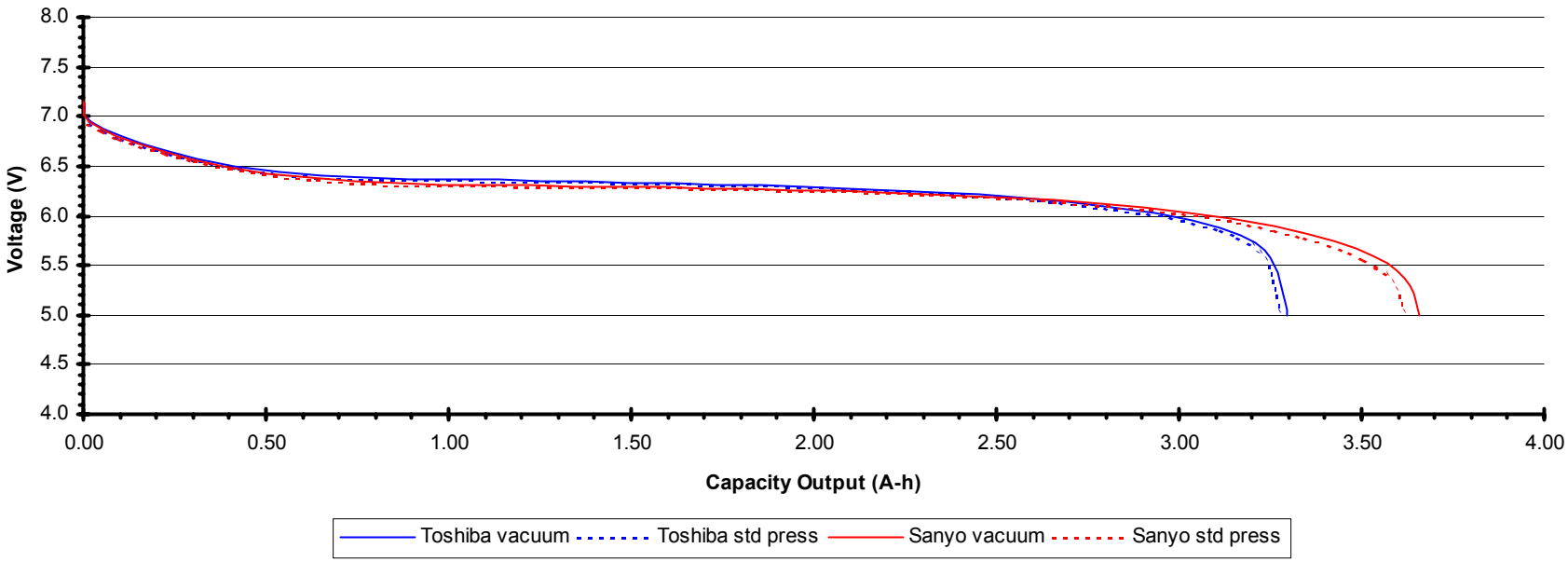
Test Method (cont.)

- Batt#1 in a thermal chamber set at 32°C
- Batt#2 in a thermal vacuum chamber set at 32°C, < 0.5 torr
- Each string controlled independently w/ a Maccor system
  - Discharge: 2.125W for 30 min
  - 60 min Charge: stepwise simulation of FPP charge algorithm
    - 1.75A start with reductions based on OCV and temperature
    - Taper from 1.75A at 6.5V to 0.58A at 6.8V then to 0.04A at 7.2V
    - Taper from 1.75A at 38°C to 0A at 45°C

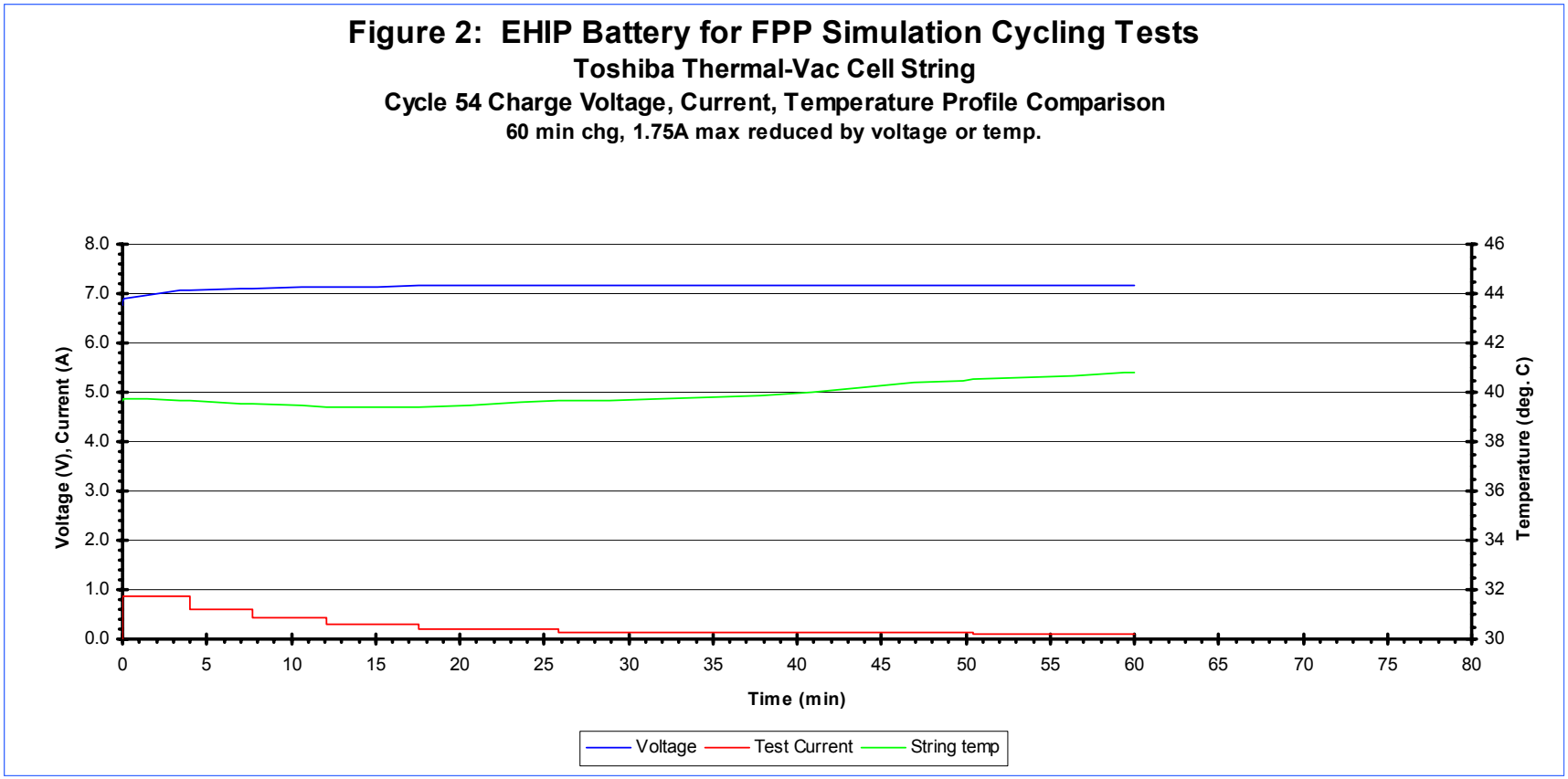


Cycle 2 Capacity Baseline

Figure 1: EHIP Battery for FPP Simulation Cycling Tests
Toshiba and Sanyo Cell Strings
Cycle 2 C/5 Baseline discharge comparison
0.90A charge, 0.72A dsch to 5.0V; Room Temperature, ambient press.



Initial Thermal Profile: Getting too hot!

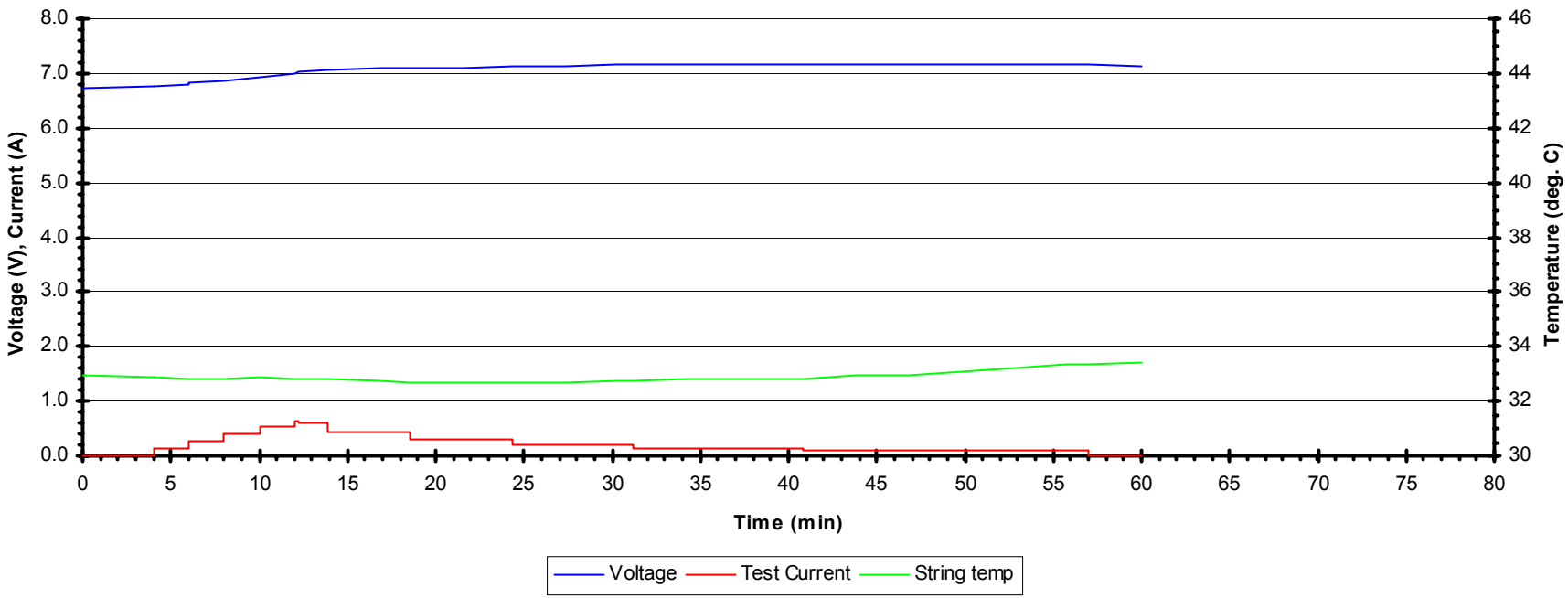


Test Method (cont.)

- First 66 cycles results
  - Batteries operating temperature drifted to > 40 °C
- Modifications to better simulate actual FPP
  - Changed initial temperature setting from 32 to 30°C
  - Add a delay followed by a gradual current increase at beginning of charge
  - Made adjustments to voltage based current limits to compensate for increased wire resistance present in actual FPP
- Modifications to the test article
  - Removed the Durette felt on the cylindrical side of the cells
  - Encapsulated the felt with copper tape

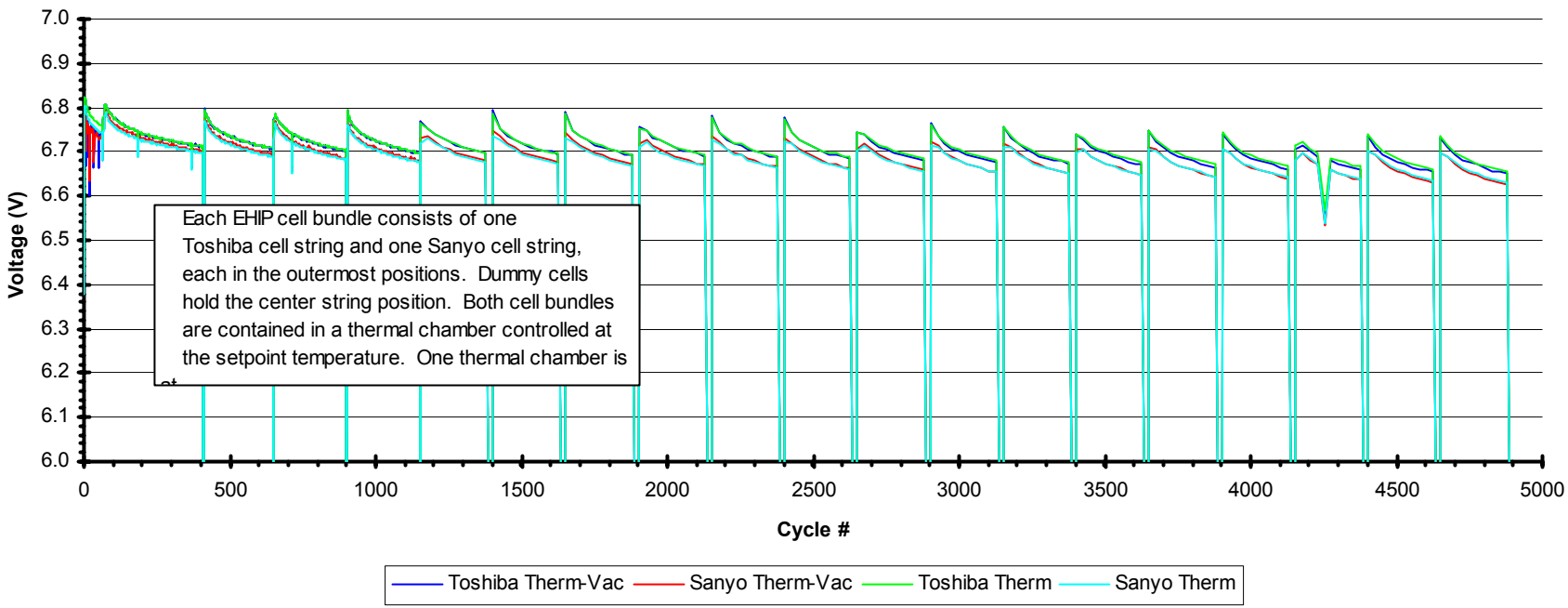
After the Modifications

Figure 3: EHIP Battery for FPP Simulation Cycling Tests
Sanyo Thermal-Vac Cell String
Cycle 1901 Charge Voltage, Current, Temperature Profile Comparison
60 min chg,, ramp up current, 1.75A max reduced by voltage or temp.



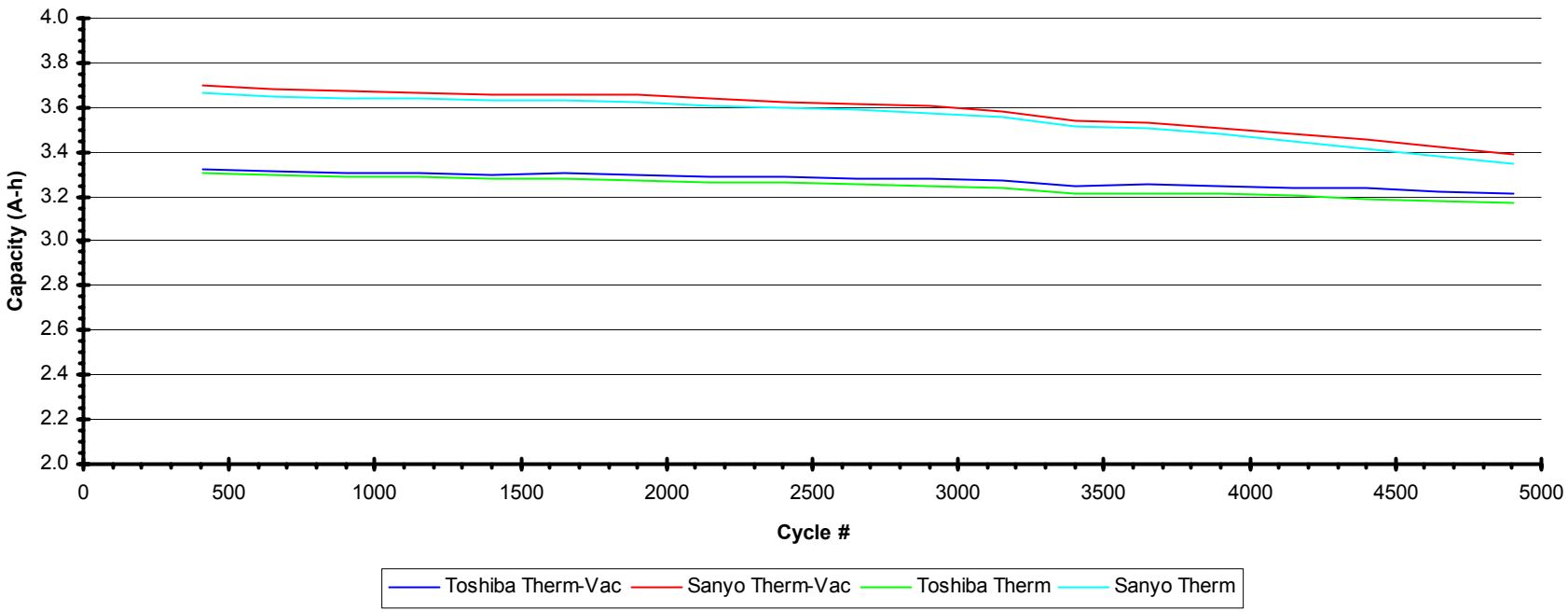
End of Discharge Voltage Trend

Figure 6: EHIP Battery for FPP Simulation Cycling Tests
Sanyo and Toshiba Cell Strings
End-of-Discharge String Voltage versus Cycle Trend
2.125W discharge for 30 minutes; Vacuum and Non-vacuum conditions



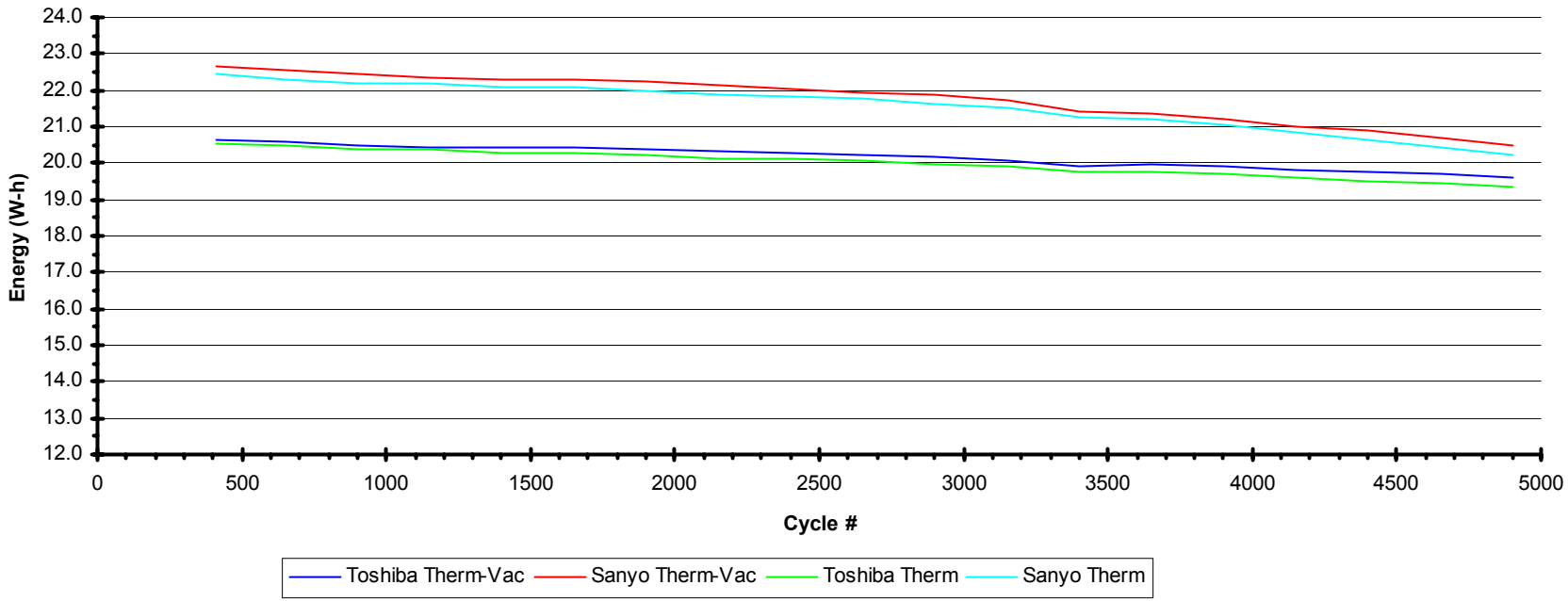
Test Results

Figure 4: EHIP Battery for FPP Simulation Cycling Tests
Sanyo and Toshiba Cell Strings
Full Discharge Capacity Trends
0.72A to 5.0V; 250 cycle interval; Vacuum and Non-vacuum conditions



Test Results (cont.)

Figure 5: EHIP Battery for FPP Simulation Cycling Tests
Sanyo and Toshiba Cell Strings
Full Discharge Energy Trends
0.72A to 5.0V; 250 cycle interval; Vacuum and Non-vacuum conditions



Test Results after 10 months

- Capacity and internal resistance degradation occurred
  - Sanyo
    - 85% increase in internal resistance
    - 9% loss in capacity
  - Toshiba
    - 75% increase in internal resistance
    - 2% loss in capacity
- Very little difference between vacuum & ambient P
  - Post test mass loss are very low
    - Sanyo: <23 mg/cell (Vac) vs < 22 mg (1 atm)
    - Toshiba: <14 mg/cell (Vac) vs < 6 mg (1 atm)
  - Capacity and resistance changes are independent of pressure
    - Losses and increases were due to the aggressive charge and warm conditions

FPP Status

- FPP was launch in Dec 2000
- It work for some months, then LOS occurred
- About several months later, its communication was re-established
  - It provided excellent data
  - the PCU is doing its job
  - the electrical fields are less of a concern than anticipated
- A later, we lost signal again
- Funding was discontinued after 10 months of testing because program decided to no longer attempt to talk to it
- FPP is still up there and it may be brought back on a summer 2003 mission