Thermal Imaging of Aerospace Battery Cells

By

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Outline

- Objective
- Experimental
- Nickel Hydrogen Cell (NiH_2)
- Lithium-Ion Cell (Li-Ion)
- Conclusions

Objective

Understand the thermal characteristics of cylindrical aerospace battery cell by studying the surface thermal profiles.

Experimental

- Cells
  - Eagle Picher 50Ah rabbit-ear (cylindrical) Nickel Hydrogen (NiH_2) cell
  - Saft 40 Ah cylindrical Lithium-Ion (Li-ion) cell
- ThermCAM S60 FLIR Systems
- Charge and Discharge with Passive cooling
  - C/2 rate
    - Charge to thermal limit of 35°C
    - Allow cell to cool
    - Discharge to 1.0V

Experimental: Brief Background on I.R. Camera

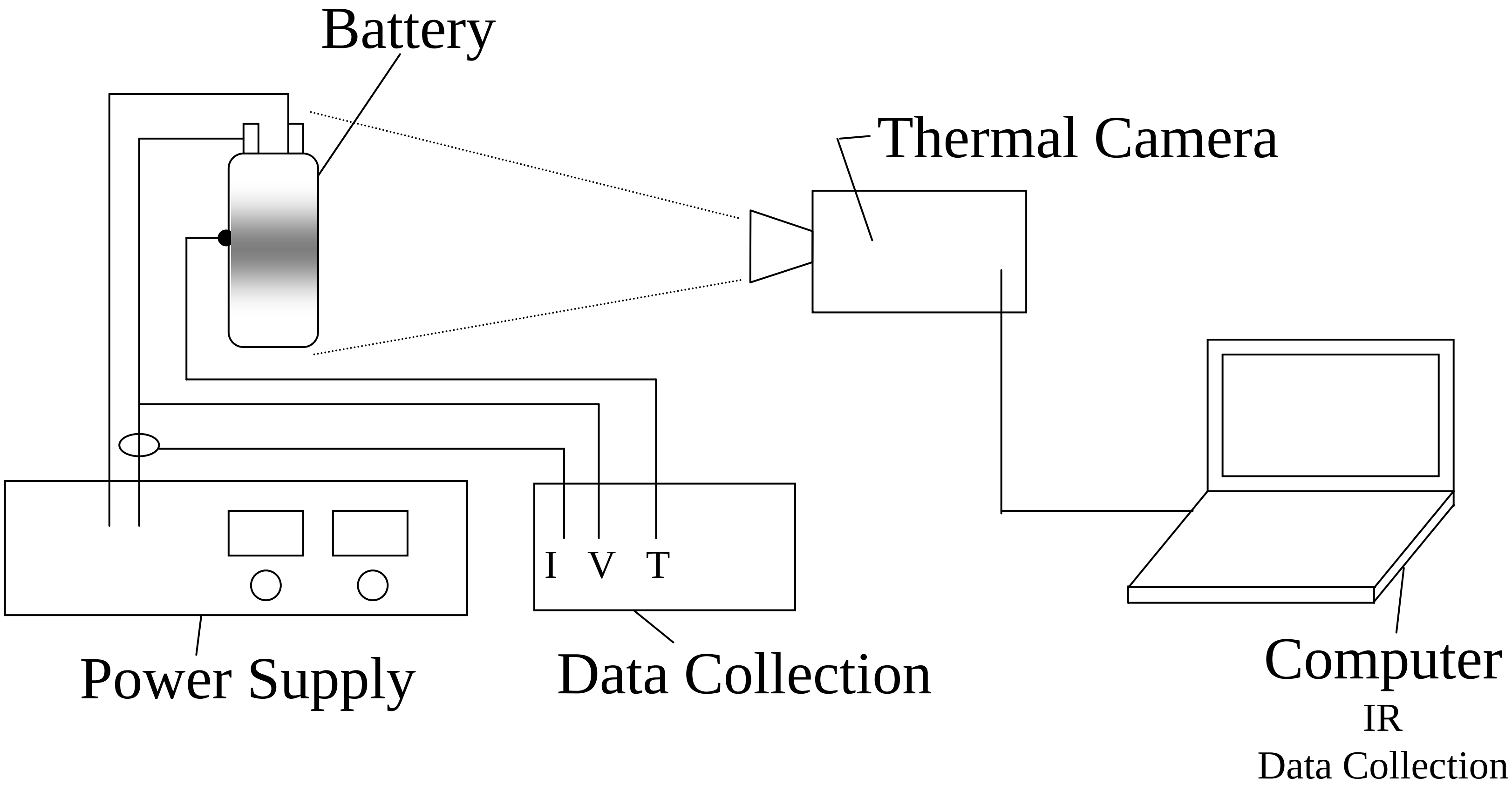
- The camera is working on the principle of Blackbody Radiation and works from 7.5µm to 13µm wavelengths
- Light is from 0.40µm to 0.70 µm
- The object under investigation needs to have constant and known emissivity. (preferably > 0.7)

    -Metals are variable from 0.045 to ~.07

    -Cell was covered with Kapton tape e~ 0.86, checked with thermistor

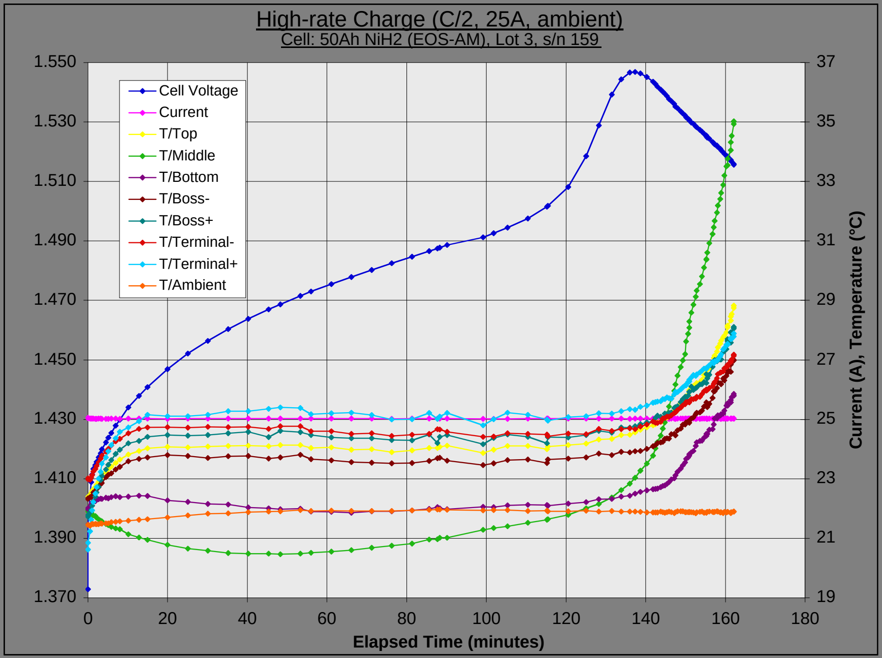
All measured Temperatures are Surface Temperatures

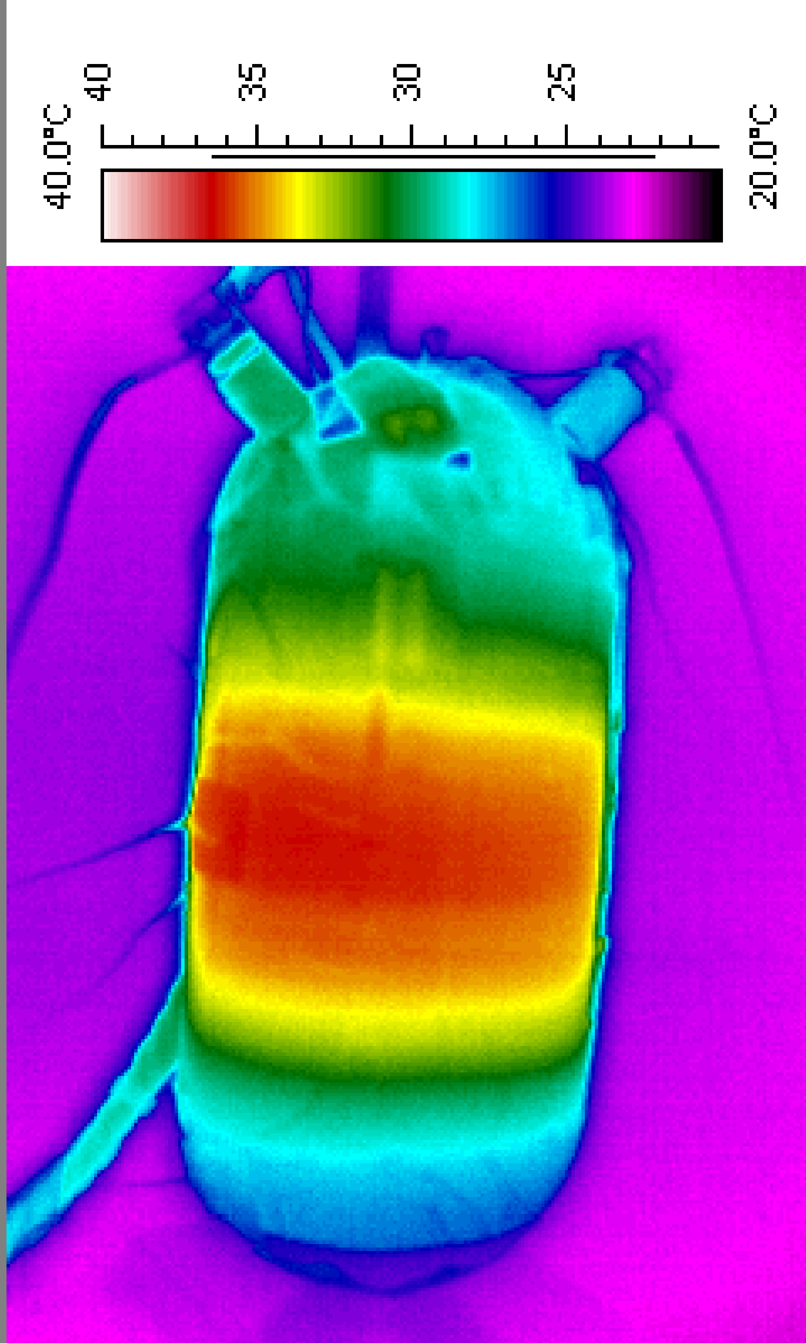
Experimental: Block Diagram



NiH$_2$ Cell: Thermal Image during Charge @ C/2

During Overcharge





Towards End of Discharge

NiH_2 Cell:

Thermal Image

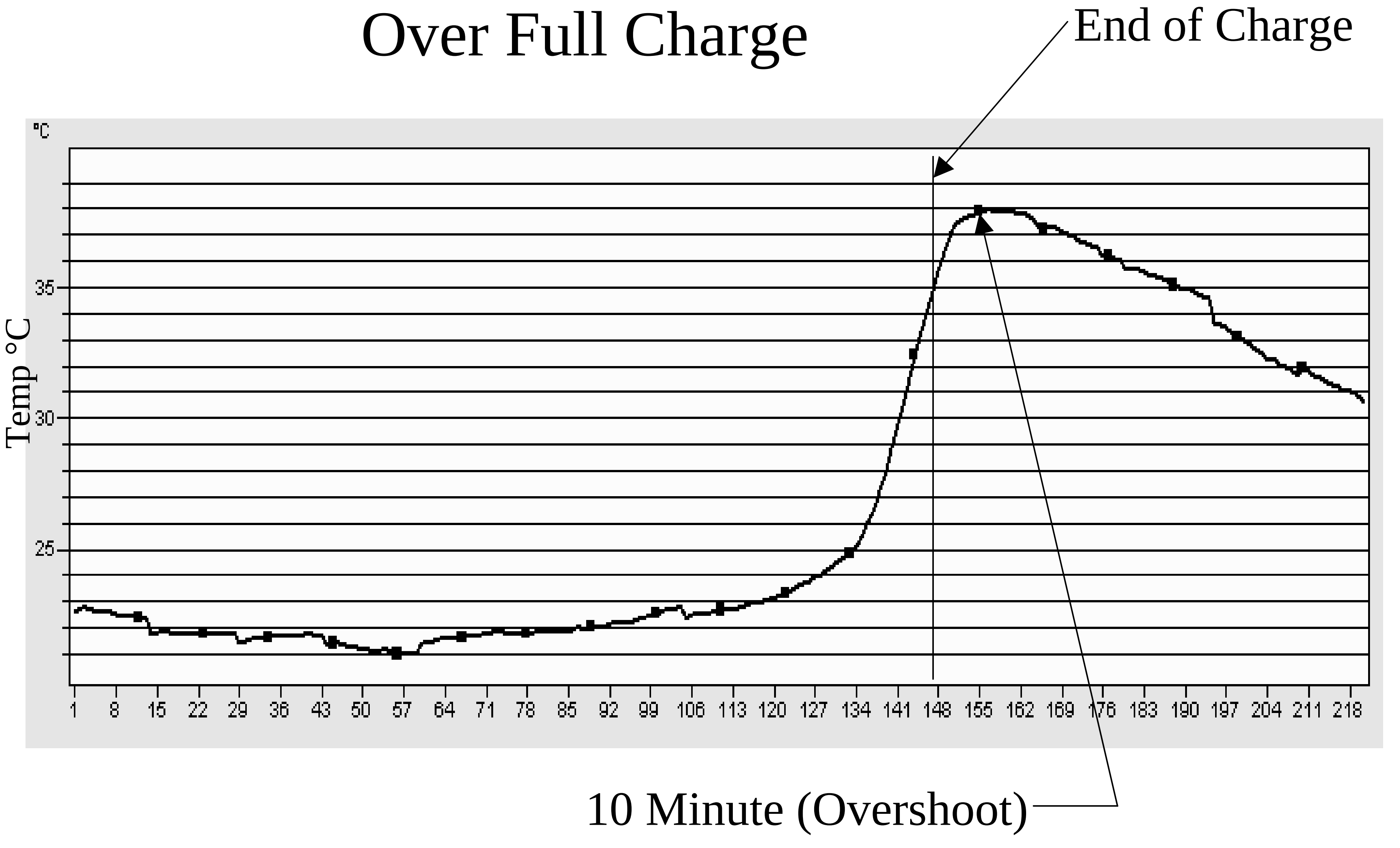
during

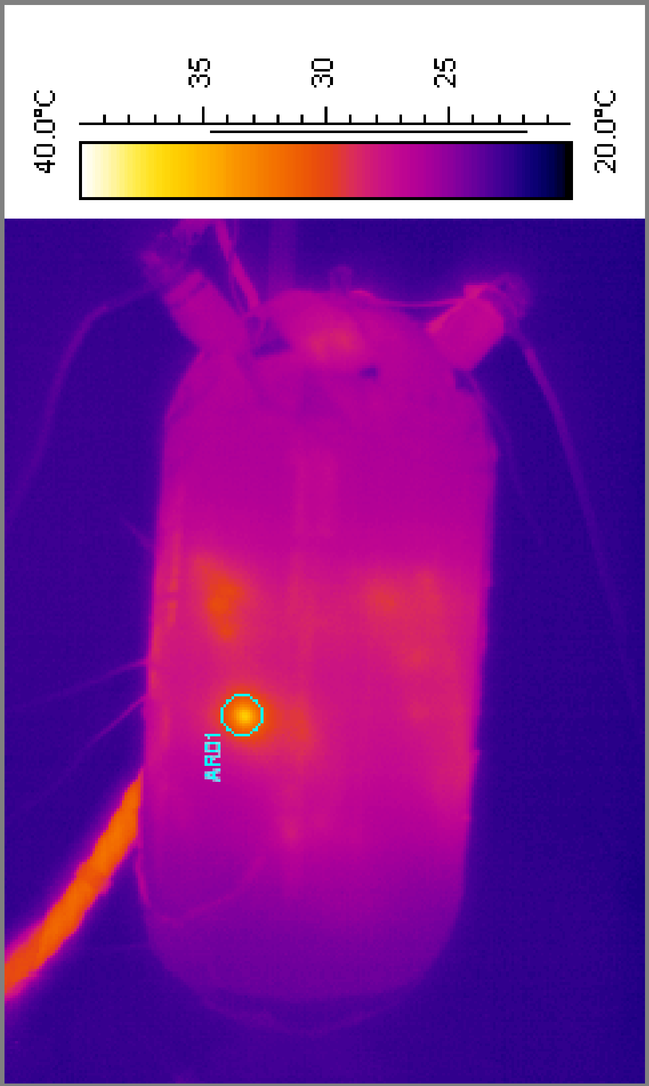
Discharge

@

C/2

NiH_2 Cell: Thermal data as obtained from IR Camera Over Full Charge

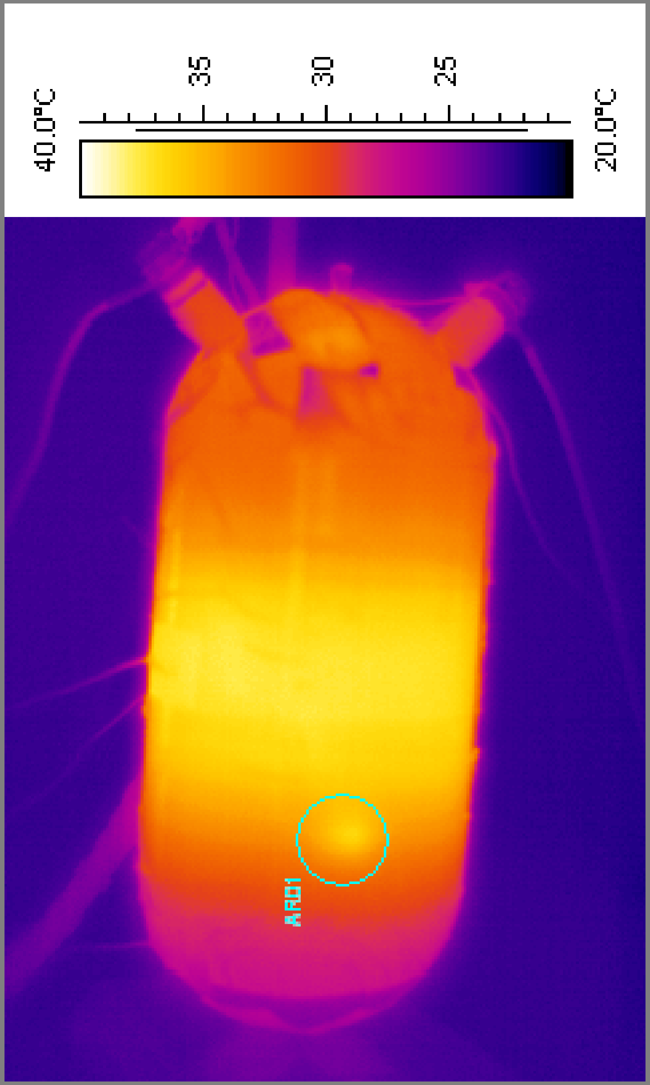




Towards start
of overcharge

NiH_2 Cell: Popping Noted during Charge (Indicated by Circle)

Short and Defined Surface Feature

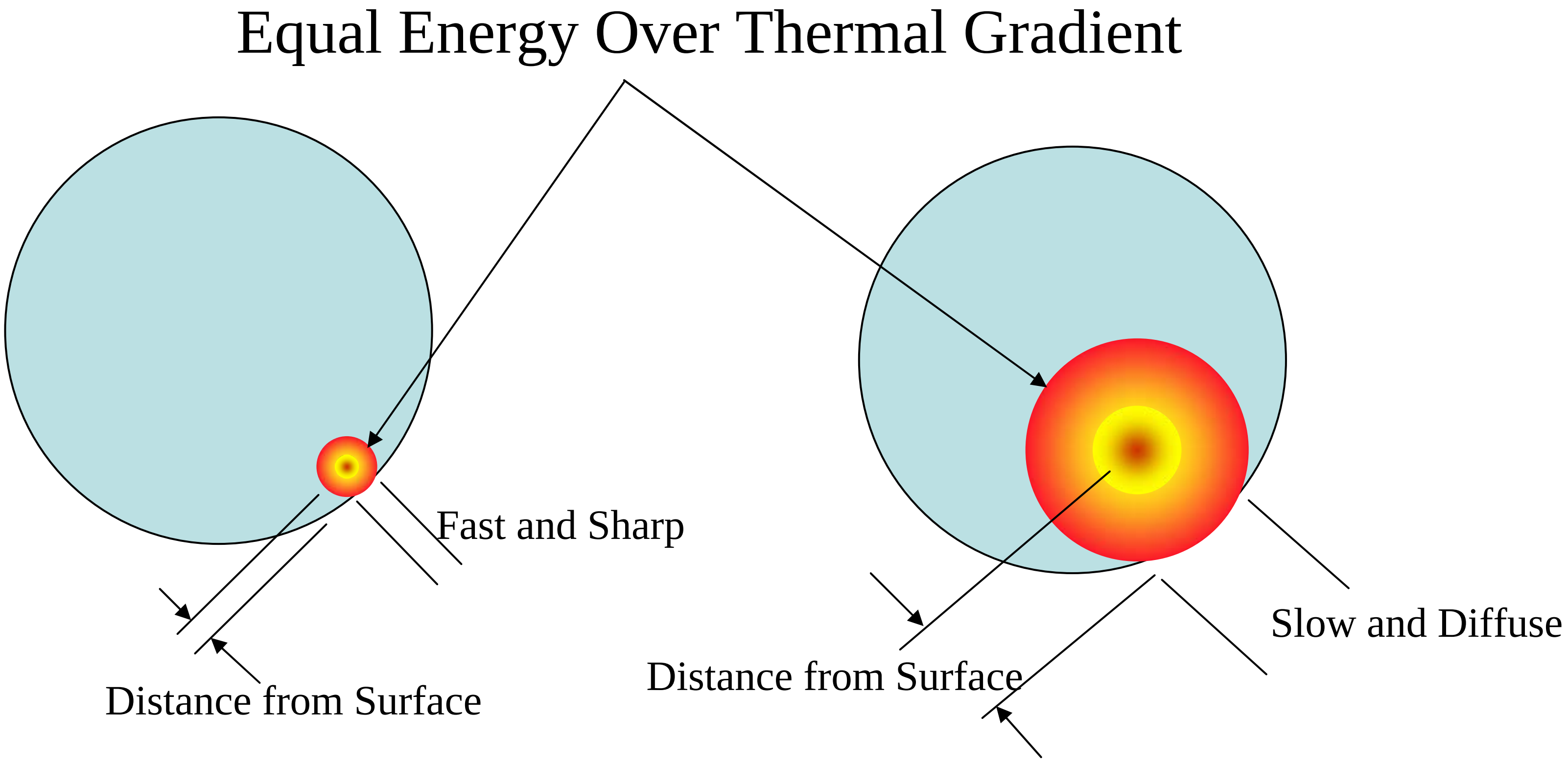


Towards end of overcharge.

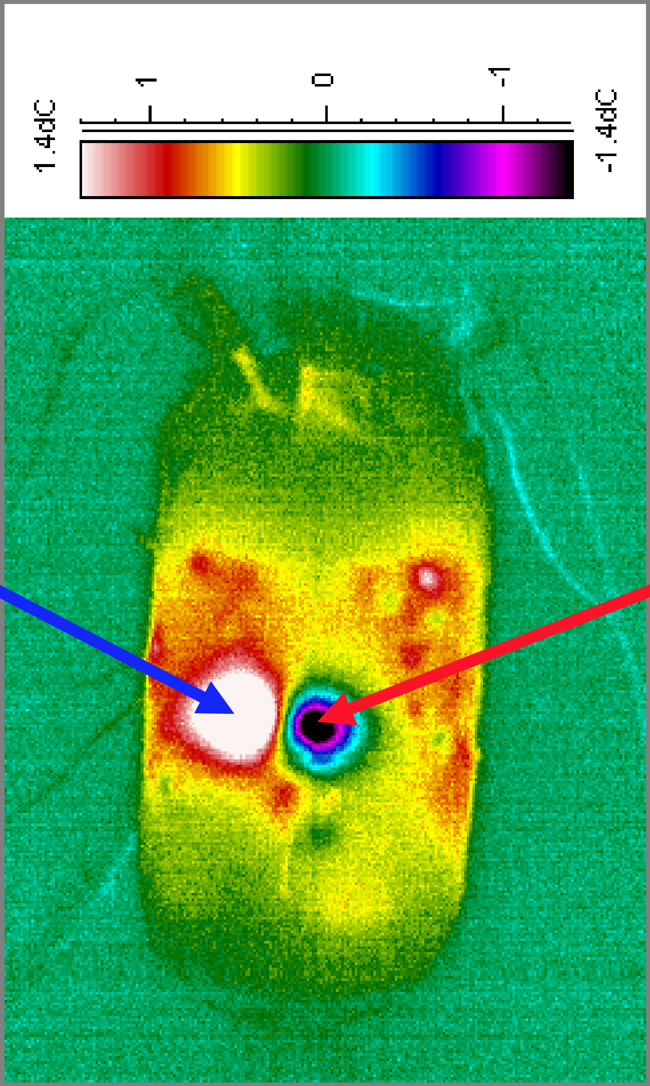
NiH_2 Cell: Popping Noted (Indicated by Circle)

Defuse Interior Feature

NiH_2 Cell: Thermal Explanation of Popping



NiH_2 Cell: Popping in Differential Temp. Mode

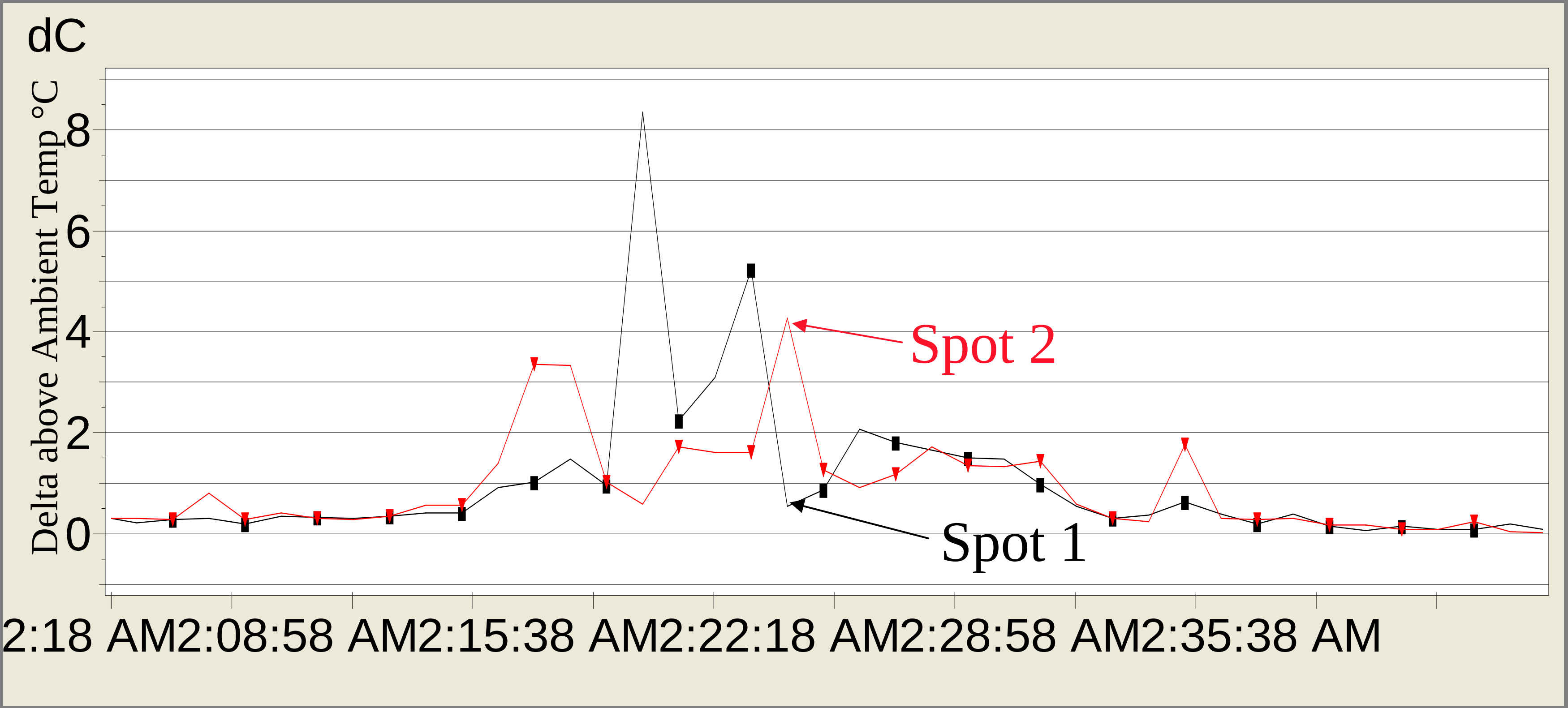


Popping-Going Hot
Spot 2

Post-Popping Return to
Ambient
Spot 1

Middle of Overcharge

NiH_2 Cell: Popping in Differential Temp Mode. Plot Over Time (Charging)



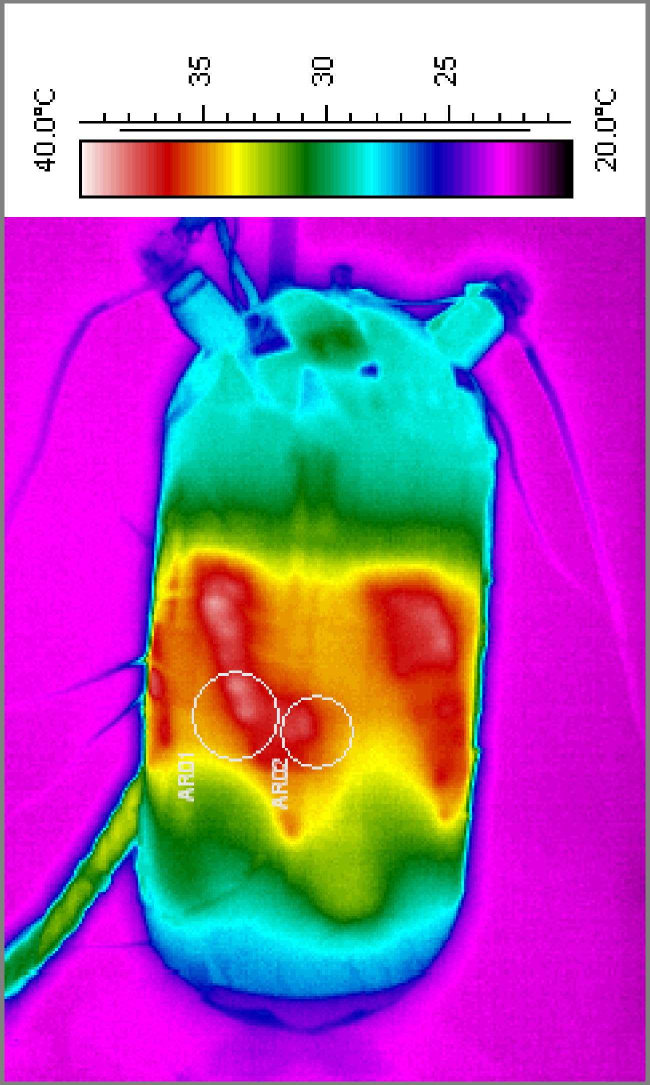
Note: Each plot has multiple steps of heating.

Pattern at end of charging

NiH_2 Cell: Popping Depicted as Circles

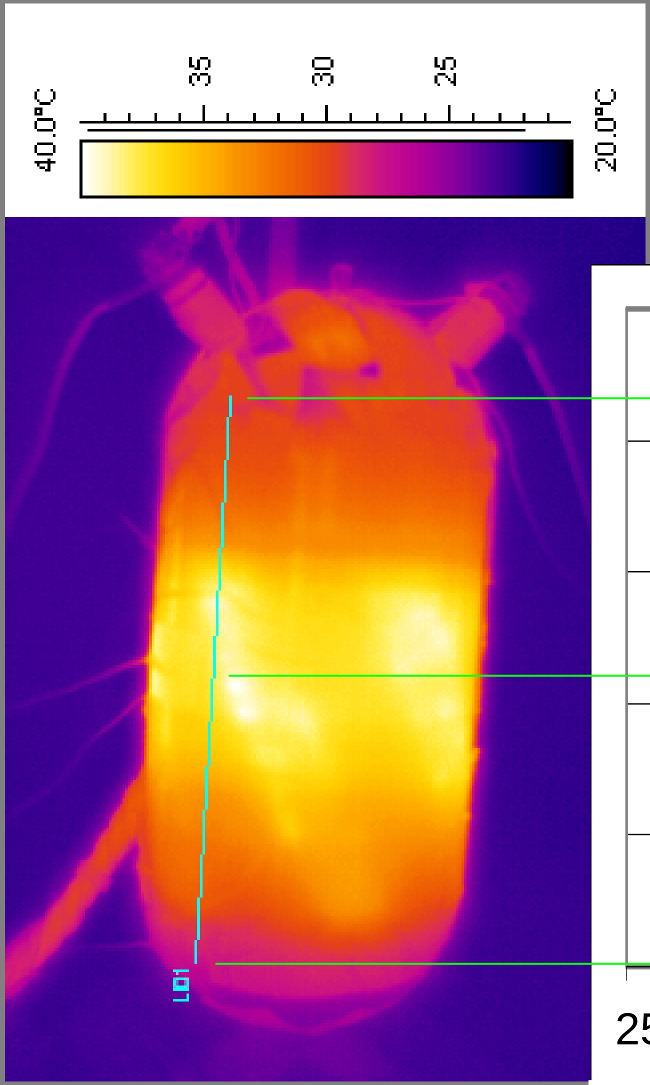
Count of pops varies from ~10 to >44

NiH_2 Cell: Catalytic Wall-wick Strip are Similar to popping pattern

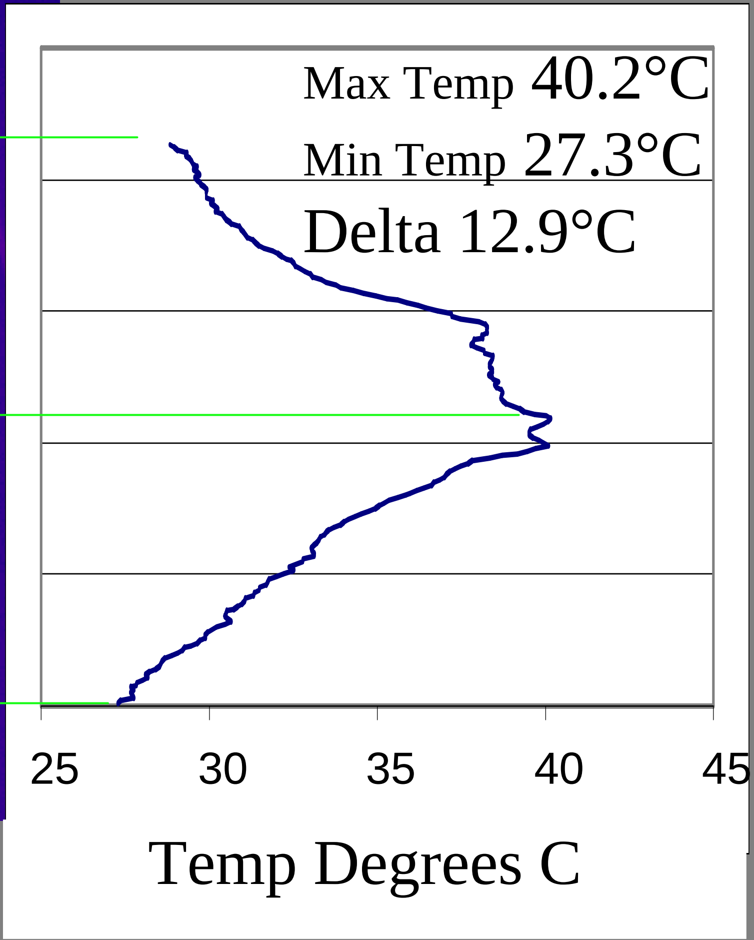


During Overcharge

NiH_2 Cell: Battery Temperature Profile
Vertical Crosscut
Charge

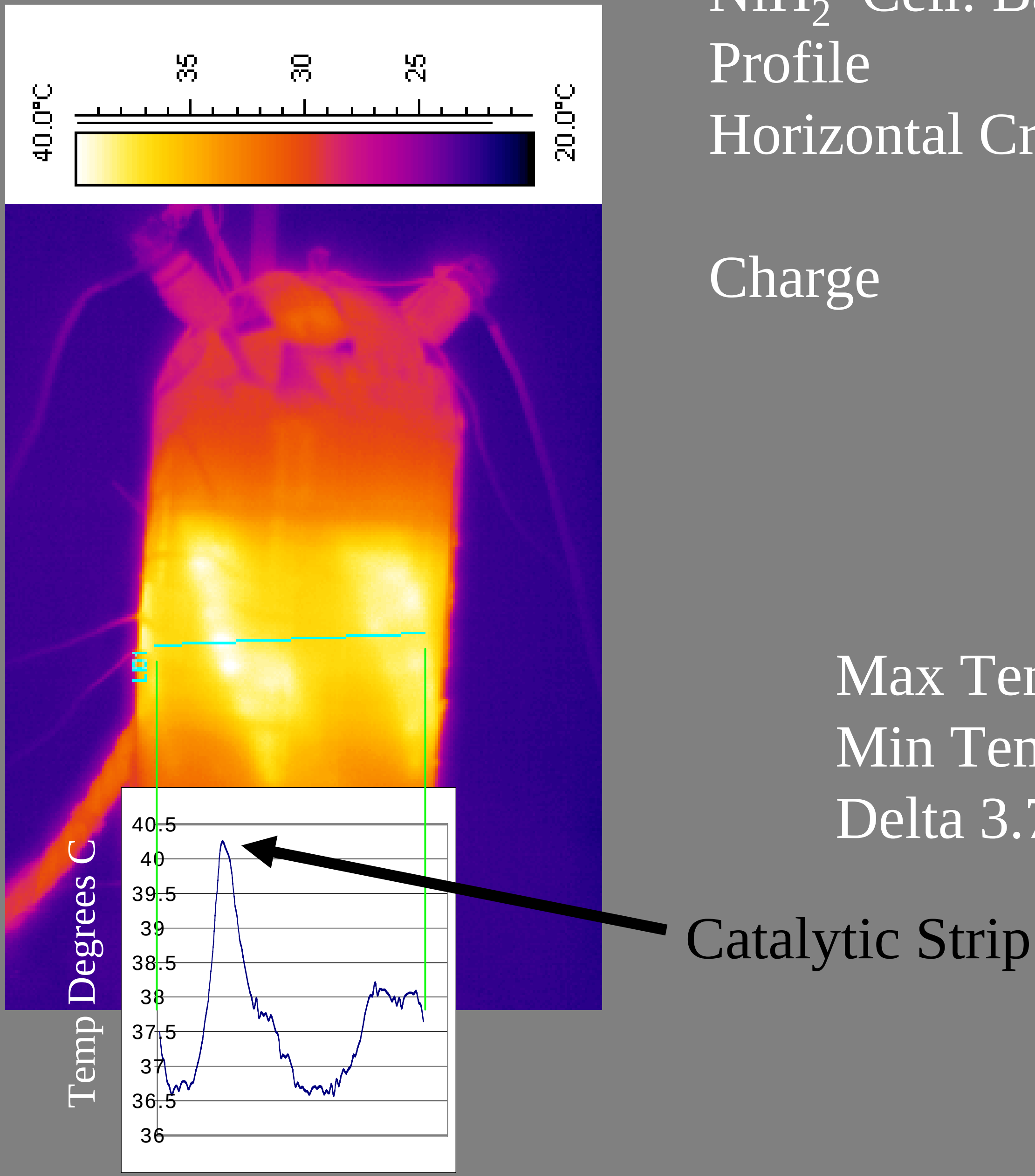


During Overcharge



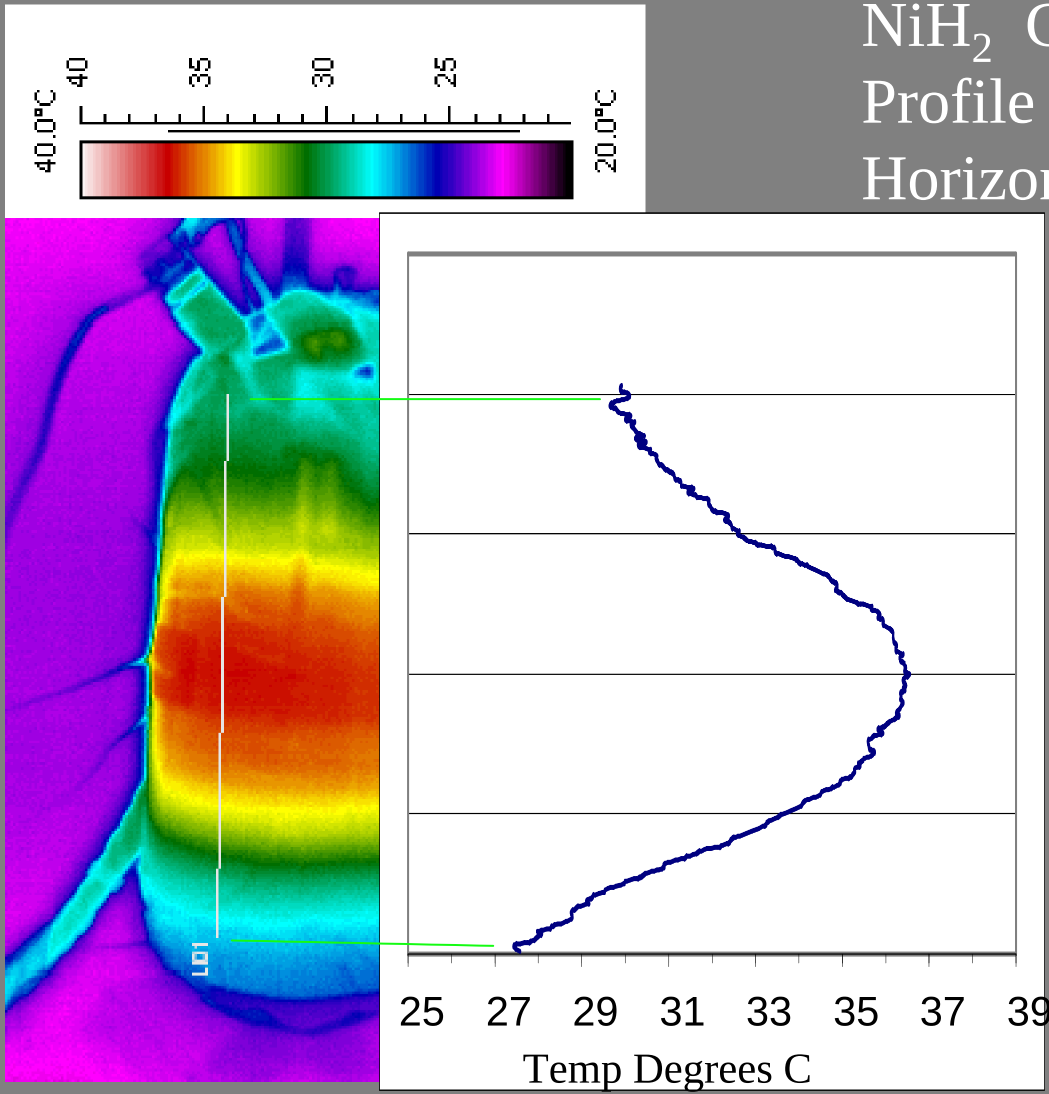
NiH_2 Cell: Battery Temperature Profile
Horizontal Crosscut

Charge



Max Temp 40.3°C
Min Temp 36.6°C
Delta 3.7°C

NiH_2 Cell: Battery Temperature Profile
Horizontal Crosscut



Discharge After Cell was allowed to return to Ambient

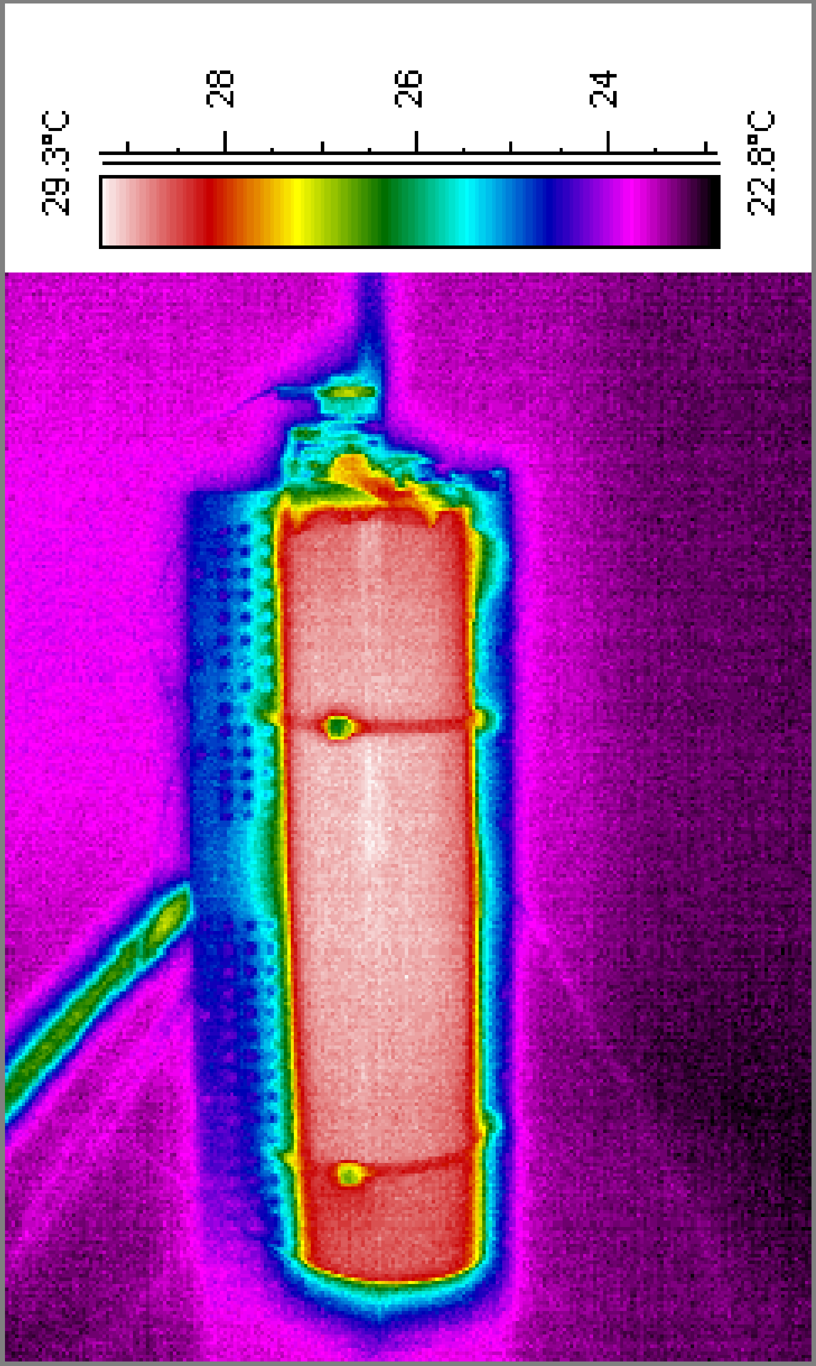
Max Temp 36.6°C
Min Temp 27.4°C
Delta 9.2°C

NiH_2 Cell: Summary

- Surface Thermal profile have been studied for 50 Ah NiH_2 Cell under
  - Charge (C/2 to Thermal Limit of 35°C) and
  - Discharge (C/2 to Min Voltage of 1.0V)
    - Cell Thermal Gradients
      - Middle of stack to top or bottom is about 12.9°C
      - Bottom is the coldest
      - Top to bottom is about 1°C
      - Across stack is about 4°C

NiH_2 Cell: Summary - Continued

- Popping is demonstrated on the catalytic wall-wick strip and at the bottom section of the cell stack; Destructive Physical Analysis of the cell confirmed the signatures
- Thermal Overshoot (After Charge Stopped) indicates cell interior is at least 4°C hotter than the pressure vessel cylindrical surface



Li-Ion Cell:

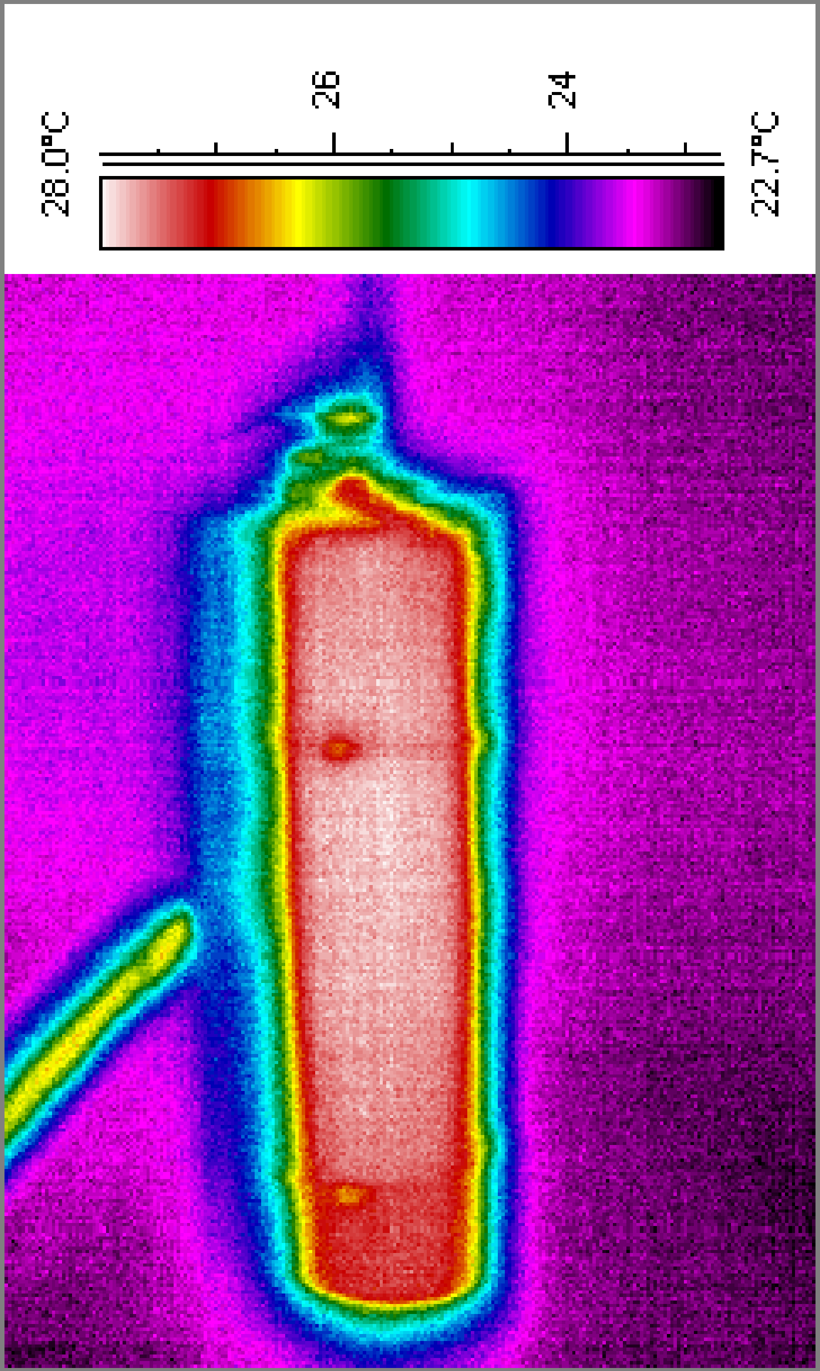
Thermal Image

during

Charge

@

C/2



Li-Ion Cell:

Thermal Image

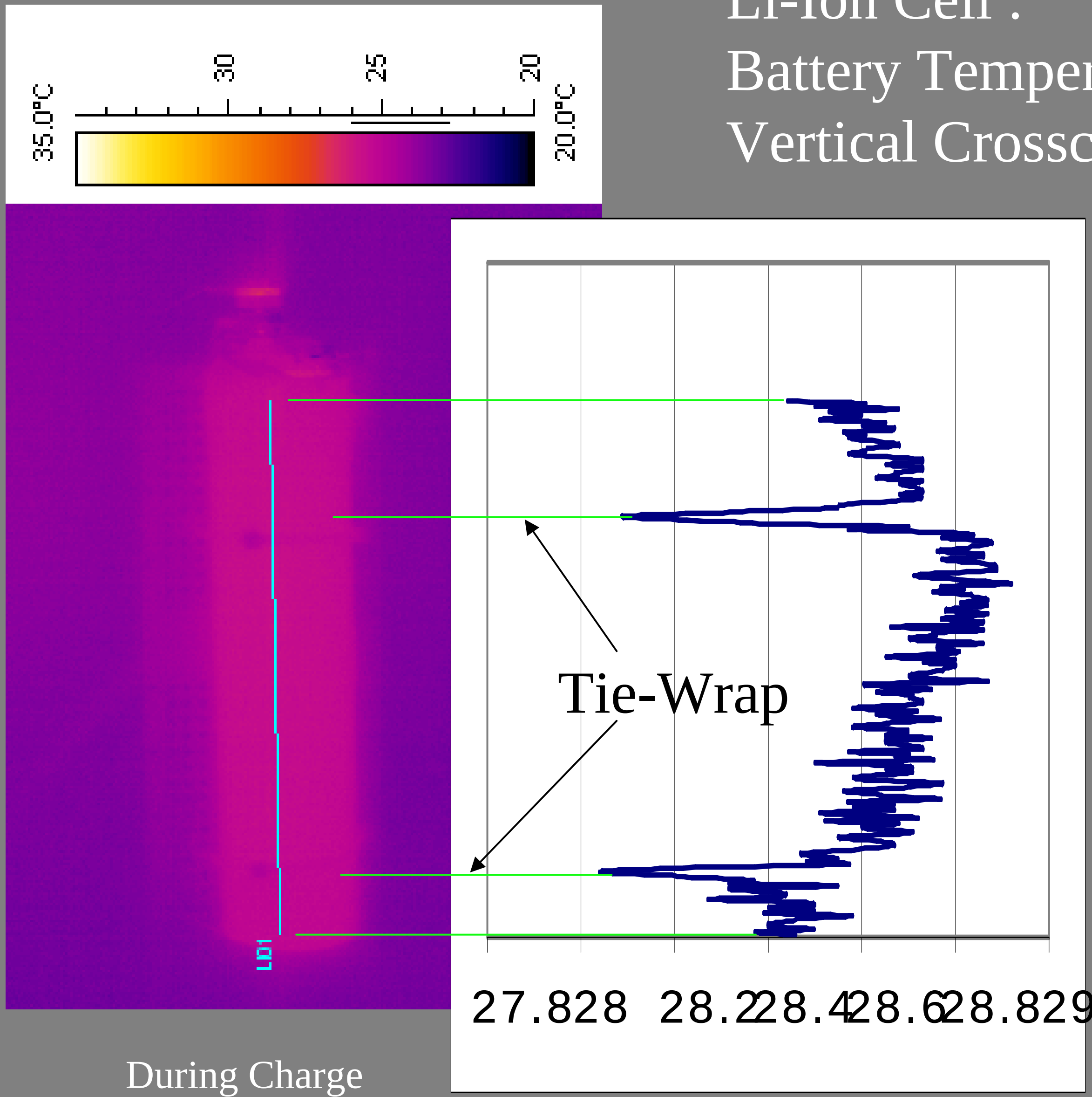
during

Discharge

@

C/2

Li-Ion Cell :
Battery Temperature Profile
Vertical Crosscut

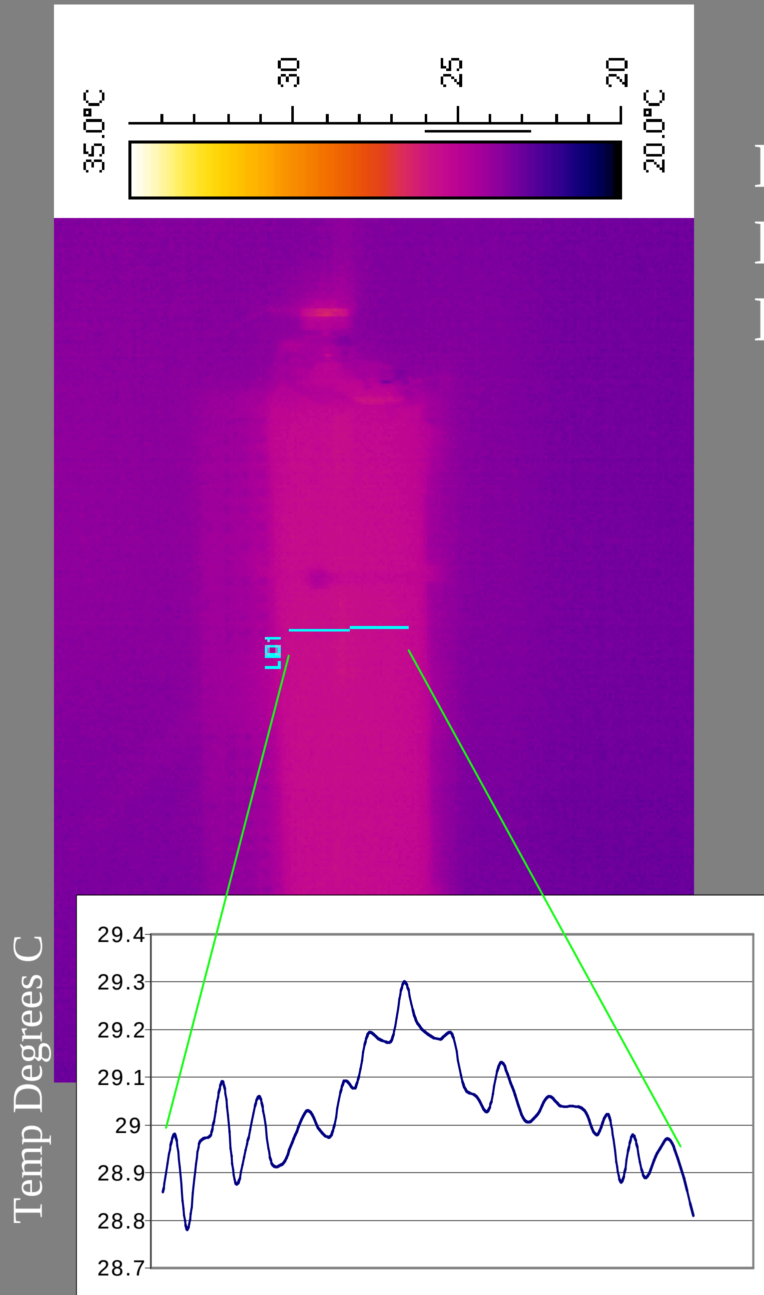


During Charge

Max Temp 28.9°C
Min Temp 28.0°C*
Delta 0.9°C

*Low Temperature is at Tie-Wrap

Li-Ion Cell:
Battery Temperature Profile
Horizontal Crosscut



Max Temp 29.3°C
Min Temp 28.8°C
Delta 0.5°C

During Charge

Li-Ion Cell: Summary

- Surface Thermal profiles have been studied for 40 Ah Lithium-Ion Cell
- Charge (C/2 charge to Voltage Limit of 4.1V with Taper)
- Discharge (C/2 to Min. Voltage of 3V)
- Less than 1°C thermal gradient on the cell vessel surface
- Significantly lower heat generation in Li-Ion cell compared to NiH_2 cell

  - May be due to a favorable charge method used for Li-Ion cell

Conclusions:

- Surface Thermal Profiles of Eagle Picher rabbit-ear 50Ah NiH_2 and of Saft 40 Ah Li-ion cylindrical cells have been studied using ThermCAM S60 FLIR Systems
- Popping Phenomenon in NiH_2 cell is demonstrated
- Temperature gradient in NiH_2 is slightly higher than normally considered
  - -for example. Middle of stack to top or bottom is about 12.9°C compared to <7°C (may be due to passive cooling)
- Less than 1°C thermal gradient on the Li-Ion cell vessel surface
- Significantly lower heat generation in Li-Ion cell compared to NiH_2 cell
  - - May be due to a favorable charge method used for Li-Ion cell