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NASA Johnson Space Center
Engineering Directorate
Propulsion and Power Division

1993 NASA Aerospace Battery Workshop

Eric Darcy

11/18/93

Determination of Thermal Properties of Commercial Ni-MH Cells

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Outline	Propulsion and Power Division	
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- Objectives
- Test plan
- Status and schedule
- Preliminary calorimetric findings
- Summary and future tests

Objectives

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Test Objectives

- To evaluate the electrical and thermal performance of commercial Ni-MH cells
- To evaluate the effectiveness of commercial charge control circuits
- To assess the abuse tolerance of these cells
- To correlate performance and abuse tolerance to cell design via disassembly

Design Objectives

- To determine which cell designs are most suitable for scale-up
- To guide the design of future Shuttle and Station based battery chargers

Test Plan

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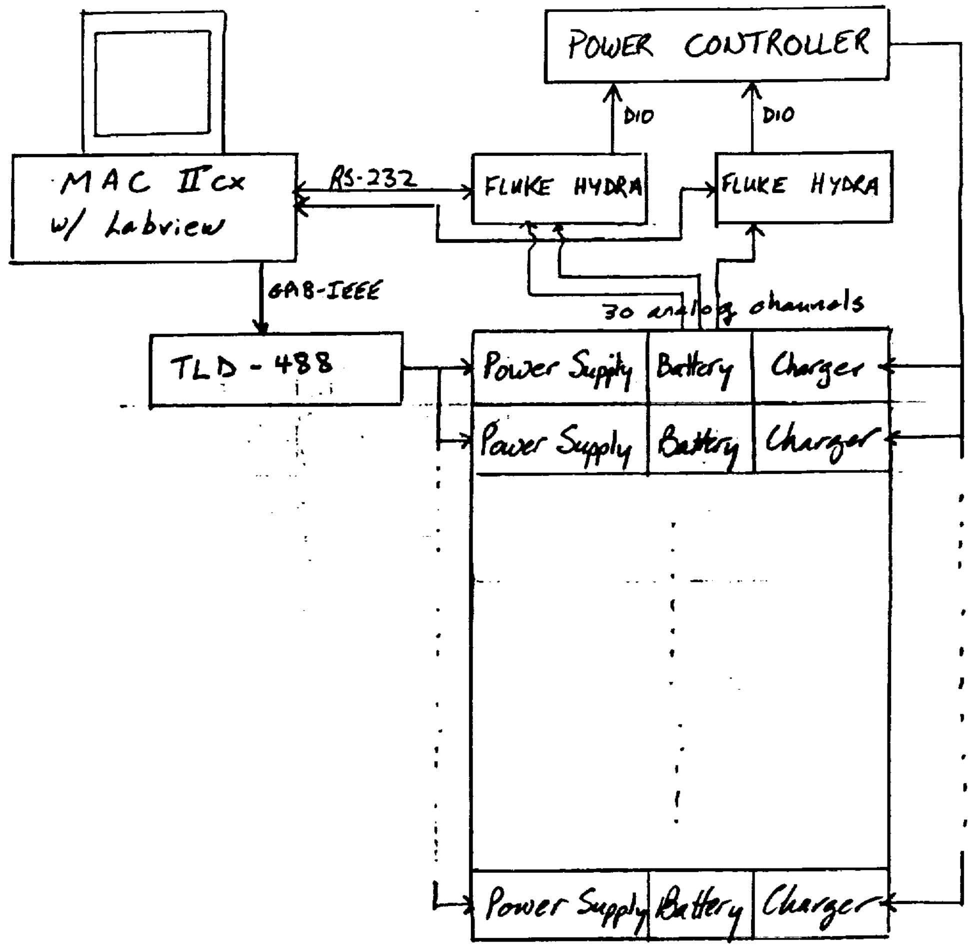
Cell types
- AB2 - Ovonic C, Harding A and AA
- AB5 - Furikaya prismatic, Gates 4/5A, Sanyo 4/3A, Toshiba 4/5 C

Chargers	Component	Current control	Cut-off method
Benchmarq	DV2003S1	const current	$-\partial V/\partial t$, $\Delta T/\Delta t$
Enstore	ECS-II	4 step current	V inflection
ICS	1700-EB	Reflex current	V inflection
Maxim	MAX712EV	const current	$\partial V/\partial t=0$

1 st Performance Evaluation using L18 Taguchi Matrix
- 3 cell types - Harding A, Sanyo 4/3A, Toshiba 4/5A
- 3 chargers - Benchmarq, Enstore, Maxim
- 3 cyling rates (cycling at 100% DOD)
  - low - C/10 charge, C/7 discharge
  - medium - C/3 charge, C/2 discharge
  - high - 2C charge, 3C discharge
- 2 temperatures - 25 and 5 deg C

Performance criteria
- Discharge capacity vs cycle
- Ah and Wh cycling efficiency



Schematic of
Automated Battery Cycling Test Stand

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Test Plan (cont.)

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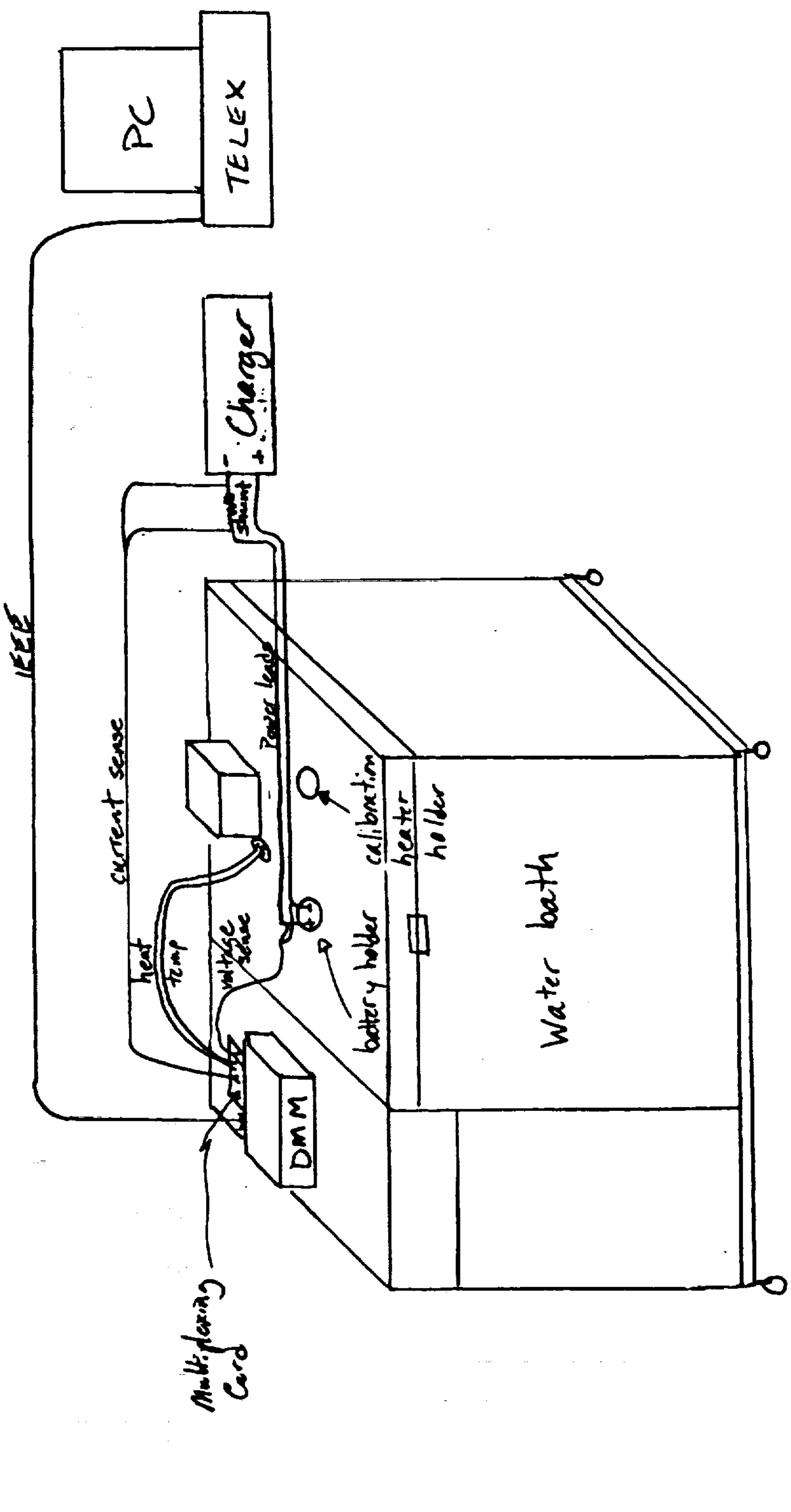
- Calorimetric Evaluation
  - Hart Scientific twin cell calorimeter
    - 200 second time constant
    - 100 μW resolution
- Parameteric Evaluation using L8 Taguchi Matrix
  - 2 cycling rates - medium and high
  - 2 Chargers - Enstore and Maxim
  - 2 Temperatures - 25 and 5 C
  - 2 Cell types - Ovonic C, Sanyo 4/3A
- Evaluation criteria
  - maximum cycle peak heat, W
  - total cycle heat energy, J

Figure 2 Schematic of Twin Cell Calorimeter

(configured for battery calorimetry)



Test Plan (cont.)

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- Abuse Tolerance Assessment on all cell types
  - Overcharge - 2 rates (C/3, 2C), 2 temperatures (25 and 5 C)
  - Overdischarge - 2 rates (C/3, 2C), 2 temperatures (25 and 5 C)
  - Short Circuit - 100 mΩ and 50 mΩ, 2 temperatures (25 and 5 C)
  - Heat-to-Vent

- Destructive Physical Analysis to determine
  - Cell pressure and gas composition
  - Porosity distribution, bulk porosity, total surface area of hydride
  - Electrolyte composition and concentration
  - Reaction distribution across cell cross-section
  - Hydride surface composition (XPS and AES)

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Test status and schedule

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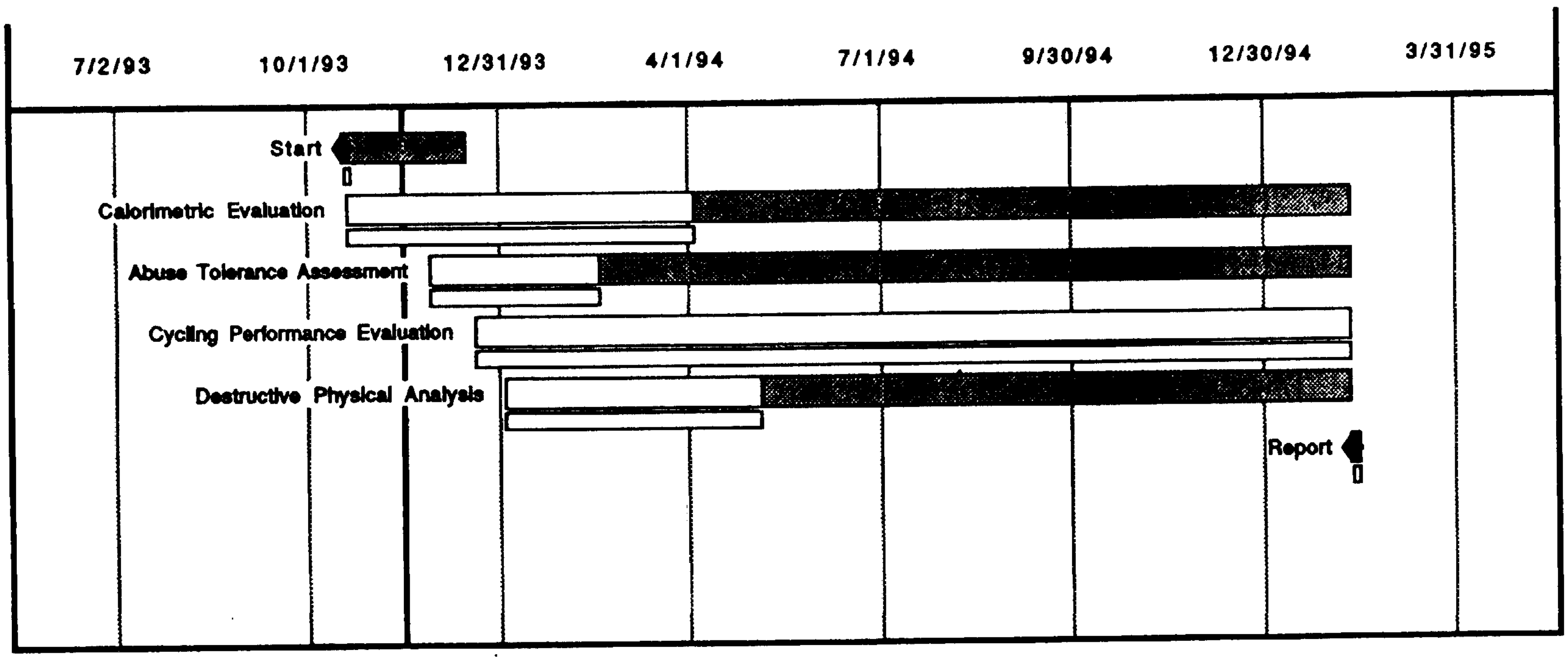

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Calorimetric Findings

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Fig. 1 - Ovonic cells, Enstore charger, low rate (0.5 A charge, 0.5 A discharge)
- Enstore charge fails to terminate at low rate
- 7.5 Ah total charge input with 3.25 Ah discharge output
- Inflection of heat profile occurs at 3.5 Ah (~100% SOC)
- Heat profile levels out to a steady rate of 0.54 W

Fig 2 & 3 - Enstore charger vs Maxim charger at high rates and room temp.
- Enstore's 4 step charge method results in lower heat rise on charge
- Enstore results in less heat energy output for the same Ah input
- Enstore's charge resulted in 35% higher capacity return on discharge

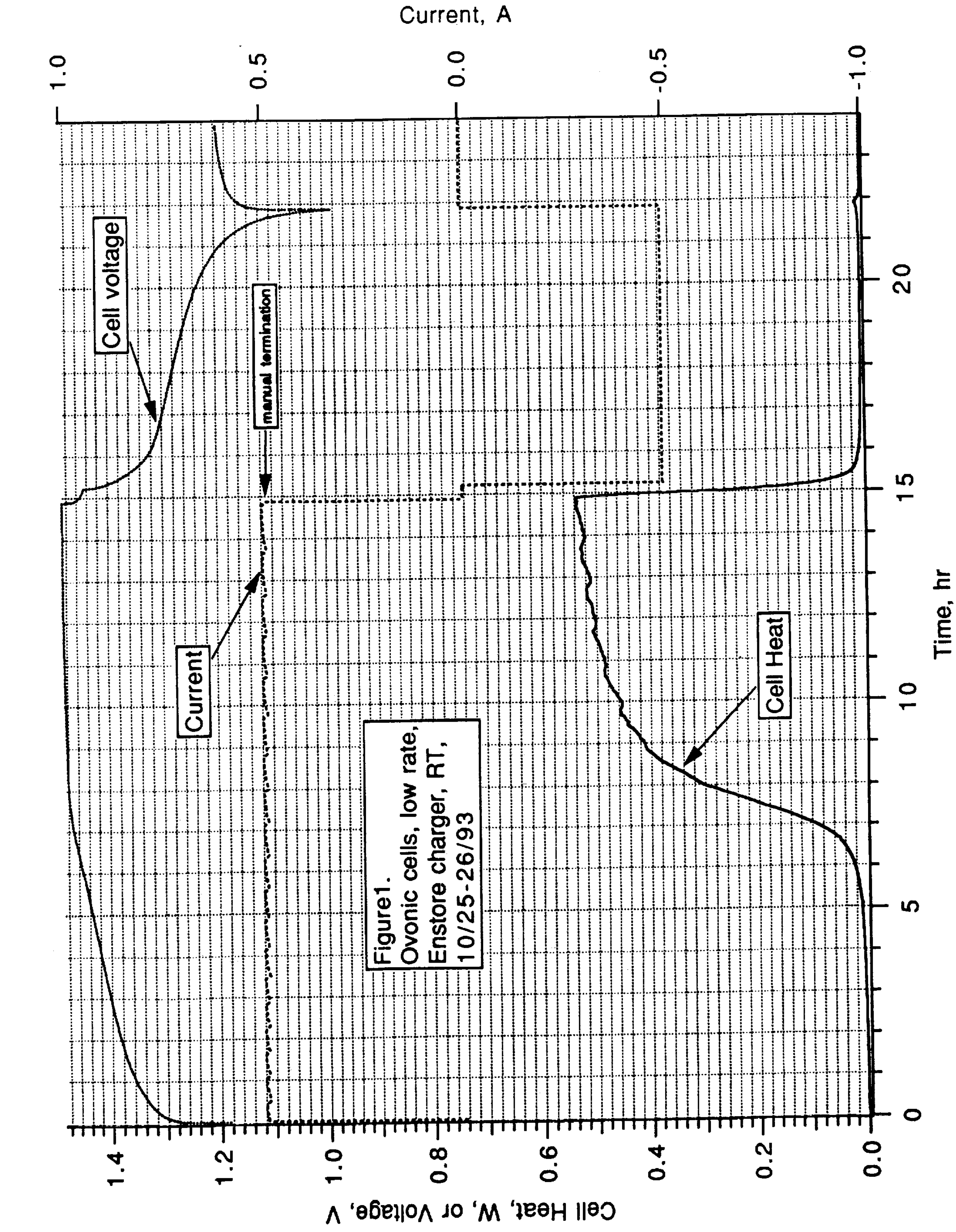


Figure1.
Ovonic cells, low rate,
Enstore charger, RT,
10/25-26/93

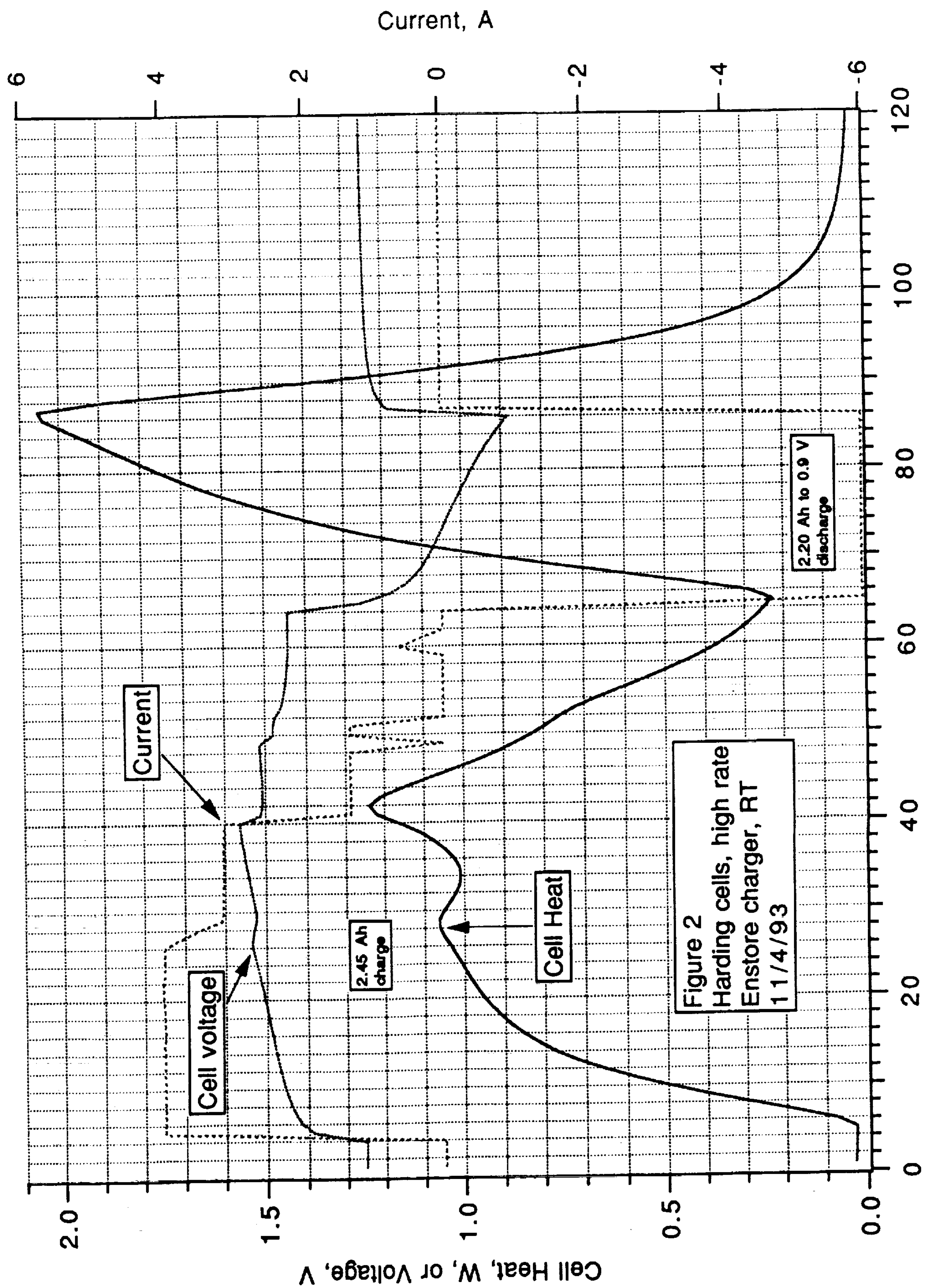
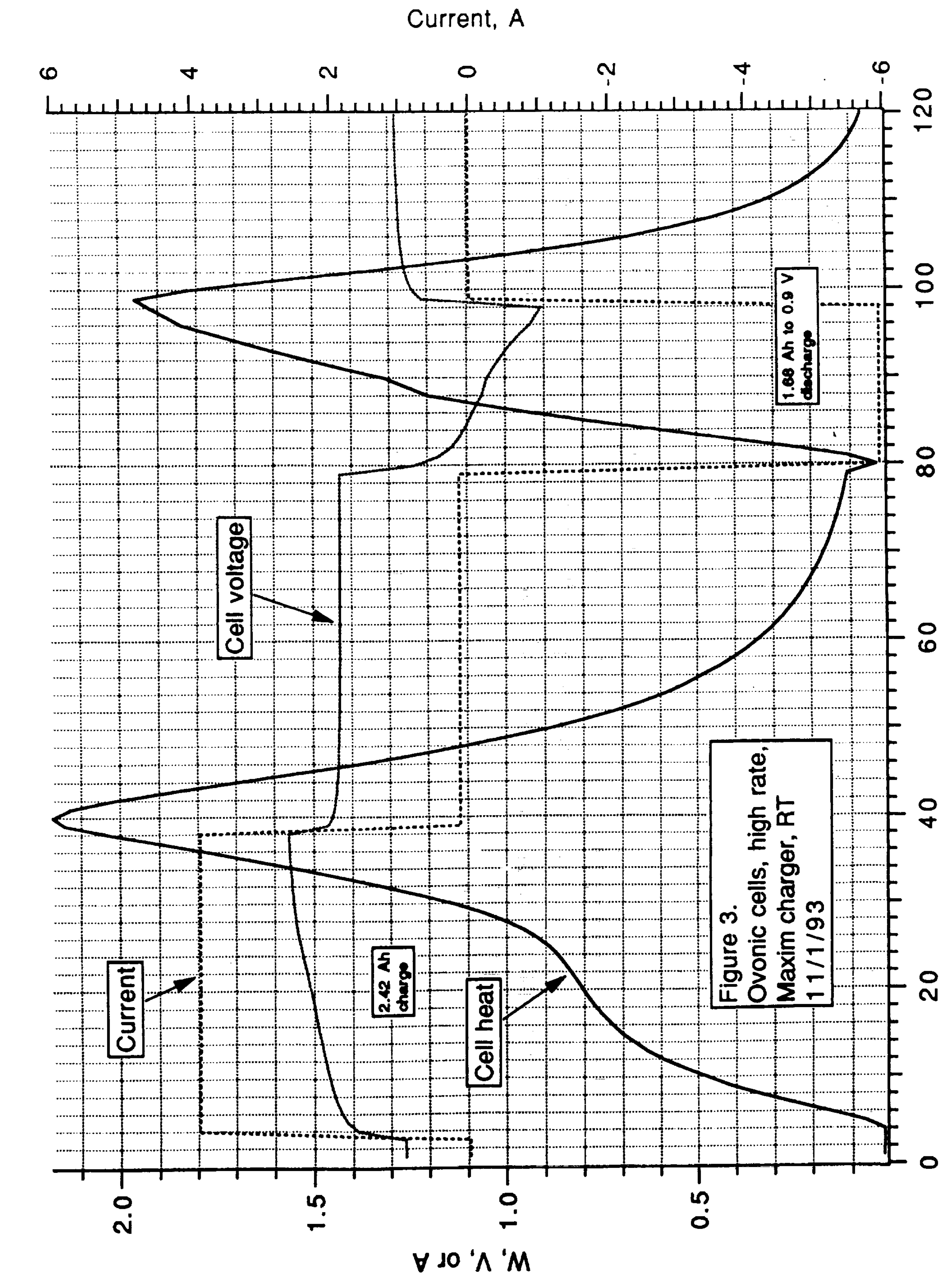


Figure 2
Harding cells, high rate
Enstore charger, RT
11/4/93


Current, A
6
4
2
0
-2
-4
-6
Time, hr
0
20
40
60
80
100
120
W, V, or A
2.0
1.5
1.0
0.5
Current
Cell voltage
Cell heat
2.42 Ah charge
1.68 Ah to 0.9 V discharge
Figure 3.
Ovonic cells, high rate,
Maxim charger, RT
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Findings (cont.)

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Fig 4 - Ni/Cd vs Ni/MH C-cells with the Maxim charger

- 1.17 A charge with 1.75 A discharge at RT
- Ni/Cd commercial cell rated at 1.8 Ah from Golden Power, type KR1800C
- Ni/MH charge input is lower, 3.92 vs 4.78 Ah with the $\partial V/\partial t=0$ method
- Ni/Cd charges cooler up to 2.67 Ah
- Ni/Cd generates more heat energy on charge which steadily climbs
- Ni/MH delivered 3.35 Ah vs 1.96 Ah to 1 V
- Ni/MH discharges with much less heat generation

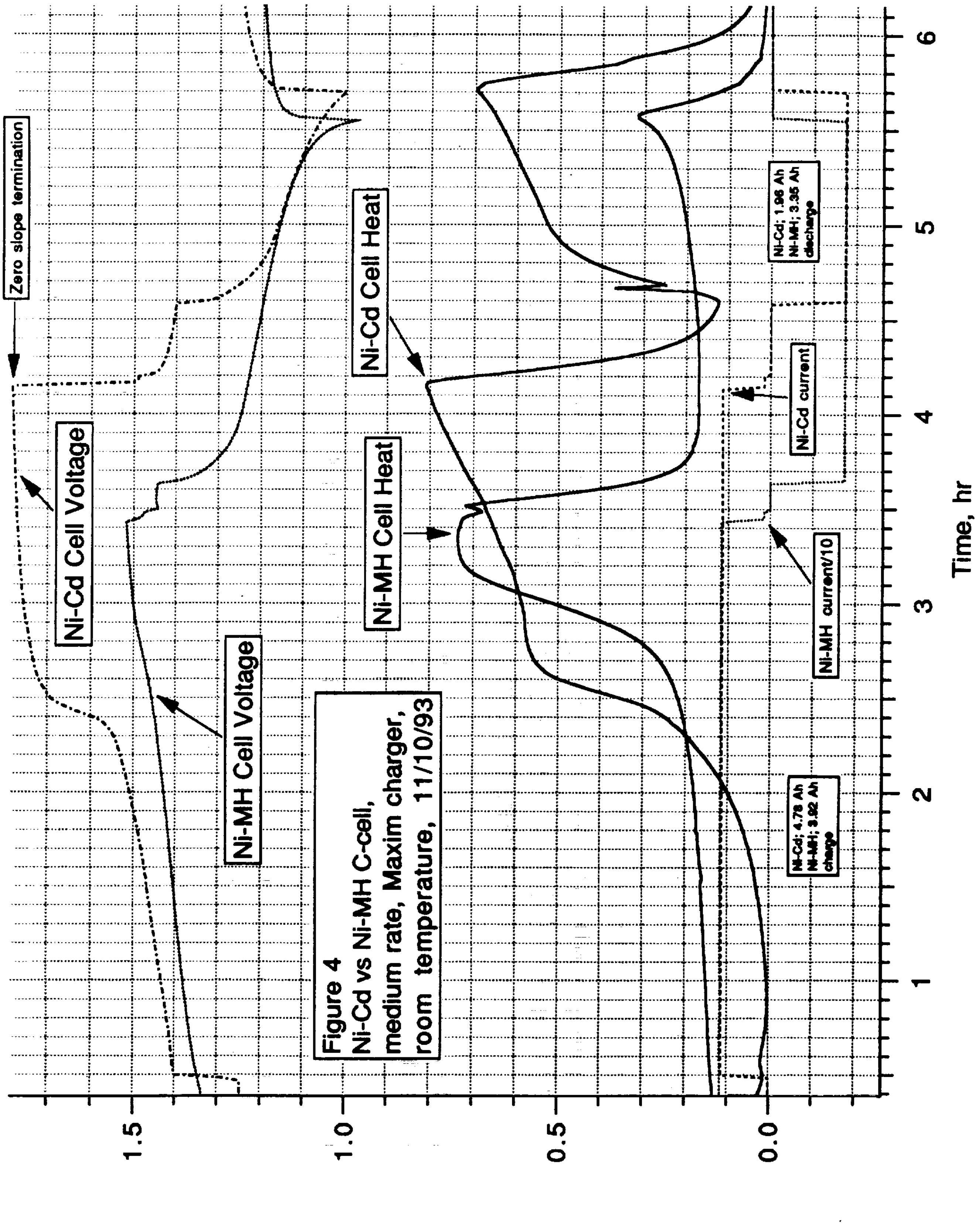

Figure 4
Ni-Cd vs Ni-MH C-cell, medium rate, Maxim charger, room temperature, 11/10/93

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Summary and future tests

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- Reflex charging with ICS circuit resulted in premature charge termination
  - Future tests - ICS has promised to provide an upgraded charger (ICS-1702) designed specifically for Ni-MH cells
- Ni-MH cells appear very tolerant to overcharge at low rates
  - Future tests - Validate mechanism with more calorimetry and DPA for O2
- Enstore's method is more electrically and thermally efficient at high rates
  - Future tests
    - compare at medium rate
    - compare at low temperature
- Ni-MH cycles much more efficiently than Ni-Cd with the $\partial V/\partial t=0$ termination
  - Future tests
    - compare using the Enstore charger (inflection method)
    - compare at low temperature