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 Pitcher 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

Experimental: Brief Background on I.R. Camera

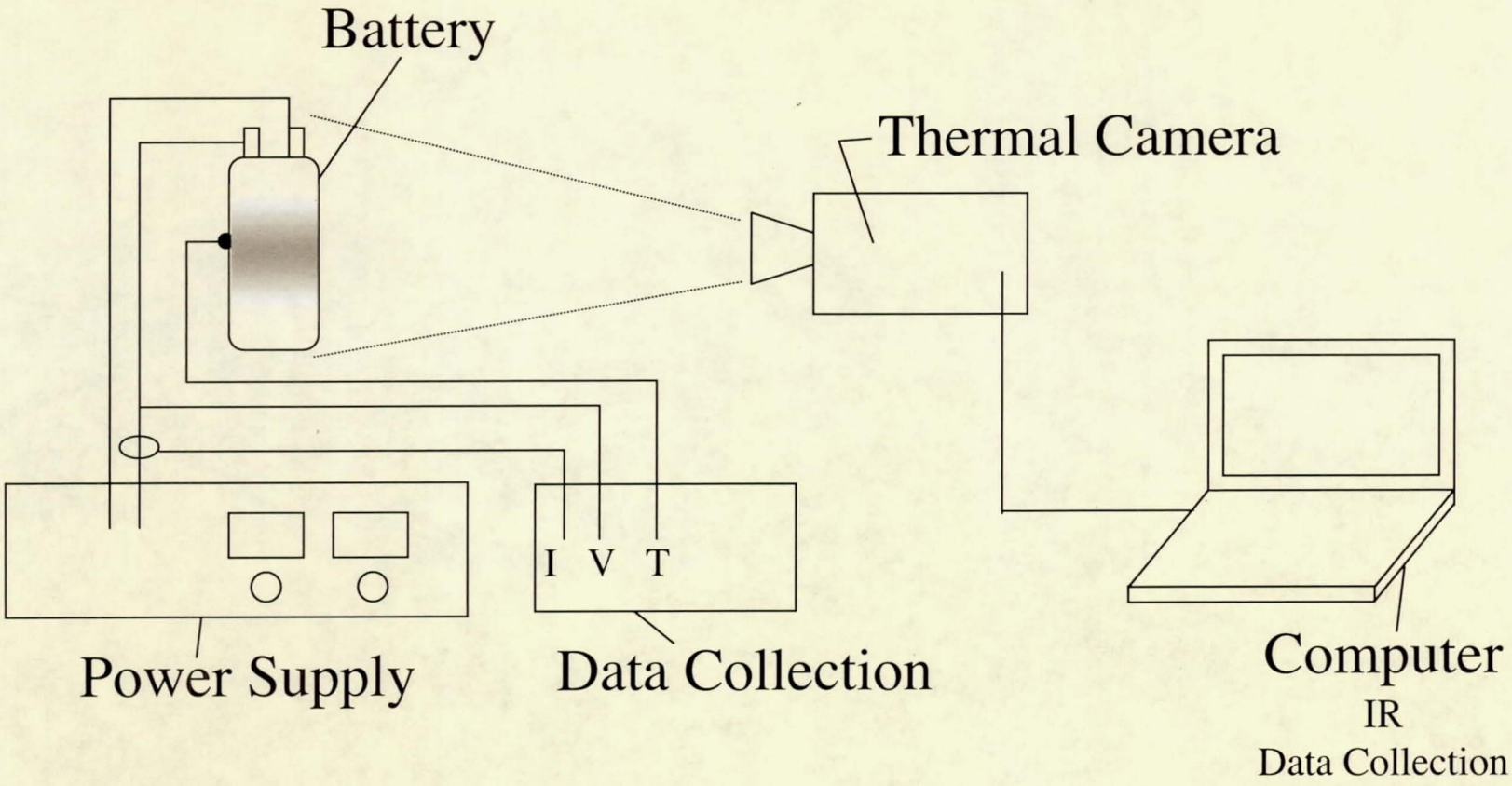
The camera is working on the principle of Blackbody Radiation and works from 7.5μm to 13μm wavelengths.

Light is from 0.40μm to 0.70 μm.

The object under investigation needs to have constant and known emissivity. (preferably > 0.7)

All measured Temperatures are Surface Temperatures

Experimental: Block Diagram



NiH_2 Cell:

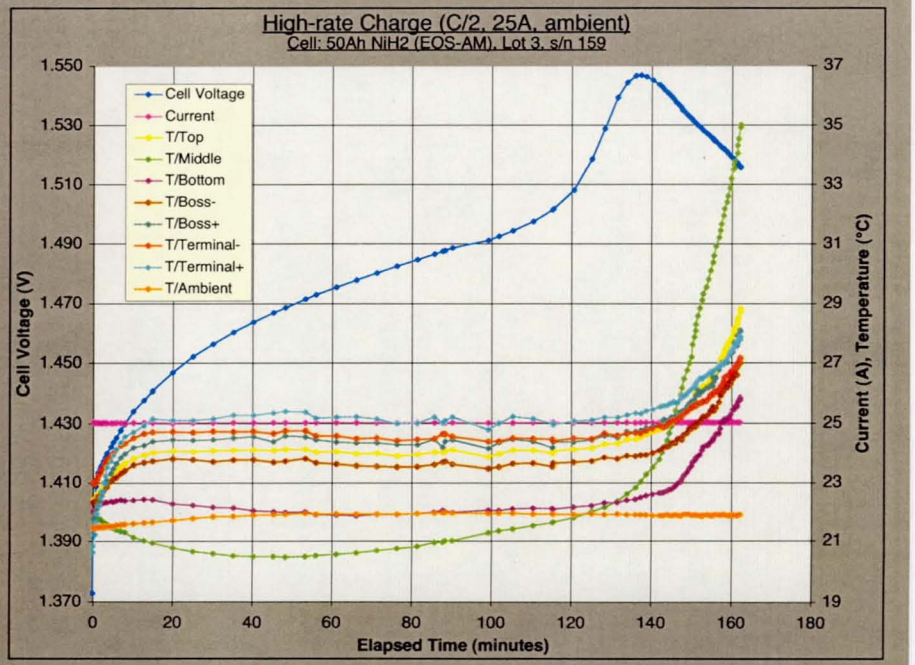
Thermal Image

during

Charge

@

C/2



NiH_2 Cell:

Thermal Image

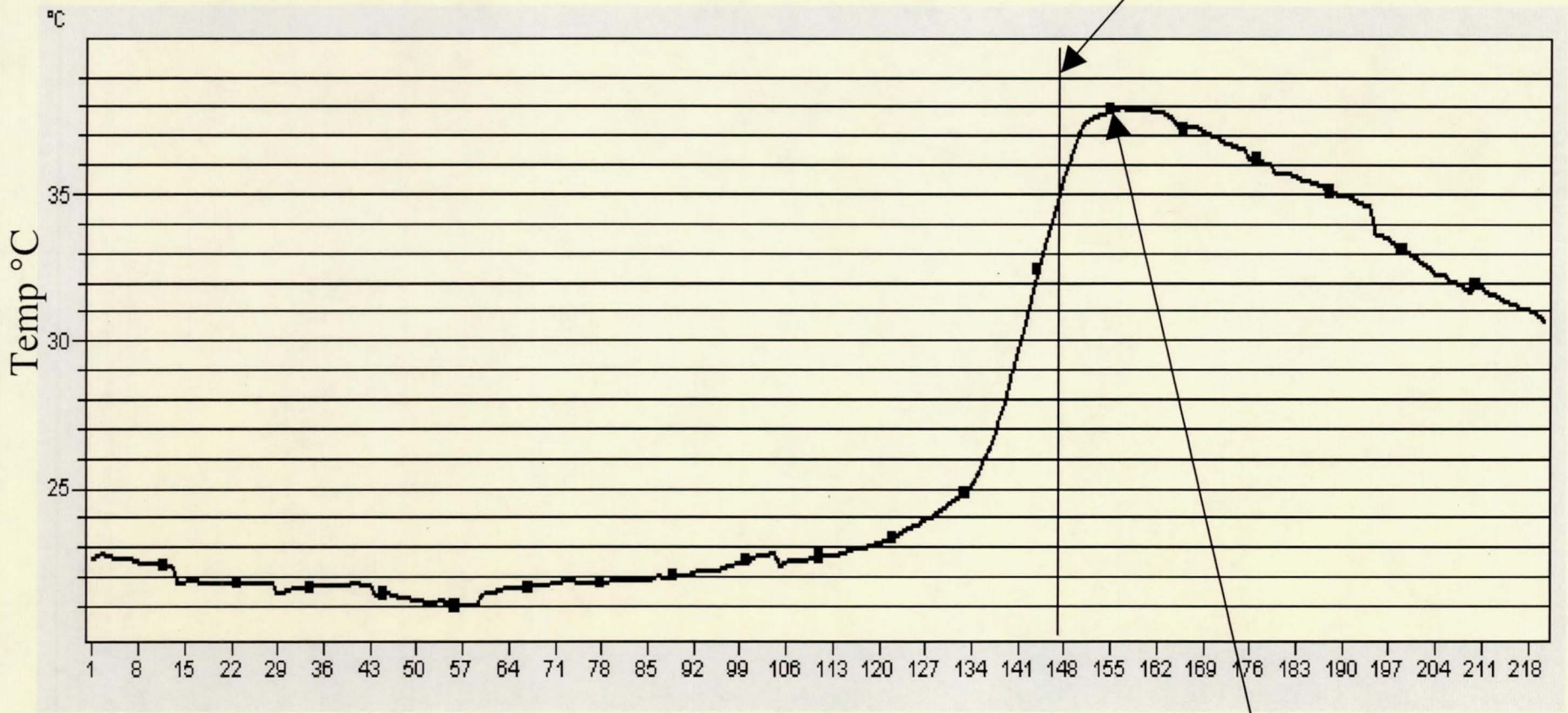
during

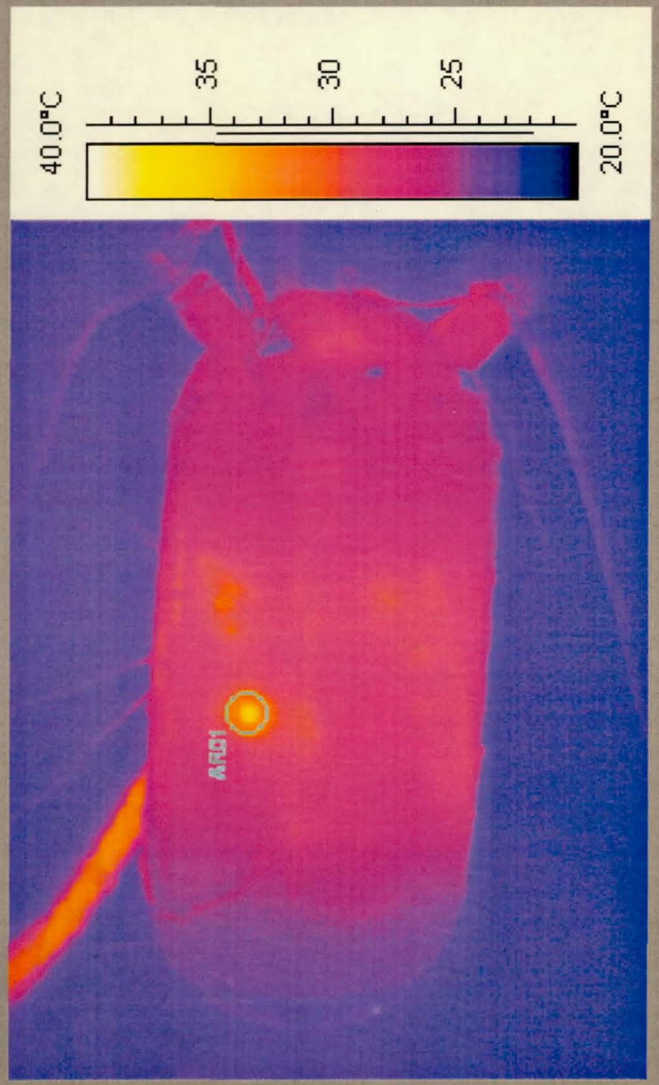
Discharge

@

C/2

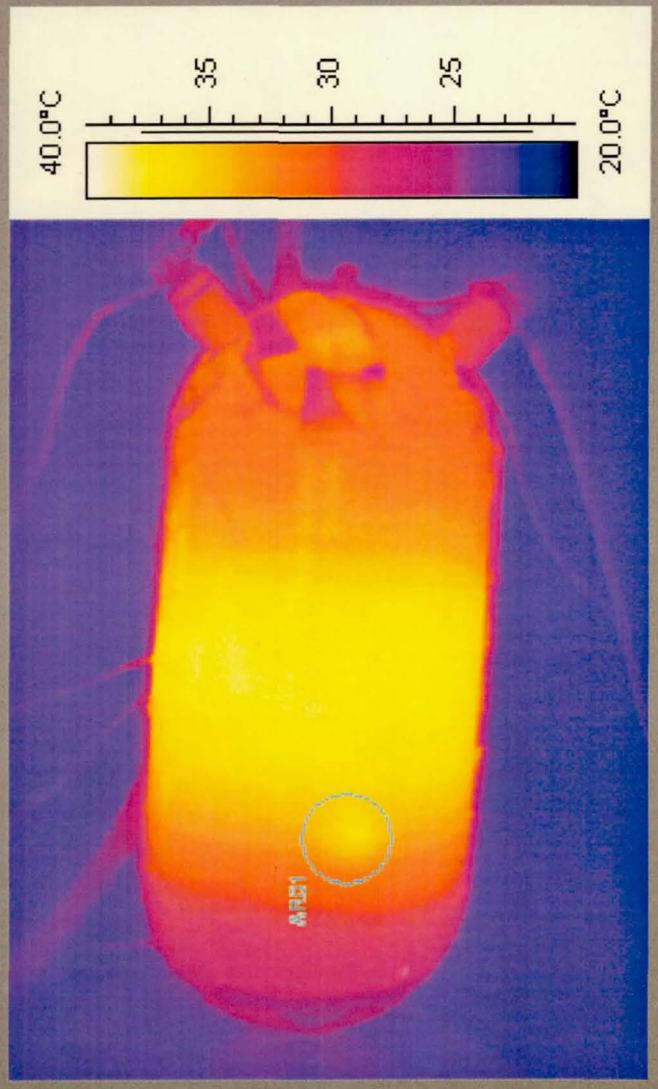
NiH_2 Cell: Thermal data as obtained from IR Camera Over Full Charge





NiH_2 Cell: Popping Noted at noted Circle

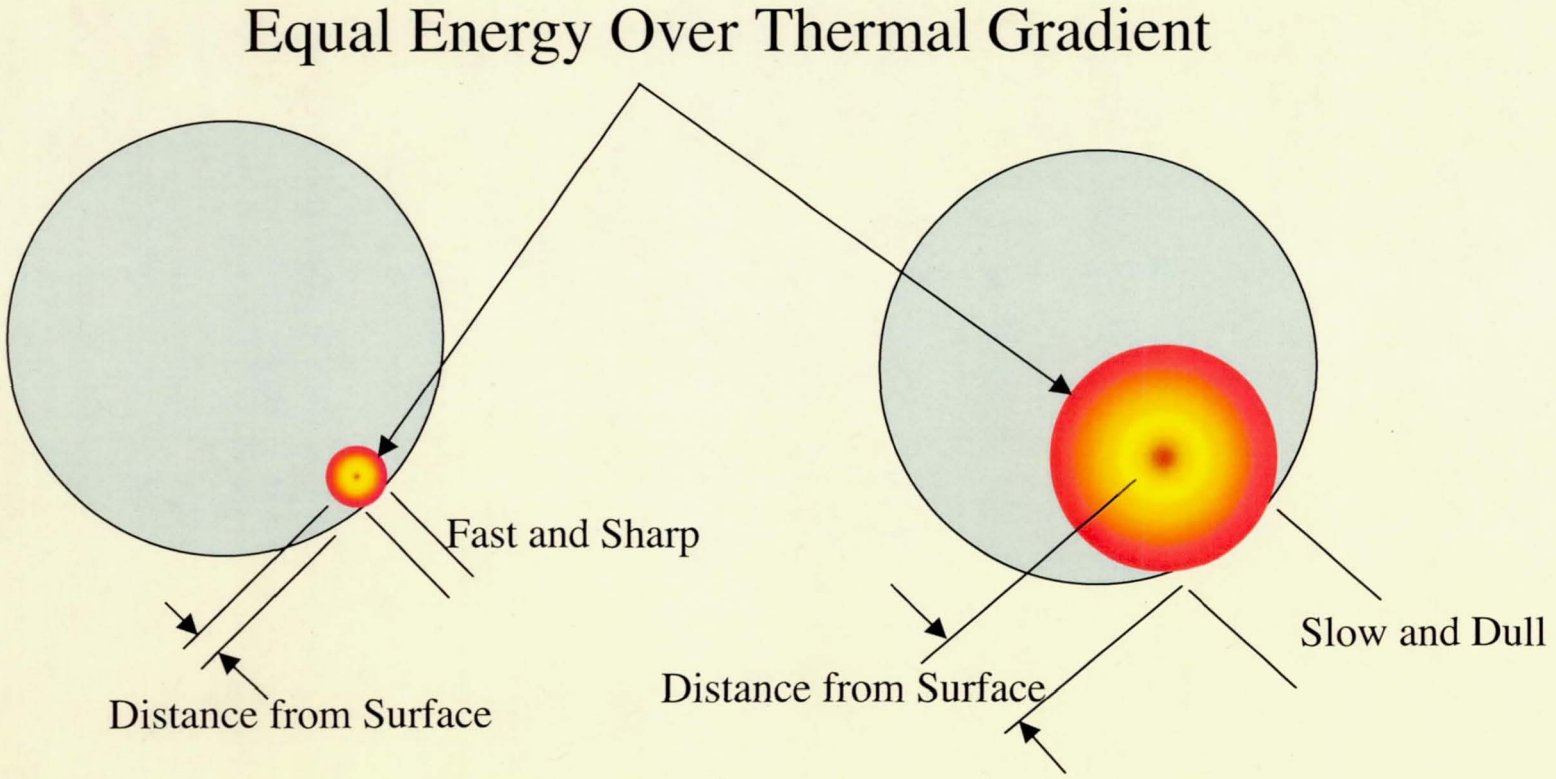
Short and Defined Surface Feature



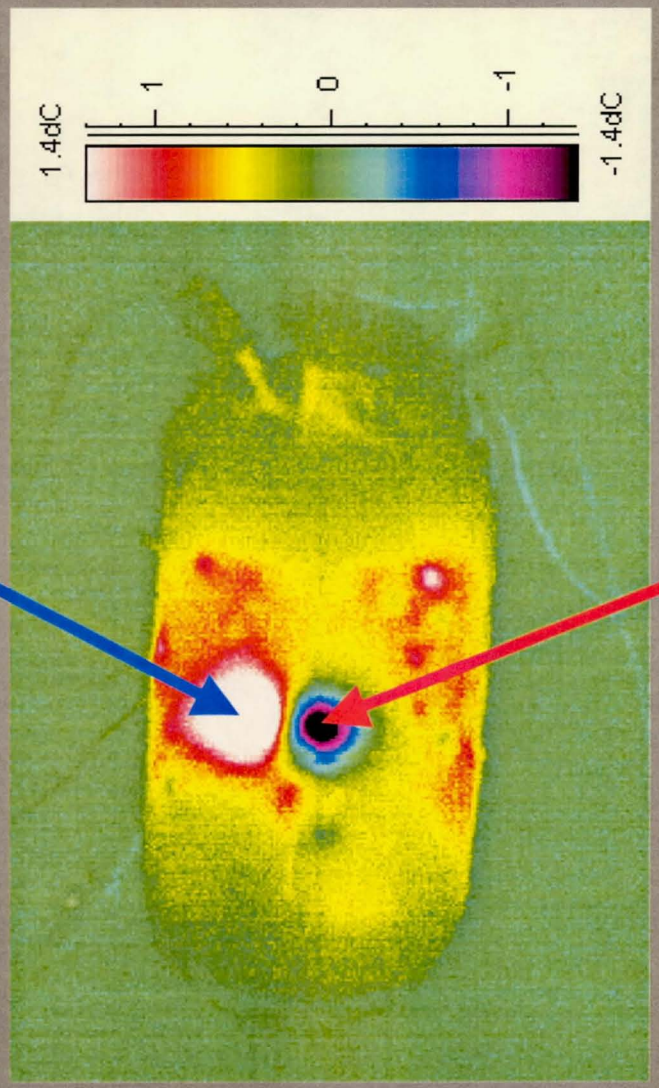
NiH_2 Cell: Popping Noted at noted Circle

Defuse Interior Feature

NiH_2 Cell: Thermal Explanation of Popping



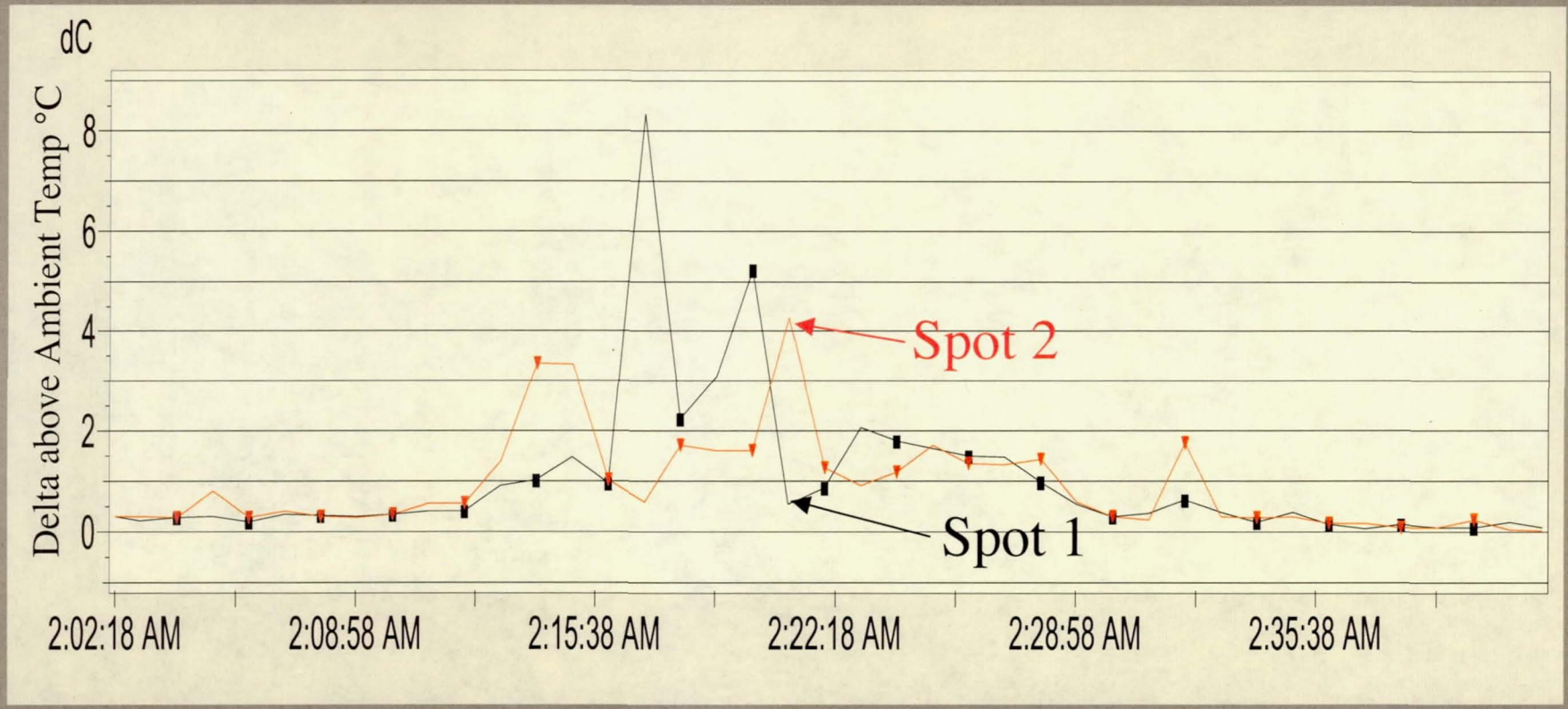
NiH_2 Cell: Popping in Differential Mode



Popping-Going Hot
Spot 2

Post-Popping Return to
Ambient
Spot 1

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



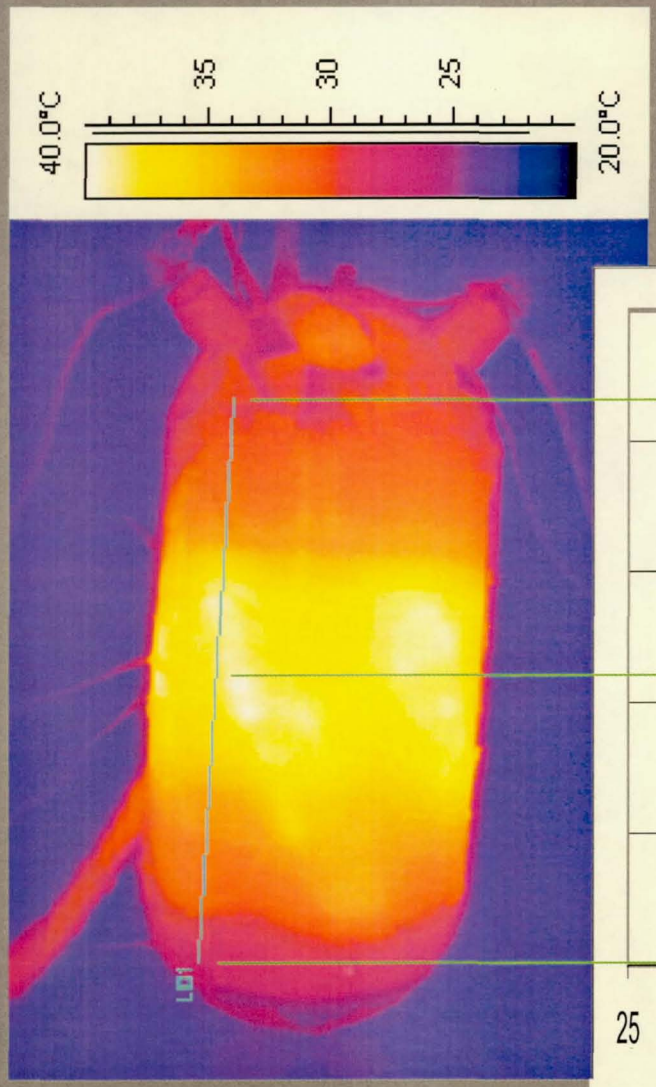
Note: Each plot has multiple steps of heating.

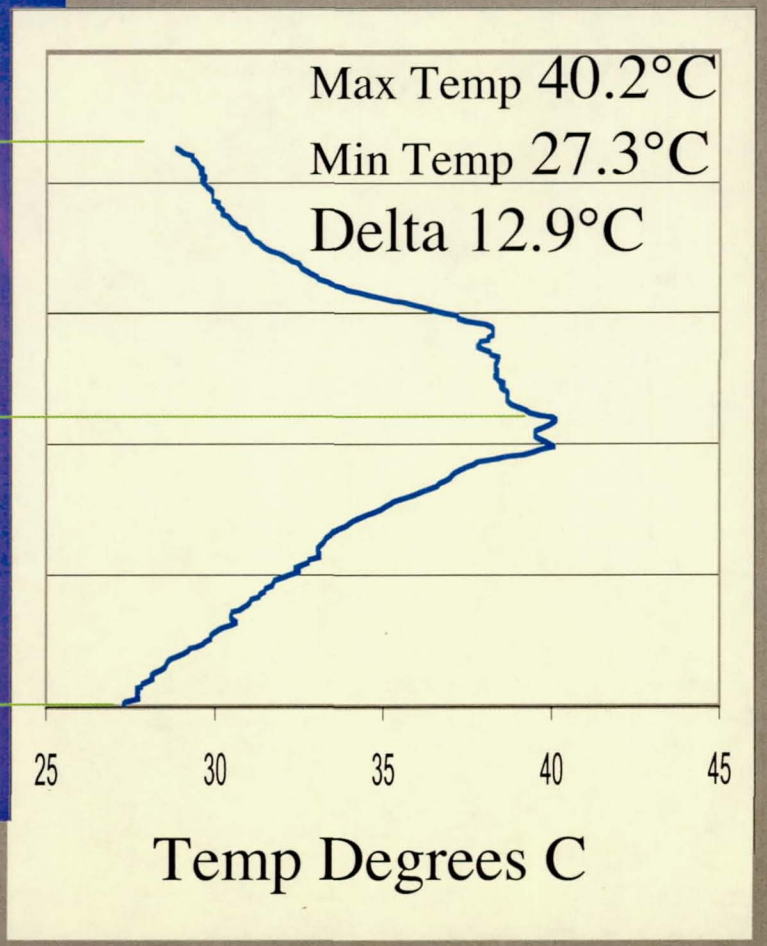
NiH_2 Cell: Popping Depicted as Circles

Count of pops varies from ~10 to >44

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

NiH_2 Cell: Battery Temperature Profile Vertical Crosscut Charge





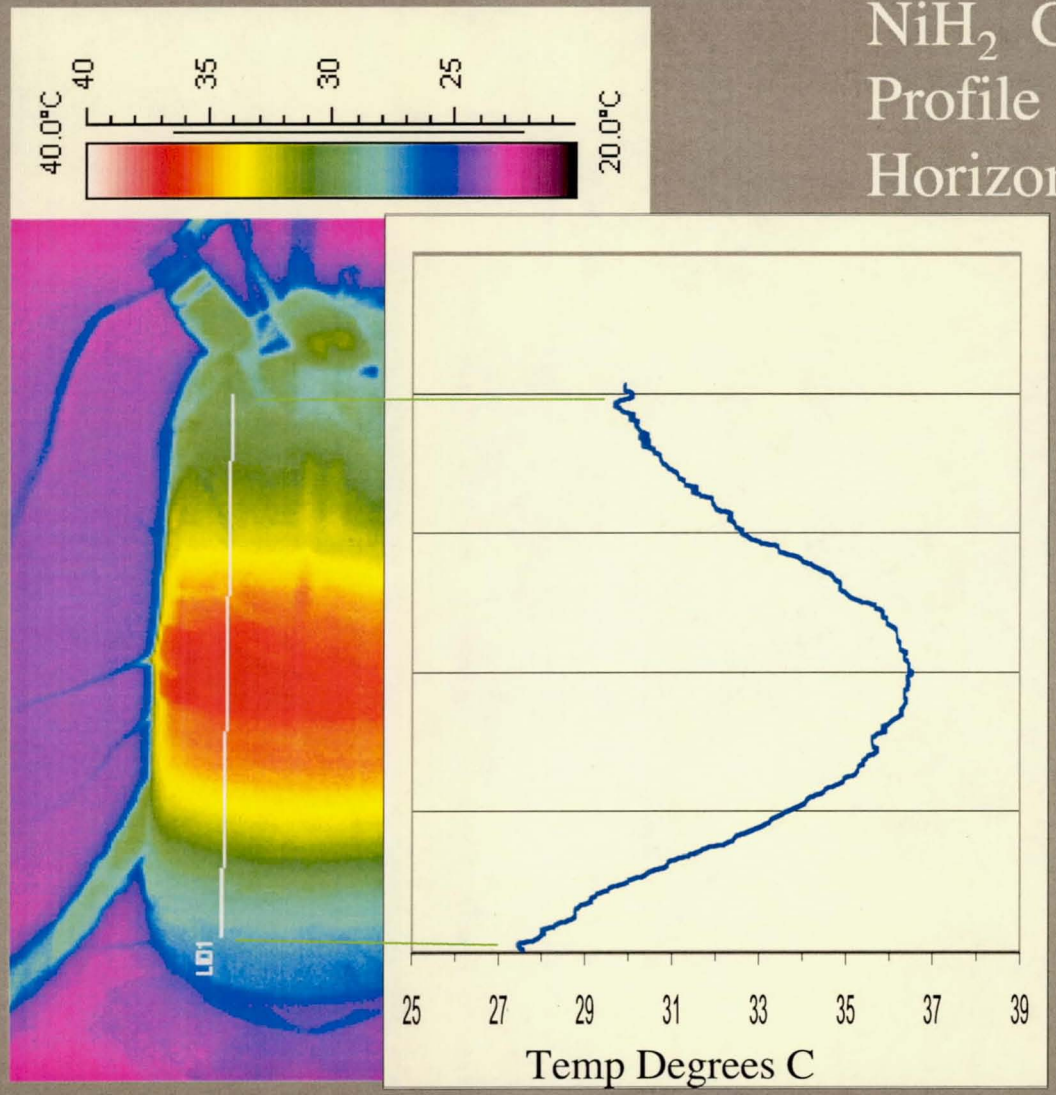
NiH_2 Cell: Battery Temperature Profile Horizontal Crosscut

Charge

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

Catalytic Strip

NiH_2 Cell: Battery Temperature Profile Horizontal Crosscut



Discharge After Cell was allowed to return to Ambient

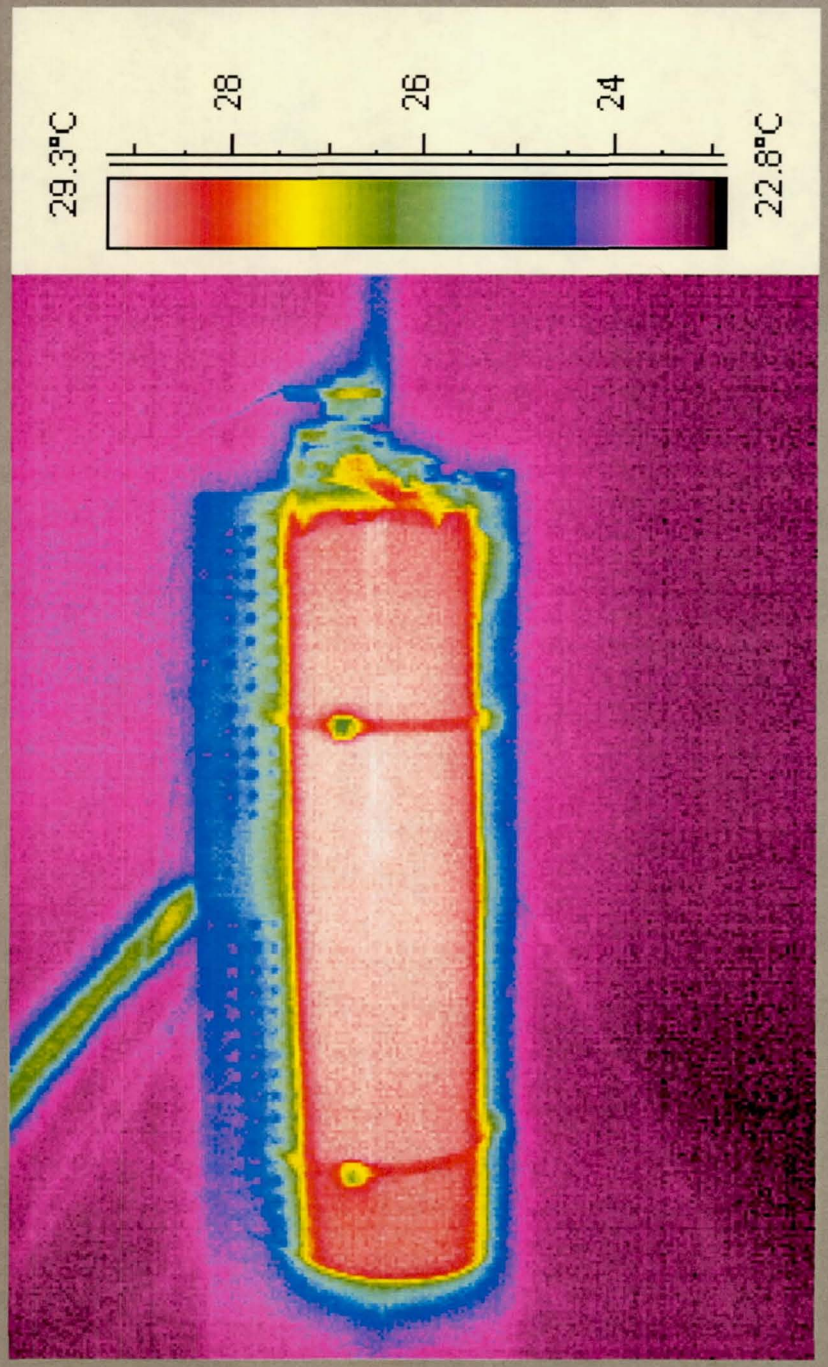
Max Temp 36.6°C
Min Temp 27.4°C
Delta 9.2°C

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:

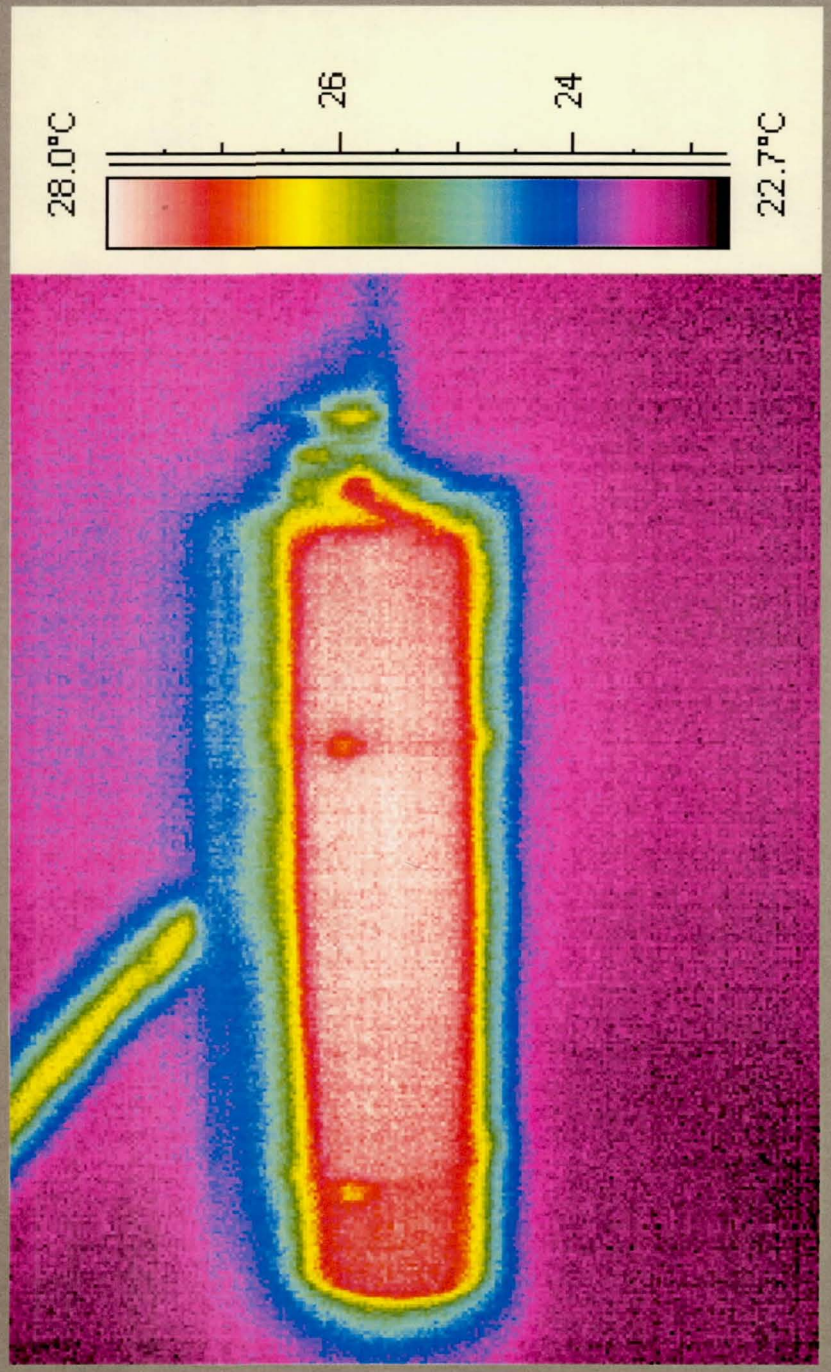
Thermal Image

during

Charge

@

C/2



Li-Ion Cell:

Thermal Image

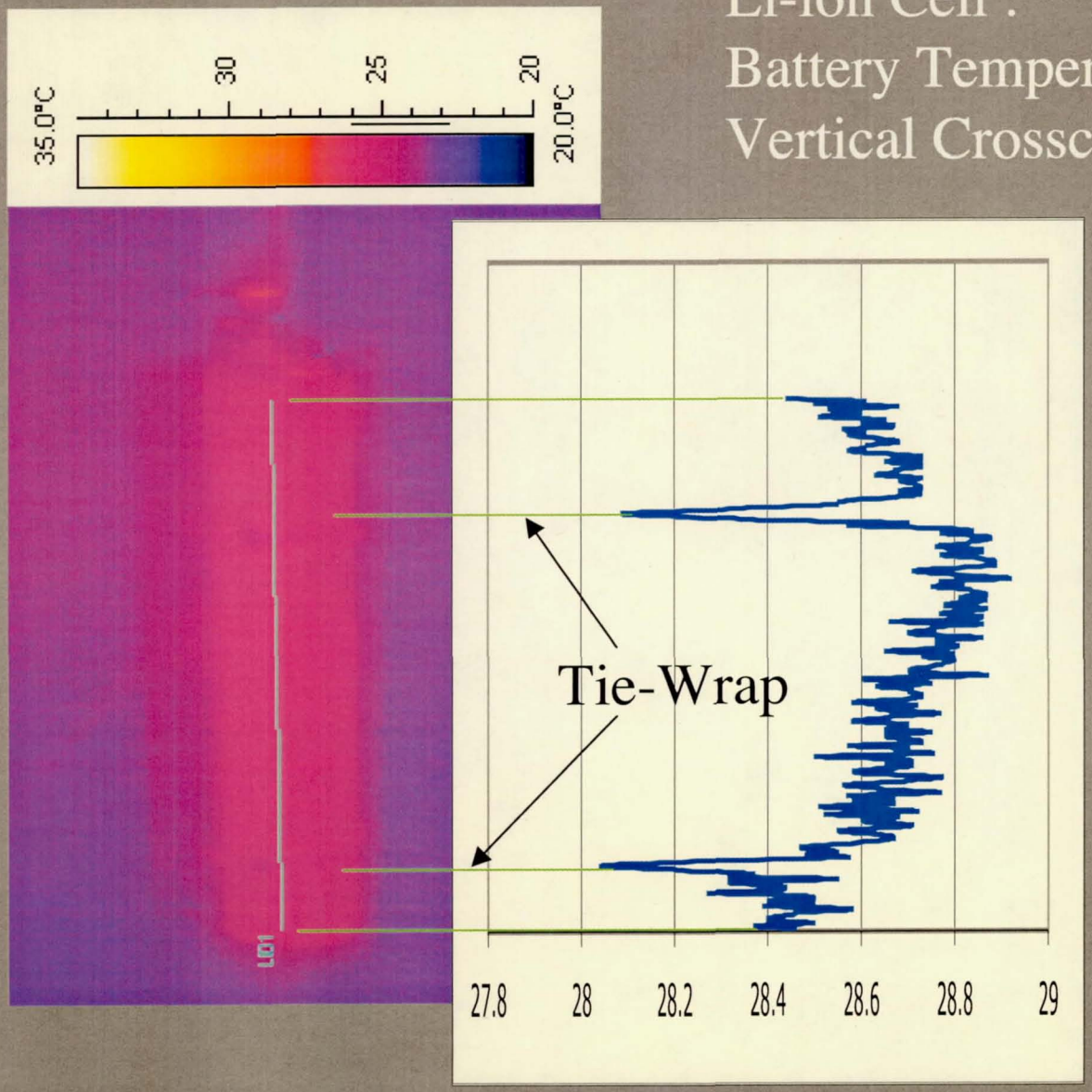
during

Discharge

@

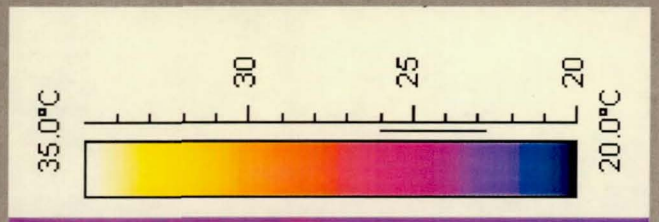
C/2

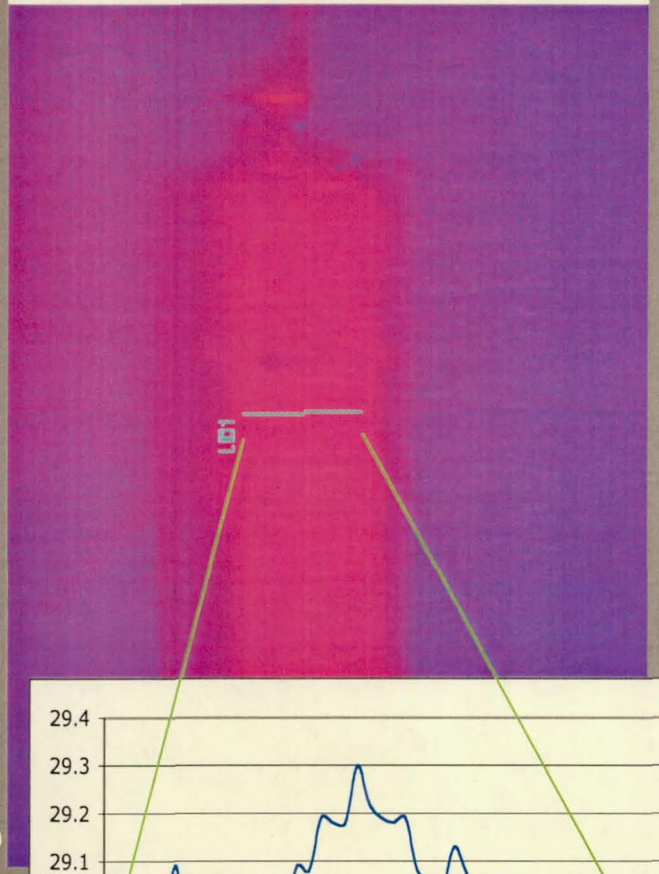
Li-ion Cell :
Battery Temperature Profile
Vertical Crosscut

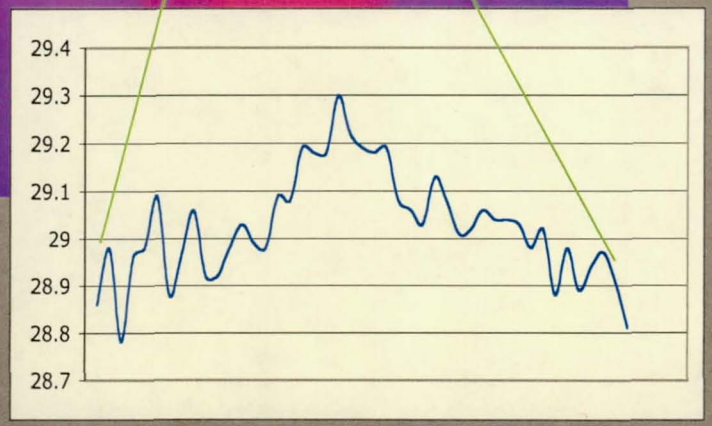


Max Temp 28.9°C
Min Temp 28.0°C*
Delta 0.9°C

*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

Li-Ion Cell: Summary

- Surface Thermal profiles have been studied for 40 Ah Lithium-Ion Cell
- Charge (C/2 charge at Voltage Limit of 4.1V)
- 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