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HEAT GENERATION DURING OVERCHARGE OF NI/H_2 CELLS

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Abstract

Heat Generation During Overcharge of Ni/H_2 Cells

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The heat dissipated during various rates of charge and overcharge of a Ni/H_2 cell was measured using a radiative-type calorimeter. A flight configuration-type Ni/H_2 cell was prepared for this study by wrapping it with heater tape (4 in. wide) and instrumenting it with 10 thermocouples. The cell was then insulated with 10 layers of aluminized Mylar. The calorimeter consisted of a liquid-nitrogen-cooled copper chamber arranged inside a vacuum jar. The following heat balance equation was used to calculate the heat dissipated:

$$mC_p \frac{dT}{dt} = Q_{diss} + Q_{in} - Q_{out}$$

where m = mass of the cell
C_p = thermal capacity of the cell
Q_{out} = measured heat using the calibration curve for the calorimeter and cell temperature
Q_{in} = heat input to the cell via the heater tape
Q_{diss} = heat dissipation
T = temperature of the cell
t = time

Measurements made during charging of the cell to the same state of charge (as indicated by pressure) showed that the total heat evolved was greatest for C/10 charge, compared with C/2 or C/4. The endothermic-to-exothermic transition occurred at 1.43 V for C/10 charge, and increased to 1.467 V at C/2 charge. The magnitude of the endothermic heat was only 3.7 percent of the total heat generated during charging.

Experimentally measured heat values were compared against those calculated using a thermoneutral potential of 1.51 V. Although there was general agreement between the calculated and measured values, a significant difference existed in the instantaneous heat values for the initial stages of cell discharge. Heat dissipated during self-discharge appears to depend on the charge rate preceding open-circuit stand.

- EXPERIMENTS USING FLIGHT MODEL NI/H_2 CELL
- DETERMINATION OF INSTANTANEOUS HEAT DISSIPATION USING A RADIATIVE TYPE CALORIMETER
- ENDOTHERMIC TO EXOTHERMIC TRANSITION DURING CHARGE
- HEAT DISSIPATION DURING OVERCHARGE AND DISCHARGE

LITERATURE DATA

C. J. JOHNSON ELECTROCHEMICAL SOCIETY, FALL, 1989	NI/H_2 CELL, CONDUCTION TYPE, SILICON OIL BATH, ISOTHERMAL CONDITIONS
H. KAWAMOTO AND ET. AL. JECS 136,1355, 1989	NA/S CELL, FURNACE, HEAT TRANSFER BY CONVECTION AND RADIATION
R. COHEN AND ET. AL. JECS 137,2649, 1990	Ca/SO CL_2 CELL, CONDUCTION TYPE, WATER BATH. CARBON CLOTH AS CONDUCTOR. FACTOR = 1W/°C
ERIC DARCY 1990 NASA BATTERY WORKSHOP	Li/BCX AND Li/SO CL_2 CONDUCTION TYPE, DROP CALORIMETRY WATER BATH. Al AS CONDUCTOR

CALORIMETER

- HEAT TRANSFER BY RADIATION
- LIQUID N_2 COOLED CHAMBER OF 0.5 M^3 (TEMP = -184°C)
- CHAMBER ENCLOSED IN A VACUUM JAR (10^{-6} MM OF HG)
- CELL HEATED BY HEATER TAPE
- CELL LEADS HEATED
- 6 THERMOCOUPLES TO MEASURE THE TEMPERATURE OF THE CHAMBER
- 2 THERMOCOUPLES TO MEASURE TEMPERATURE OF CELL LEADS
- 8 THERMOCOUPLES TO MEASURE CELL TEMPERATURE

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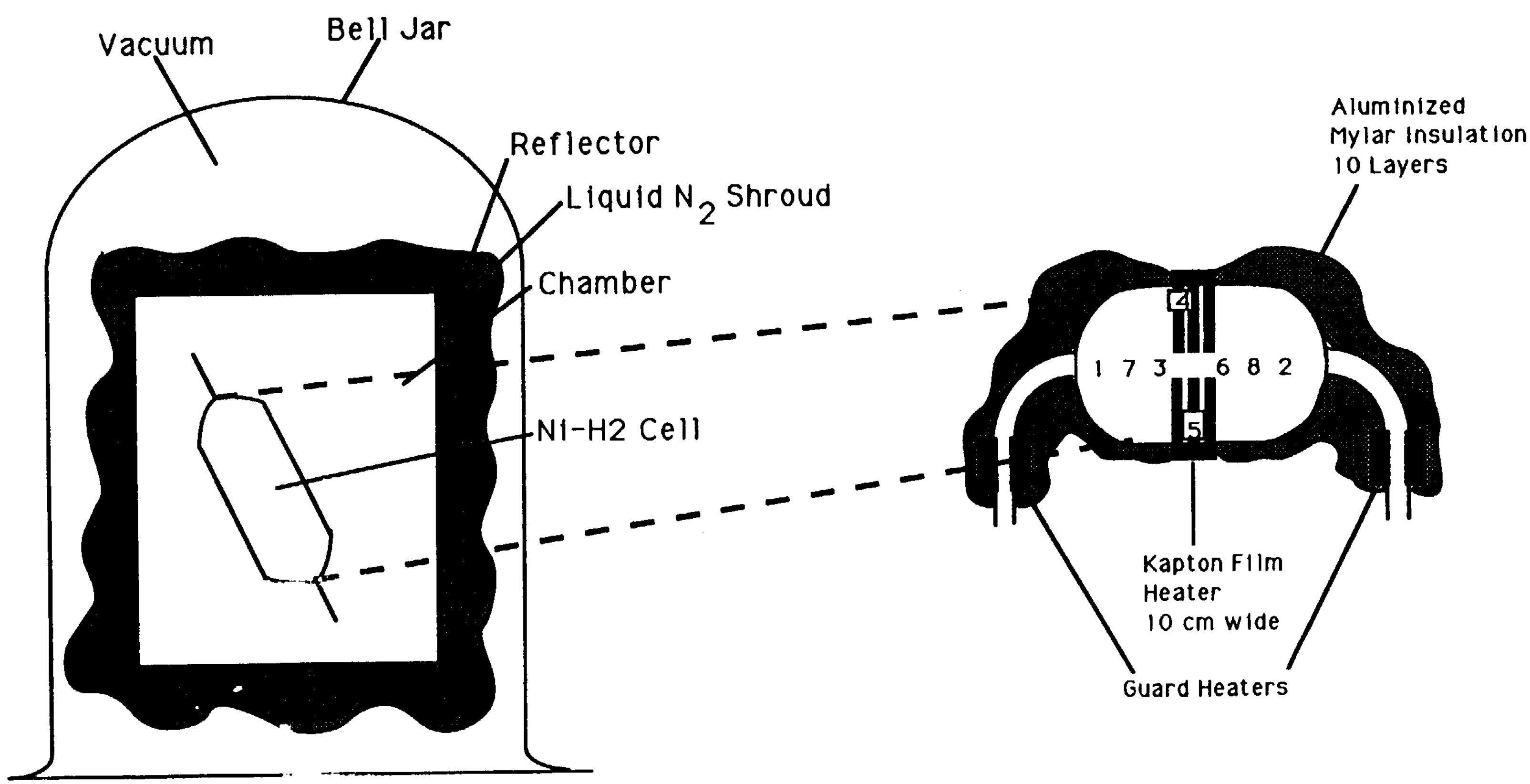
CALORIMETER



CALIBRATION AND MEASUREMENT

- SPECIFIC HEAT DETERMINATION OF AL CYLINDER 958 J/KG°C
- HEAT OF FUSION OF WATER, 75.6 CAL/GM
- CELL INSTALLED IN THE DISCHARGED STATE
- 7W OF HEATER POWER TO MAINTAIN CELL AT 0°C
- CELL TEMPERATURE MONITORED CONTINUOUSLY
- CELL THERMAL CAPACITY DETERMINATION, 1631 J/°C

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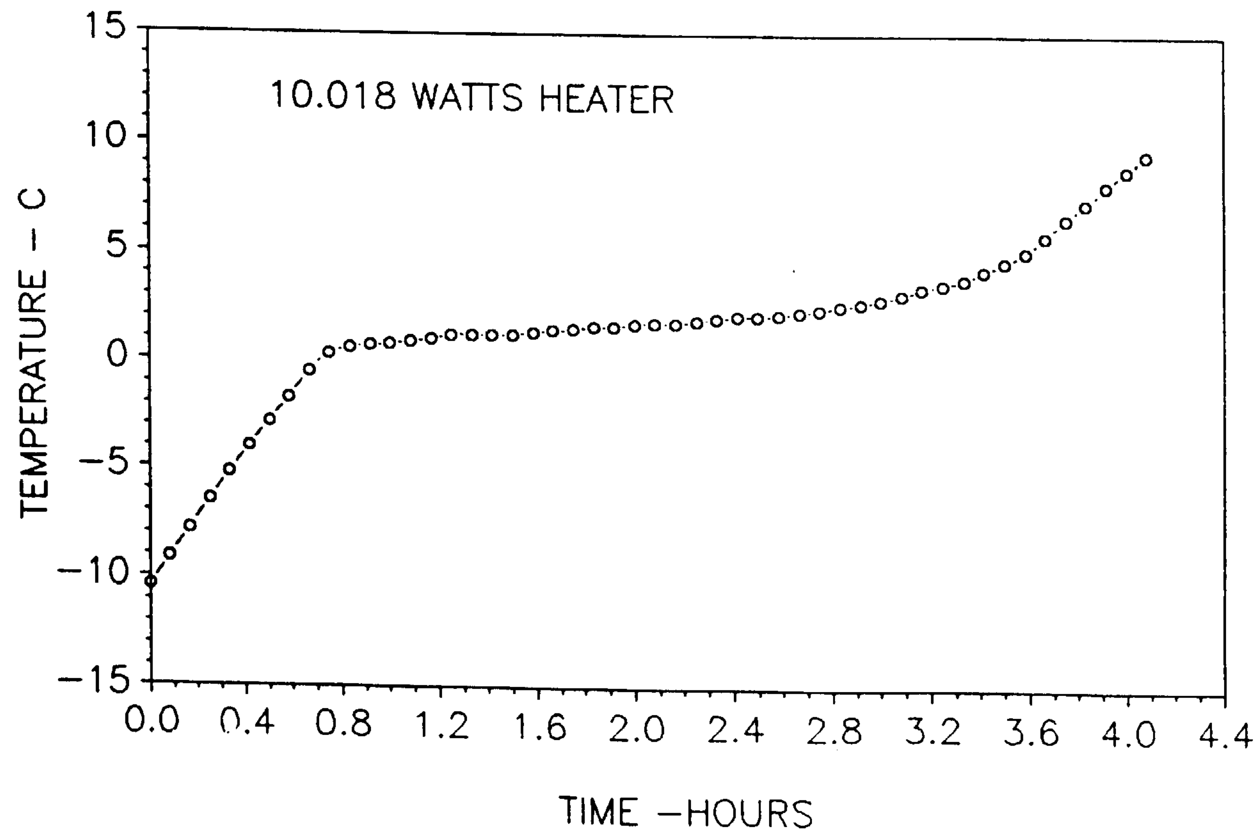
CELL CALIBRATION
ALUMINUM CYLINDER - 100 GRAMS H_2O



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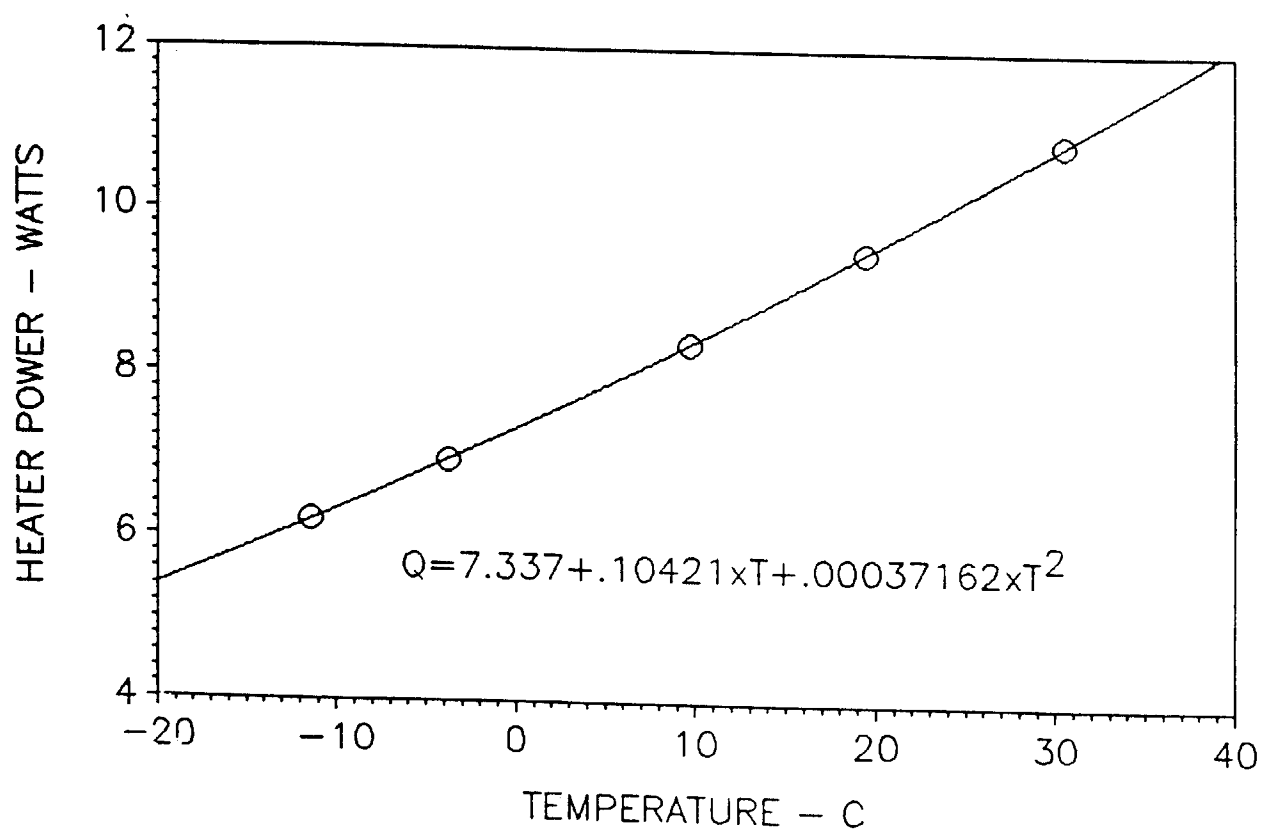
BATTERY CELL CALIBRATION - (1-6 CELL)
NO CHARGE - HEATER POWER ONLY



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THERMAL ANALYSIS

- HEAT DISSIPATION CALCULATED USING ENTHALPY VOLTAGE

$$Q_{(discharge)} = -I\,(E_H - E_L)$$

$$Q_{(charge)} = -I\,(\eta E_H - E_L)$$

- FACTOR ANALYSIS TECHNIQUE (STATISTICAL APPROACH)

$$Q = C_1 + C_2 Y_1 + C_3 Y_1^2 \ldots .\ C_n Y^5 m$$

Y_n = independent variable, C_n = dimensional constant

GOVERNING EQUATIONS

$$m\,c_p \frac{dT}{dt} = Q_{diss} + Q_{in} - Q_{out}$$

c_p = thermal capacity of the cell

m = mass of the cell

Q_{in} = cell heater power = current x voltage

Q_{out} = calculated using the equation formulated from experimental values of cell temperature

= $7.337 + 1.0421T + 0.00037162\ T^2$

Q_{diss} = heat dissipation

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CALCULATION OF THERMAL CAPACITY

MATERIAL	SPECIFIC HEAT J/gM °C	M X Cp JOULE/°C
POLYPROPYLENE SCREEN	1.88	66.928
POSITIVE	0.7	353.92
NEGATIVE	0.6	42.24
ZIRCAR	0.67	59.496
KOH-31%	3.24	845.64
INCONEL	0.44	120.428
NICKEL	0.46	87.63
ALUMINUM	0.96	80.352
POLYSULFONE	1.004	30.8228
POLYPROPYLENE	1.88	39.856
MISCELL.	1	5.3
TOTAL		1732.6128

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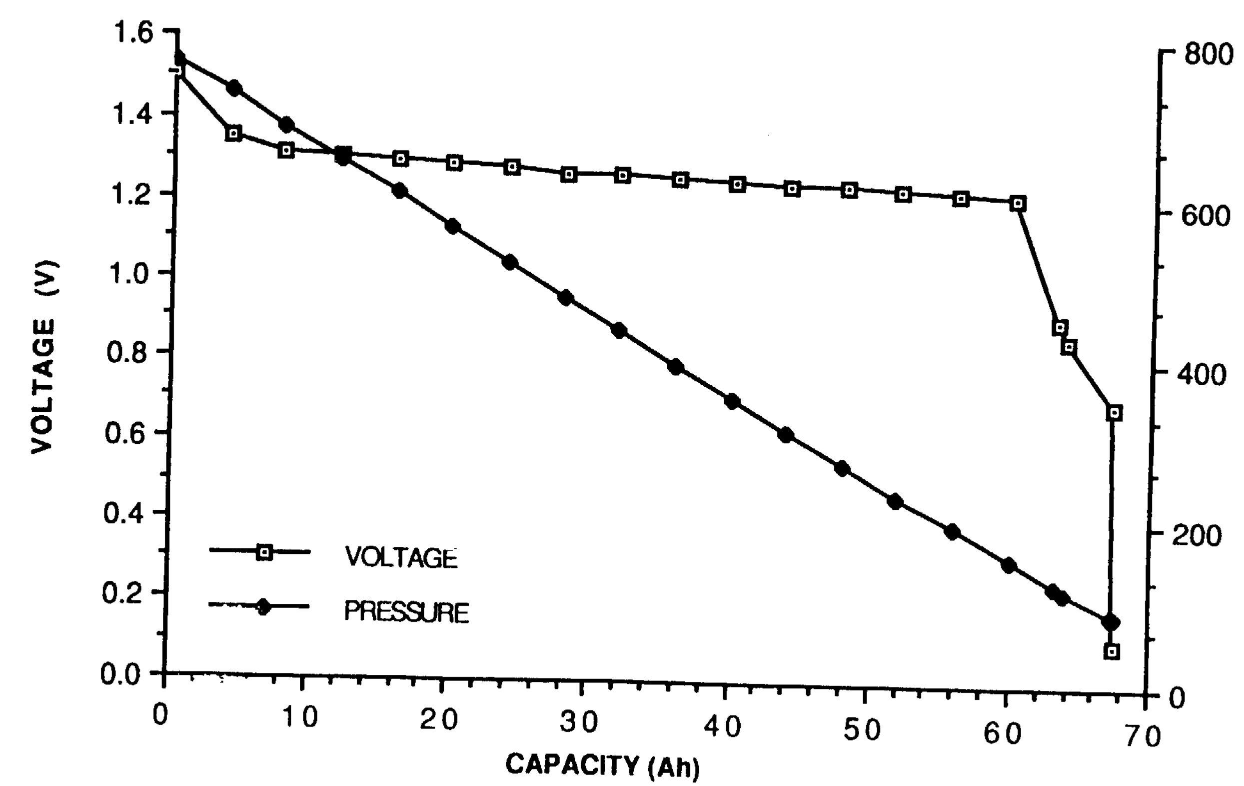
VOLTAGE PROFILE OF I-VI S/N 12-1304 DURING C/2 DISCHARGE



TEMPERATURE DISTRIBUTION

STATE OF CHARGE		CELL DOMES 1 °C	CELL DOMES 2 °C	STACK AVERAGE OF 4 °C	ΔT DOME TO STACK °C
4.8A Charge	Mid-Charge	-3.75	-3.78	-2.6	1.165
	EOC	15.5	15.87	17.25	1.74
12A Charge	Mid-Charge	-5.47	-5.57	-4.64	0.88
	EOC	2.89	3.41	4.61	1.48
24A Charge	Mid-Charge	-3.02	-4.19	-3.73	0.13
	EOC	6.66	7.35	10.62	3.62
24A Discharge	Mid-Discharge	-8.98	-7.16	-7	1.07
	EOD	3.61	5.24	6.81	2.39

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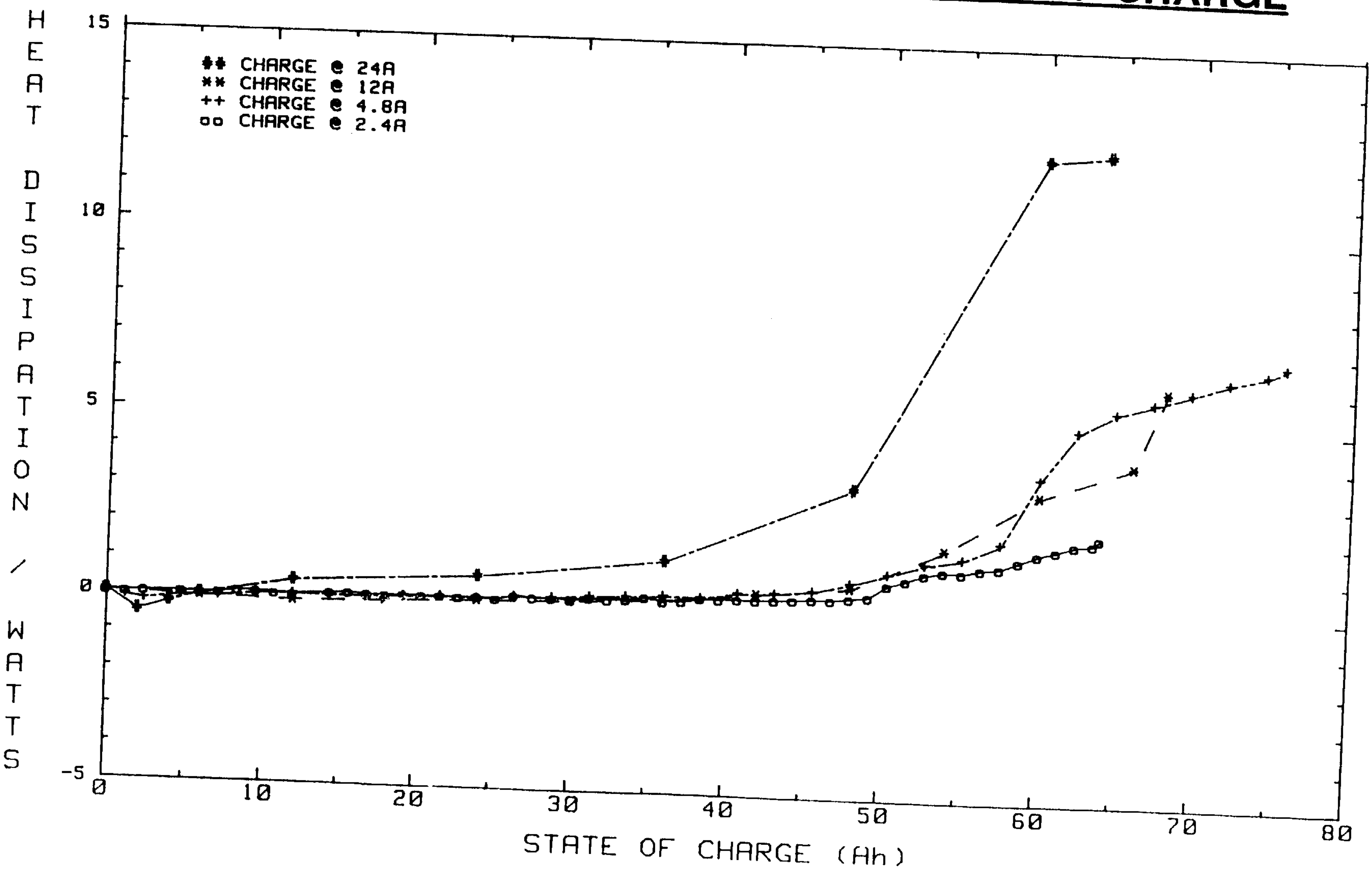
HEAT DISSIPATION AT VARIOUS RATES OF CHARGE



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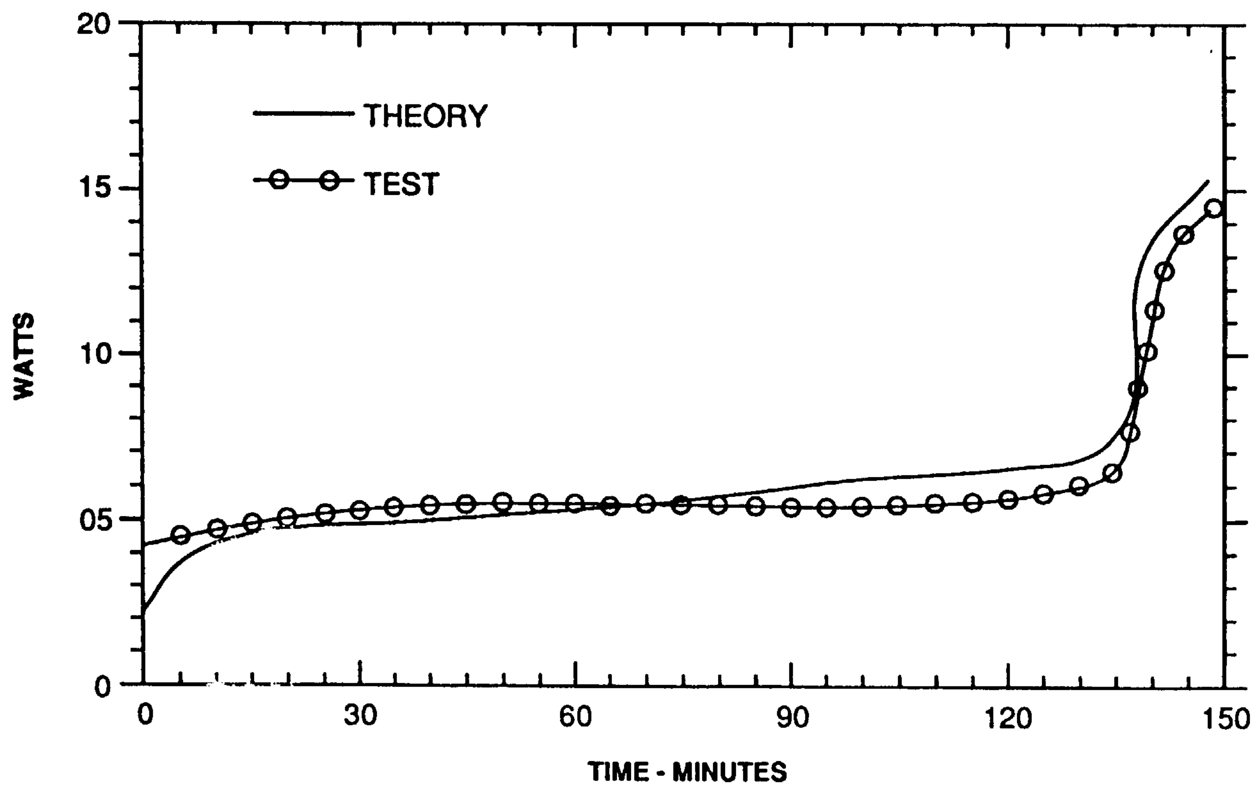
HEAT DISSIPATION DURING DISCHARGE AT C/2



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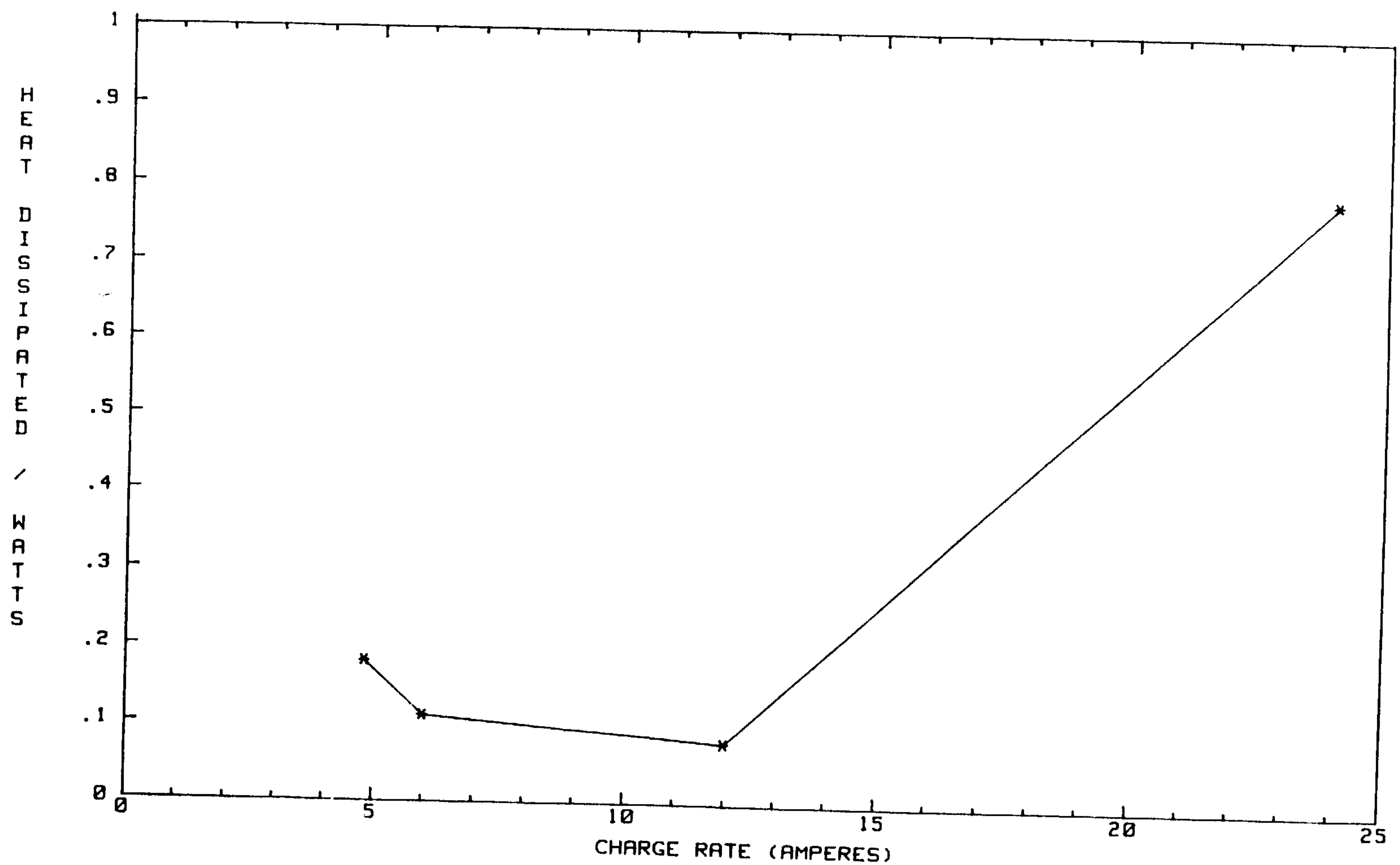
VARIATION OF HEAT DISSIPATION AT 50% CHARGED STATE



COMPARISON OF CALCULATED AND EXPERIMENTAL HEAT DISSIPATION AT C/10 CHARGE

CHARGE INPUT AH	CALCULATED HEAT WATTS	EXPERIMENTAL HEAT WATTS
2.4	-0.575	-0.222
9.6	-0.32	-0.145
14.4	-0.219	+0.005
19.2	-0.143	+0.04
24.0	-0.095	+0.06
28.8	+0.39	+0.124
38.4	+0.47	+0.238

ENDOTHERMIC HEAT

- HEAT DISSIPATION OF 0.453 WATTS IS REQUIRED TO DECREASE THE CELL TEMPERATURE BY 1°C
- BOTH EXPERIMENTAL AND THEORETICAL DATA INDICATE THAT COOLING BY ENDOTHERMIC EFFECT IS NOT VERY SIGNIFICANT (LESS THAN 1.25°C)
- ENDOTHERMIC TO EXOTHERMIC TRANSITION OCCURS AT 1.43V AT C/10 WHICH INCREASES TO 1.467V AT C/2 CHARGE

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EXPLANATION FOR INCONSISTENCY

- AMBIGUITIES IN E_H, THE ENTHALPY VOLTAGE

  1) ΔH of -69.6 K Cal DERIVED FROM NI/CD REACTIONS
  2) SINCE $\Delta H = \Delta E + P\Delta V$, E_H IS A FUNCTION OF PRESSURE
  3) Δ H FOR CHARGED AND DISCHARGED FORMS OF $NI(OH)_2$ NOT CONSIDERED

- INACCURATE VALUE FOR CHARGE EFFICIENCY

HEAT DISSIPATION DURING TRICKLE CHARGE AT C/100

TEMPERATURE °C	MEASURED HEAT WATTS	CALCULATED HEAT WATTS
6.8	1.08	0.9021
4.8	1.017	0.9039
1.37	0.7552	0.910
-1.07	0.748	0.9176
-22.6	0.766	0.9746

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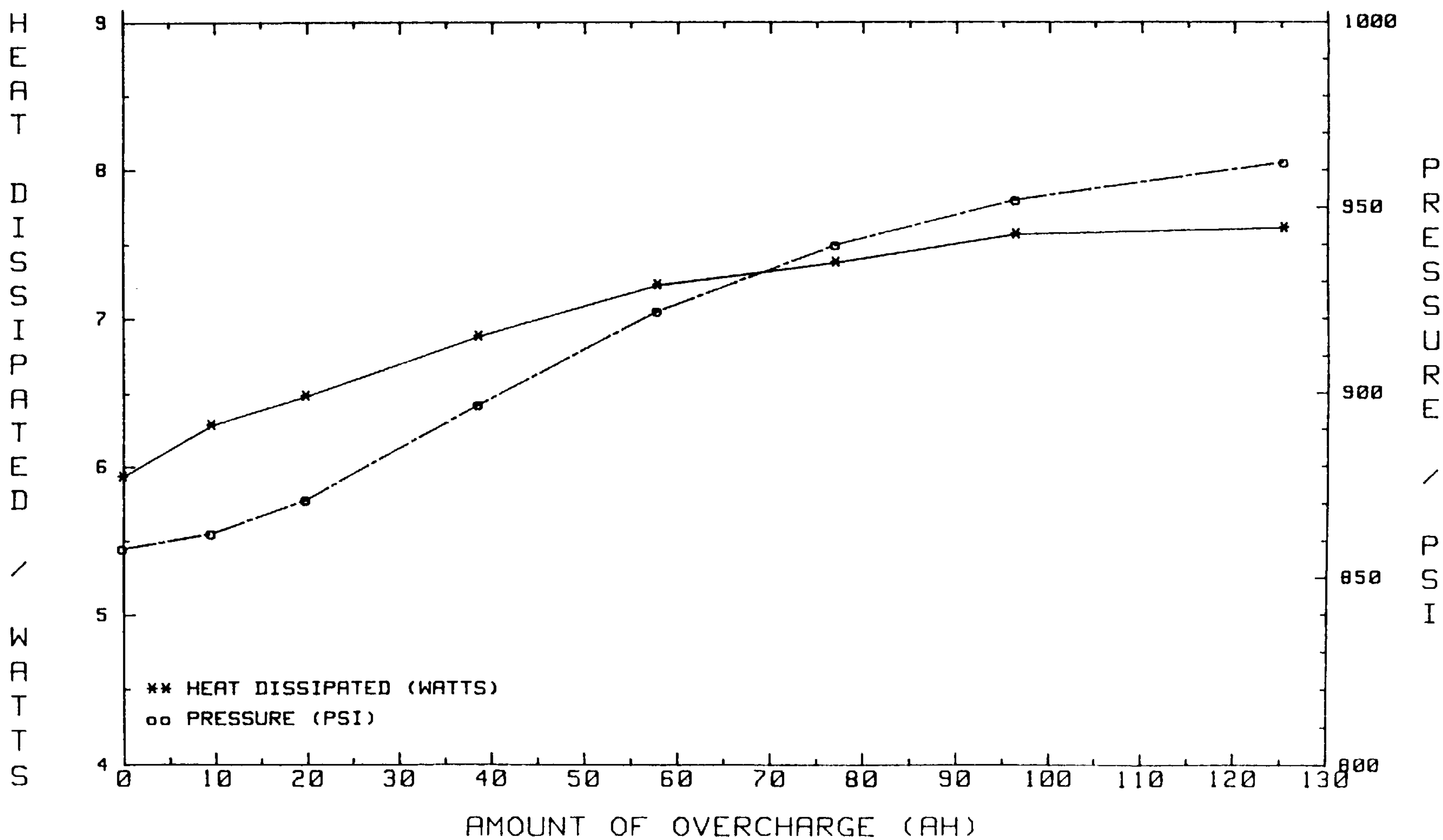
RELATIONSHIP BETWEEN HEAT GENERATION AND PRESSURE INCREASE DURING C/10 OVERCHARGE AT -3 +/- 3o C



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HEAT DISSIPATION DURING OPEN CIRCUIT STAND

CHARGE RATE PROCEEDING THE OPEN CIRCUIT STAND	TEMPERATURE (°C)	CELL PRESSURE (PSI)	HEAT DISSIPATED (WATTS)
C/10	1.7	826	0.85
C/20	6.0	830	1.11
C/4	6.3	839	1.68
C/2	13.7	854	1.91

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CONCLUSIONS

- ENDOTHERMIC HEAT IS A VERY SMALL PART OF THE TOTAL HEAT DISSIPATED DURING CHARGE
- HEAT DISSIPATION IN THE FIRST ONE HOUR OF SELF-DISCHARGE APPEARS TO DEPEND ON THE CHARGE RATE PRIOR TO OPEN-CIRCUIT STAND
- THERE IS A DIVERGENCE BETWEEN THE CALCULATED AND EXPERIMENTAL HEAT DISSIPATION WHICH COULD BE LARGELY DUE TO INACCURATE VALUES FOR E_H AND CHARGE EFFICIENCY