Use of Calorimetry for End of Charge Determination

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TESTING of AEROSPACE BATTERIES @ BOEING

CHEMISTRY	SYMBOL	APPLICATIONS
Nickel Hydrogen	NiH_2	Future Power Systems
Nickel Cadmium	NiCd	Small Power Subsystems
Nickel Metal Hydride	NiMH	SEDSAT Experiment
Fibrous Nickel Cadmium	F-NiCd	Starter Battery for Boeing 777
Lithium Thionyl Chloride	$Li-SOCl_2$	NASA Space Qual
Lithium Bromine Complex	Li-BCX	NASA - EVA suit
Zinc Silver Oxide	Zn-AgO	Boeing - IUS

Application of Heat Flow Measurements on Batteries

1) ESTABLISH THERMAL NEUTRAL POTENTIAL

PERMITS CALCULATION OF HEAT FLOW FROM VOLTAGE

2) IDENTIFY INEFFICIENT CHARGING

$$\beta\text{-NiOOH} + H_2O + e^- \Leftrightarrow \beta\text{-Ni(OH)}_2 + OH^-$$

$$H_2 + 1/2O_2 \Rightarrow H_2O + Q$$

3) UNDERSTAND SELF DISCHARGE MECHANISMS

$$2\ NiOOH + H_2 \Rightarrow 2\ Ni(OH)_2 \qquad \Delta H = 144.85\ kJ/mole$$

4) PROVIDE ACCURATE VOLTAGE/TEMP. DATA

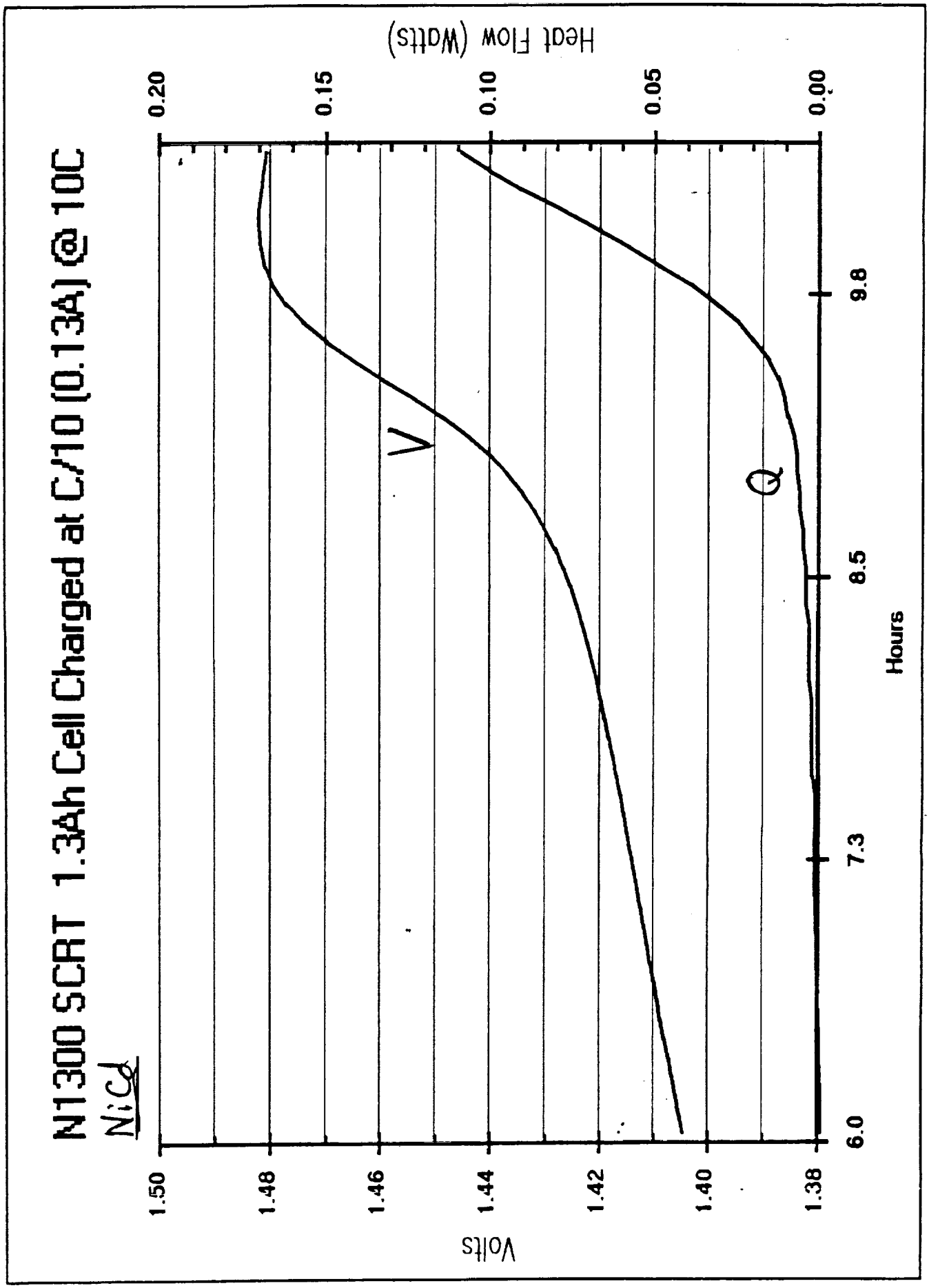
PARAMETRIC DATA NEEDED FOR VT CONTROL

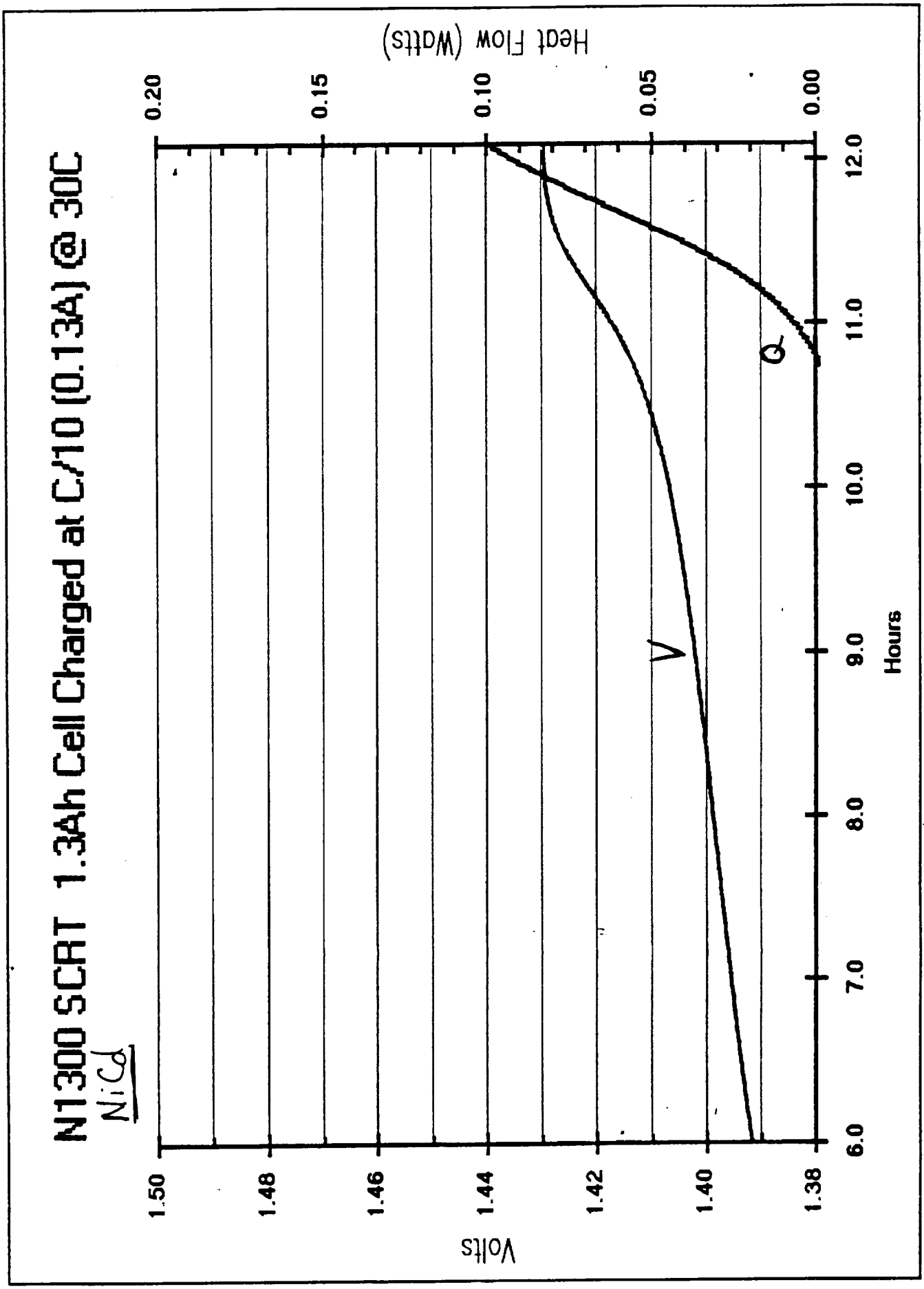
INDICATORS of INEFFICIENT CHARGING

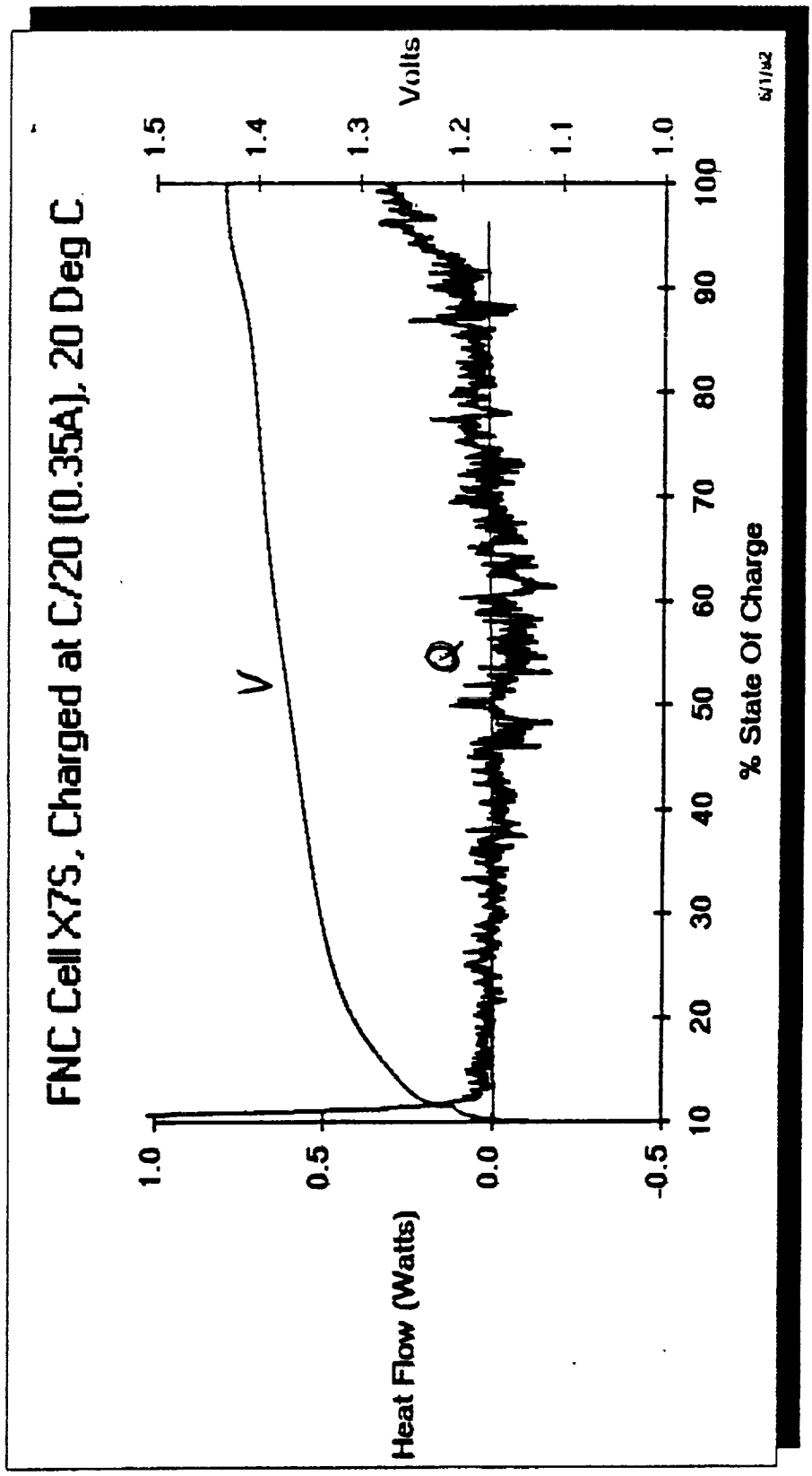
1) INCREASED HEAT FLOW FROM H_2 + O_2 RECOMBINATION REACTION

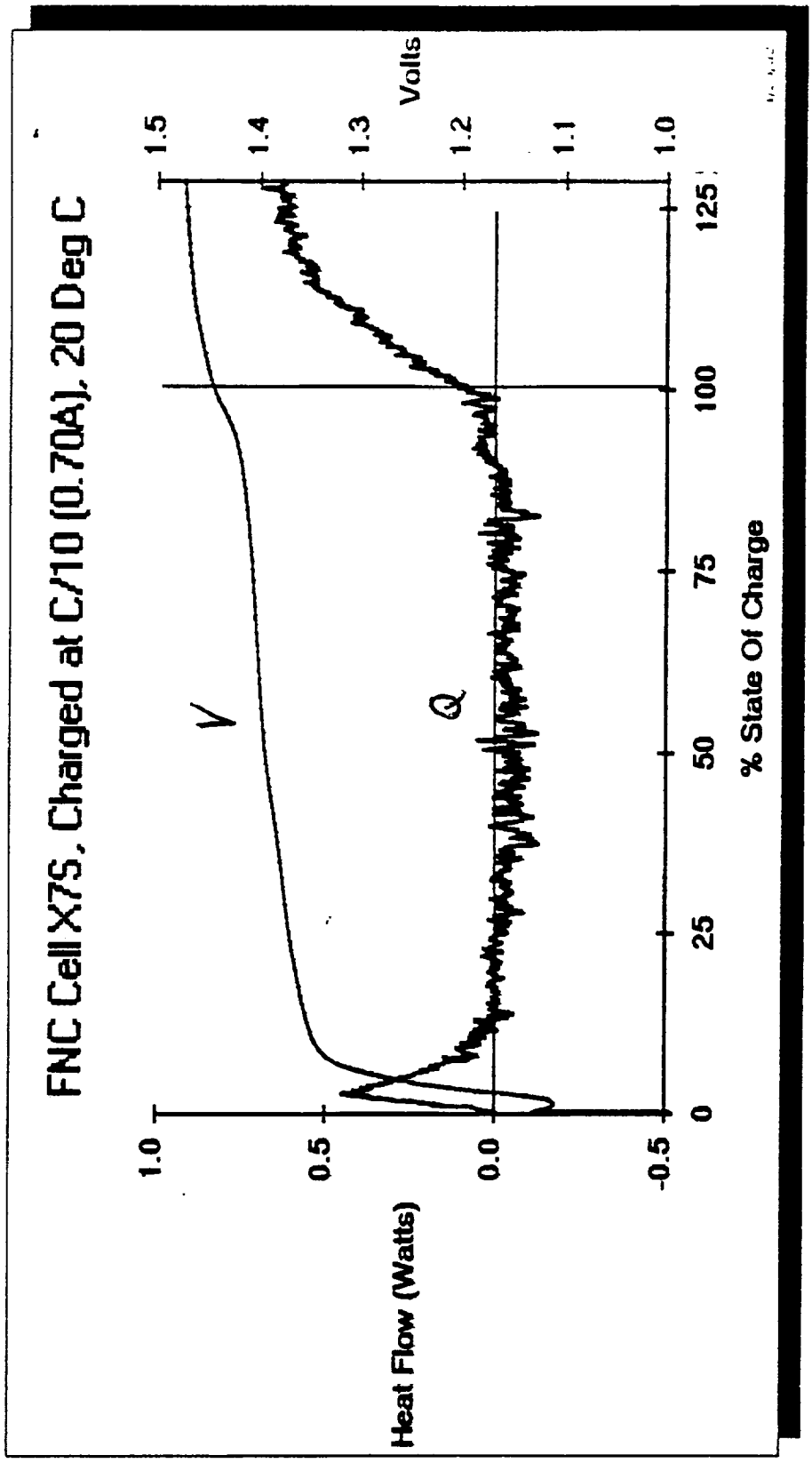
2) VOLTAGE "ROLL OVER"

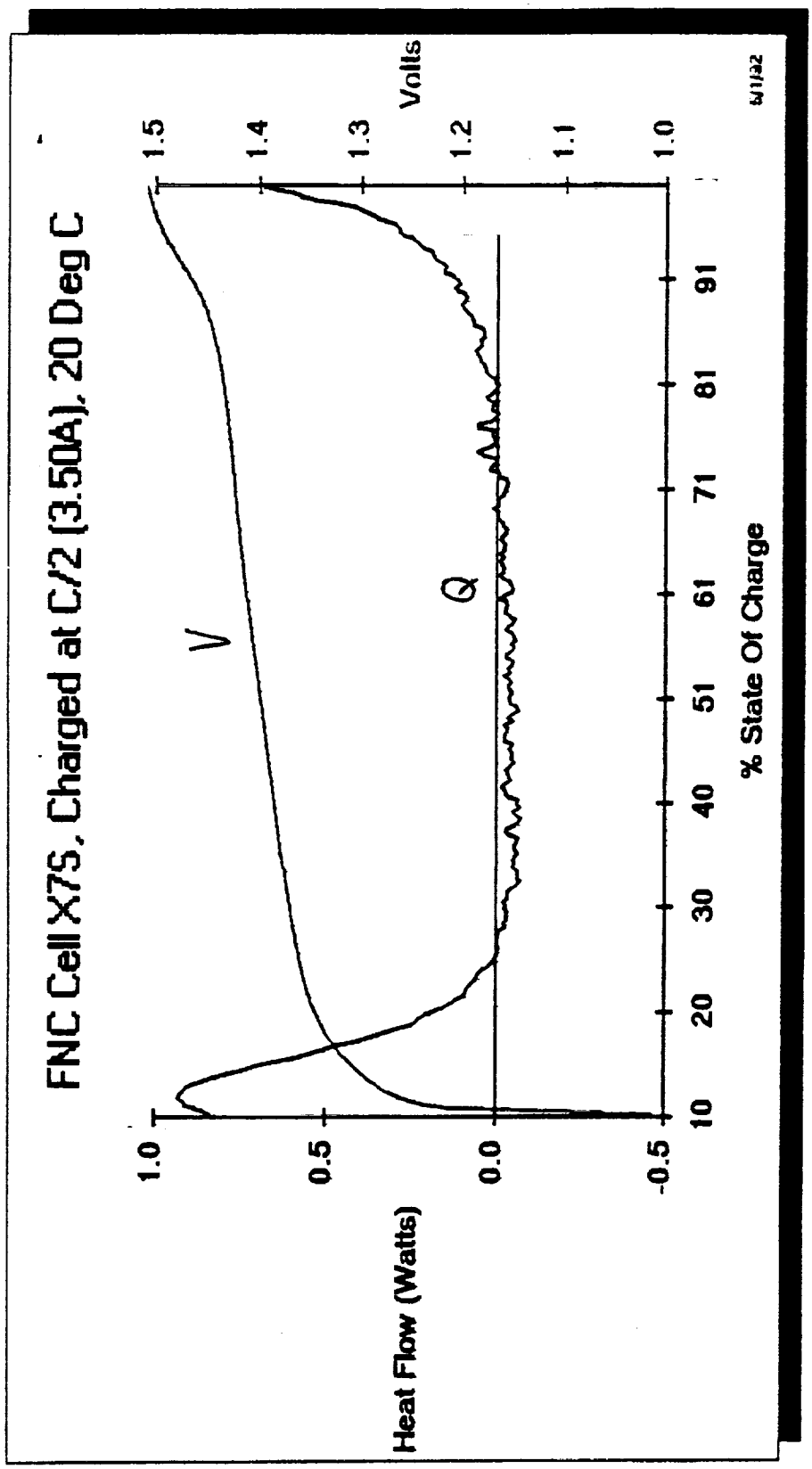
3) LOSS of LINEAR INCREASE IN PRESSURE on NiH_2 CELLS

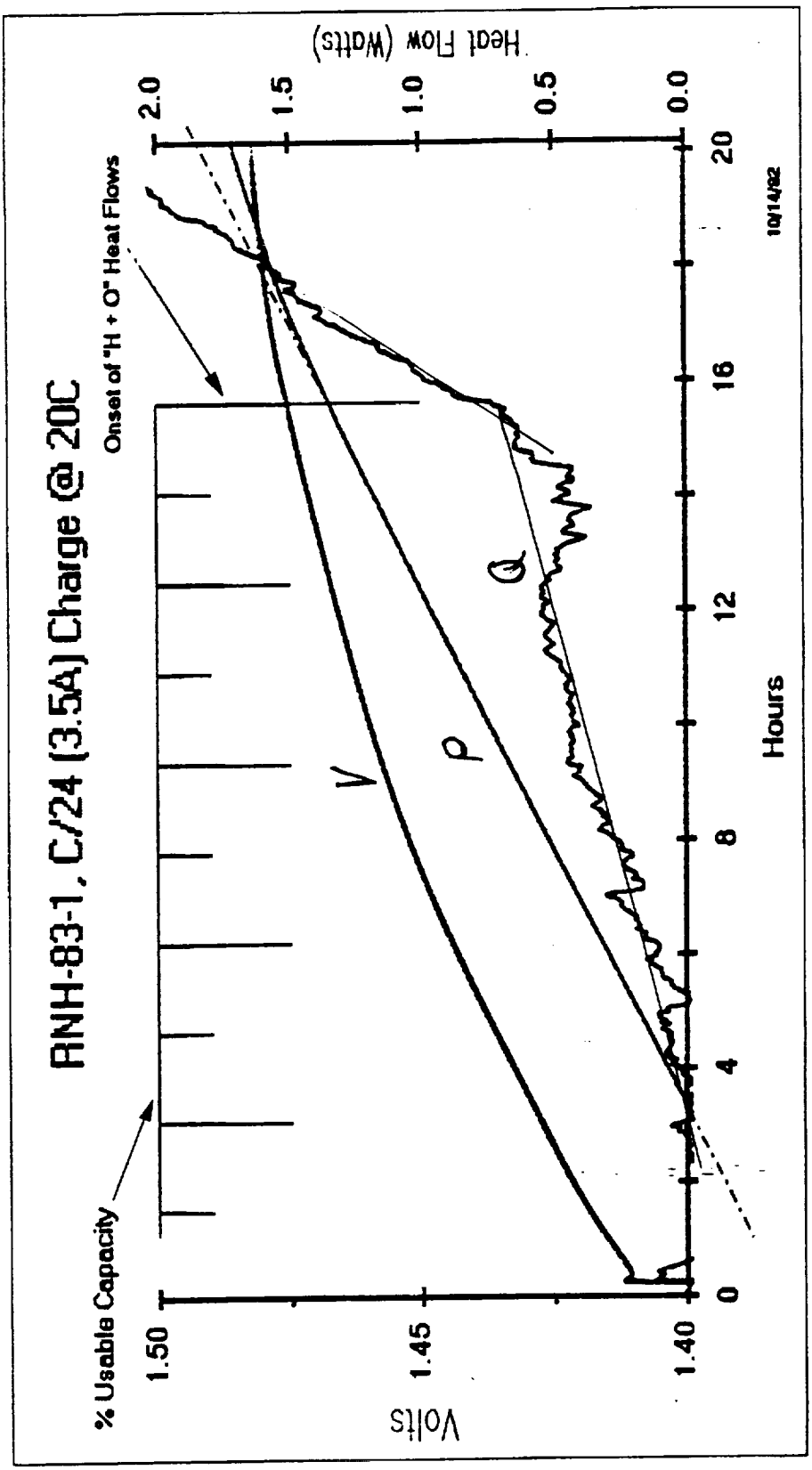

N1300 SCRT 1.3Ah Cell Charged at C/10 (0.13A) @ 10C
NiCd
Heat Flow (Watts)
0.20
0.15
0.10
0.05
0.00
Volts
1.50
1.48
1.46
1.44
1.42
1.40
1.38
Hours
6.0
7.3
8.5
9.8
V
Q

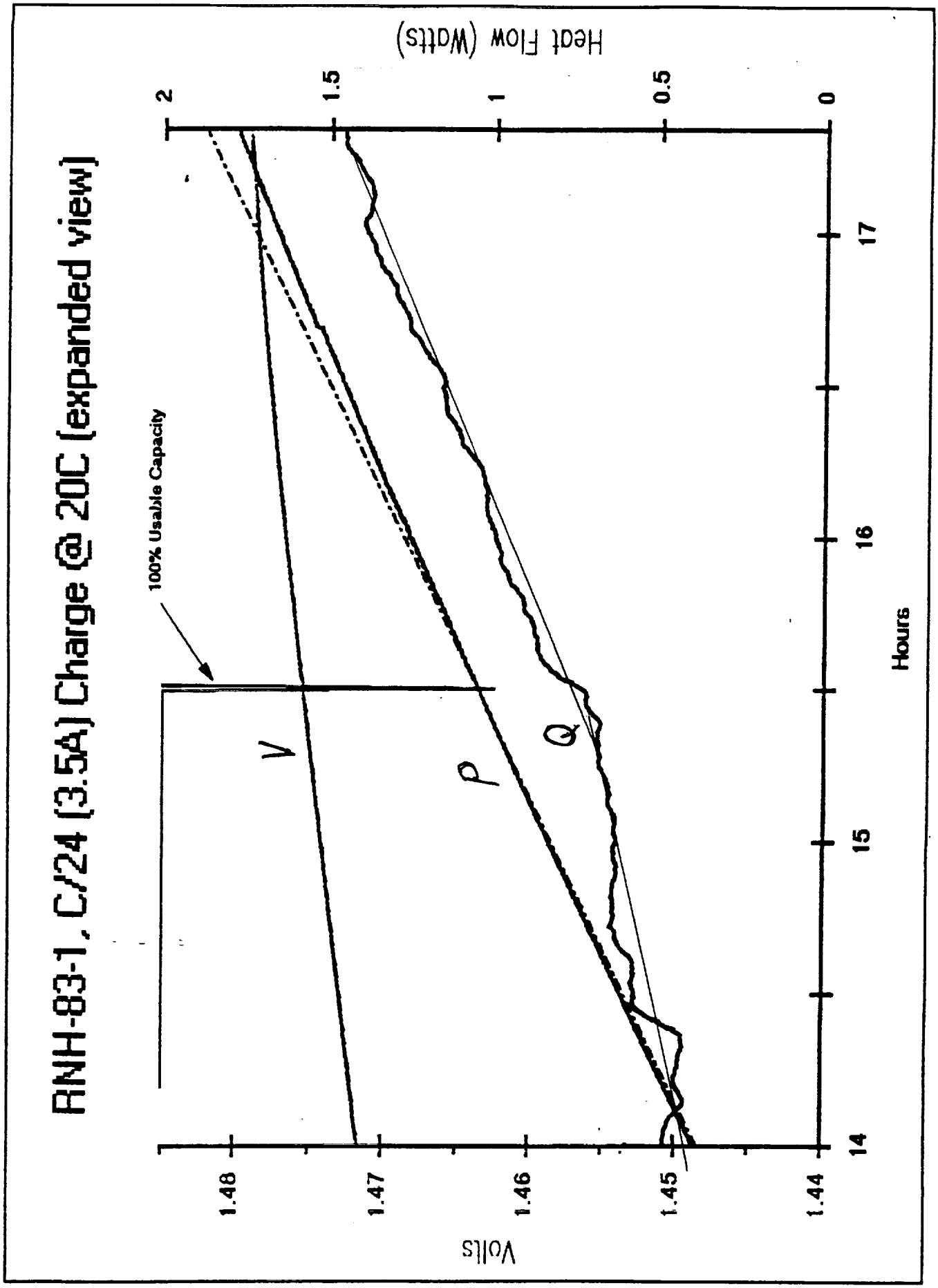

N1300 SCRT 1.3Ah Cell Charged at C/10 (0.13A) @ 30C
NiCd
Heat Flow (Watts)
0.20
0.15
0.10
0.05
0.00
Volts
1.50
1.48
1.46
1.44
1.42
1.40
1.38
Hours
6.0
7.0
8.0
9.0
10.0
11.0
12.0
Q
V

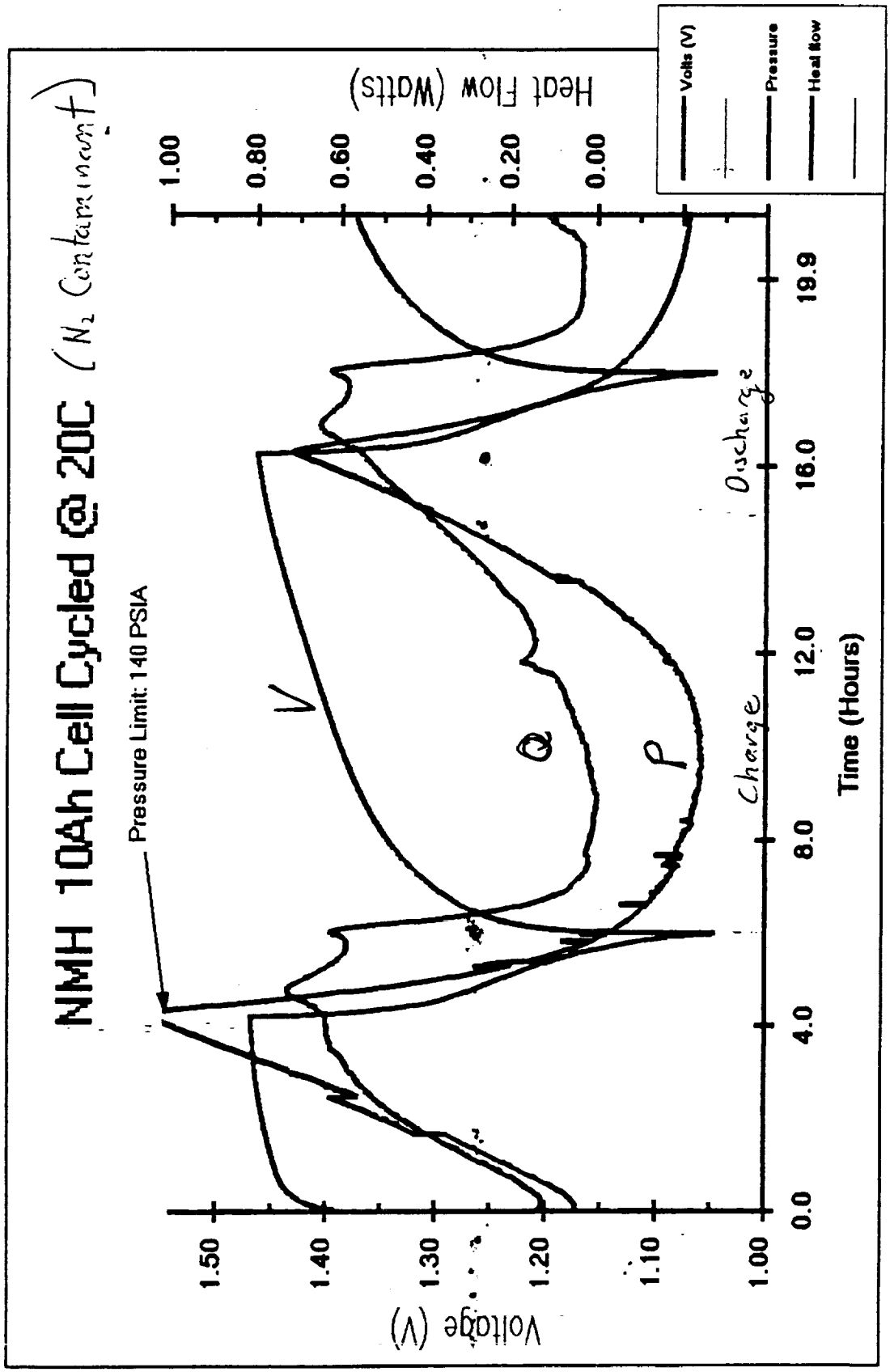

FNC Cell X7S, Charged at C/20 (0.35A), 20 Deg C
Volts
1.5
1.4
1.3
1.2
1.1
1.0
V
Q
% State Of Charge
10
20
30
40
50
60
70
80
90
100
Heat Flow (Watts)
1.0
0.5
0.0
-0.5


FNC Cell X7S, Charged at C/10 (0.70A), 20 Deg C
Volts
1.5
1.4
1.3
1.2
1.1
1.0
V
Q
1.0
0.5
0.0
-0.5
Heat Flow (Watts)
0
25
50
75
100
125
% State Of Charge


FNC Cell X7S, Charged at C/2 (3.50A), 20 Deg C
Volts
1.5
1.4
1.3
1.2
1.1
1.0
V
Q
1.0
0.5
0.0
-0.5
Heat Flow (Watts)
10
20
30
40
51
61
71
81
91
% State Of Charge


RNH-83-1, C/24 (3.5A) Charge @ 20C
Onset of "H + O" Heat Flows
% Usable Capacity
Heat Flow (Watts)
Volts
Hours
V
P
Q
2.0
1.5
1.0
0.5
0.0
1.50
1.45
1.40
0
4
8
12
16
20
10/14/92


RNH-83-1, C/24 (3.5A) Charge @ 20C (expanded view)
Heat Flow (Watts)
2
1.5
1
0.5
0
100% Usable Capacity
V
P
Q
Volts
1.48
1.47
1.46
1.45
1.44
14
15
16
17
Hours


NMH 10Ah Cell Cycled @ 20C (N_2 Containment)
Pressure Limit: 140 PSIA
Volts (V)
Pressure
Heat flow
Heat Flow (Watts)
1.00
0.80
0.60
0.40
0.20
0.00
Voltage (V)
1.50
1.40
1.30
1.20
1.10
1.00
0.0
4.0
8.0
12.0
16.0
19.9
Time (Hours)
Charge
Discharge
V
Q
P

NiMH Cell Gas Analysis - Preliminary Results Summary

Cell pressure recovers within minutes after sampling

Hydrogen and nitrogen predominant, lesser amounts water, oxygen, others

No evidence for the presence of methane

Significant percentage of oxygen present at 100% charge in one cycle

Oxygen consumed completely during discharge cycle

Explosive mixtures of hydrogen and oxygen are present at some times

Significant gas composition changes occur during storage in a discharged state

SUMMARY

1) All Ni - Based Batteries Studied Indicated Increased Q @ End of Charge

2) NiH_2 Cells Showed Increase in Q related to Charge Inefficiency
   Q Increase & Deviation from Linear Increase in H_2 Pressure synonymous

3) Heat Flow (Q) from NiMH was Complicated by Presence of N_2 Contaminant

Advanced Technologies Session

Session Organizer: *Eric Darcy*
NASA Johnson Space Center