SECOND PROGRESS REPORT

FOR

RESEARCH INTO FUNDAMENTAL PHENOMENA ASSOCIATED WITH SPACECRAFT ELECTROCHEMICAL DEVICES — CALORIMETRY OF NICKEL-CADMIUM CELLS

October 1, 1966 — December 31, 1966

Contract No. NAS 5—10105

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For

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Research into Fundamental Phenomena Associated
with Spacecraft Electrochemical Devices -
Calorimetry of Nickel-Cadmium Cells

By

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ABSTRACT

During this reporting period the investigations of the six ampere-hour nickel-cadmium cell with "Adhydrode" control electrode were concluded. These investigations involved:

1) Cycling Experiments (40% depth of discharge, 110% recharge)

2) Charge Efficiency Studies

3) Transducer Study

The 40% depth represents the deepest discharge to which the cell had been subjected during these investigations. As expected, this 40% depth of discharge produced the greatest thermal effect, 1.18 watts and the maximum build-up of oxygen pressure. Enthalpy changes (ΔH) obtained from the thermal response for this experimental series remained in excellent agreement with the calculated theoretical value (33.1 kcal/equiv) for these reactions.

During the efficiency studies the charge rate was varied from $\frac{c}{10}$ (0.6 amps) to $\frac{c}{1.2}$ (5.0 amps) resulting in only a slight variation in the efficiency. The average efficiency obtained was 83.6%.

After the completion of 335 cyclic experiments the cell was removed from the calorimeter and fitted with a transducer for the purpose of

correlating the Adhydrode signal with the oxygen pressure in the cell. A correlation was made but was not as consistent as desired. The experimental work in the immediate future will be done on the 12 ampere-hour cell.

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I. INTRODUCTION

The major purpose of this program is to train electrochemists to perform research and solve problems in the space battery field. The problems are those specifically encountered by NASA's Goddard Space Flight Center.

A review of the accomplishments prior to October 1, 1966 would include 1) a literature survey of calorimetry; 2) the design and construction of a continuous flow calorimeter and 3) the evaluation of a six ampere-hour nickel-cadmium cell which was subjected to the following orbital conditions:

a) 79 cycles undergoing 25% depth of discharge and a 110% recharge

b) 74 cycles undergoing 15% depth of discharge and a 114% recharge

c) 93 cycles undergoing 25% depth of discharge and a 114% recharge

During this reporting period the investigations of this same battery have involved:

1) 74 cycles undergoing 40% depth of discharge and a 110% recharge

2) charge efficiency studies

3) transducer studies

II. EXPERIMENTAL PROCEDURE

1. Cycling Experiments (40% depth of discharge, 110% recharge)

The same six ampere-hour nickel-cadmium cell was used for this experimental series as had been used to obtain the data for the first report. The continued reliability of the cell was substantiated by means of a capacity check. Before beginning this experimental series (Exp. Series D) the cell was recharged for sixteen hours at a $\frac{C}{10}$ rate or at 0.6 amps. Cycling was initiated by discharging the cell at 4.75 amps for 30 minutes or to a 40% depth. Then, the cell was charged at a constant current of 2.65 amps until a terminal voltage of 1.49 volts was obtained at which point (approx. 55 mins.) the cycle became voltage limiting for the remainder of the 110% recharge step (6 mins.) During the cycling, continual recording of the current, voltage, and thermal output of the cell, as well as the Adhydrode's voltage output, were made.

2. Charge Efficiency Experiments

The same cell was used for these experiments. The effect on the efficiency of varying the charge rate was investigated. The charge rates studied were, $\frac{C}{10}$ (0.60 amps), $\frac{C}{8}$ (0.75 amps), $\frac{C}{6}$ (1.00 amps), $\frac{C}{4}$ (1.50 amps), $\frac{C}{2}$ (3.00 amps), and $\frac{C}{1.2}$ (5.00 amps). Each charging condition was examined using constant current and was terminated when an Adhydrode signal of 100 mv. across a 6.8 ohm resistor was obtained. Then, the cell was discharged at $\frac{C}{2}$ (3.00 amps) until a terminal voltage of zero was reached. During the above testing the efficiency and the rate of heat generation by the cell were recorded.

3. Transducer Experiments

During the course of experimental Series D (40% depth of discharge, 110% recharge) signals in excess of 181 mv. (across a 6.8 ohm resistor) were generated by the Adhydrode control electrode. Conversations with H. Seiger of Gulton Industries and K. Sizemore of Goddard Space Flight Center, NASA led to the conclusion that the Adhydrode oxygen-pressure relationship above an output 181 mv. (across a 6.8 ohm resistor) had not as yet been investigated. The attempt to gain this information before proceeding to the twelve ampere-hour cell is referred to as the "Transducer Study." This study was begun by entering the cell through the negative terminal via a threaded capillary tube. To this was attached a Glennite Pressure Transducer and a valve through which a vacuum could be applied. The procedure for accomplishing this mechanically is given in detail in Appendix 2. The pressure transducer was calibrated with an Amthor Dead Weight Pressure Gauge Tester. A plot of millivolt output of the transducer versus the absolute pressure is shown in Figure 1. A calibration plot of the cell pressure versus the Adhydrode Control Electrode as reported by K. Sizemore* appears in Figure 2.

The cell while external to the calorimeter (not thermostated) was subjected to the following experiments:

a) 15% depth of discharge and a 110% recharge

b) 25% depth of discharge and a 110% recharge

c) 40% depth of discharge and a 110% recharge

d) 15% depth of discharge and continuous overcharge

* K. Sizemore, "Use of the Adsorption Hydrogen Electrode and the Oxygen Fuel-Cell Electrode in Nickel-Cadmium Cells," NASA Goddard Report #X-716-66-83, April 1966, p. 12.

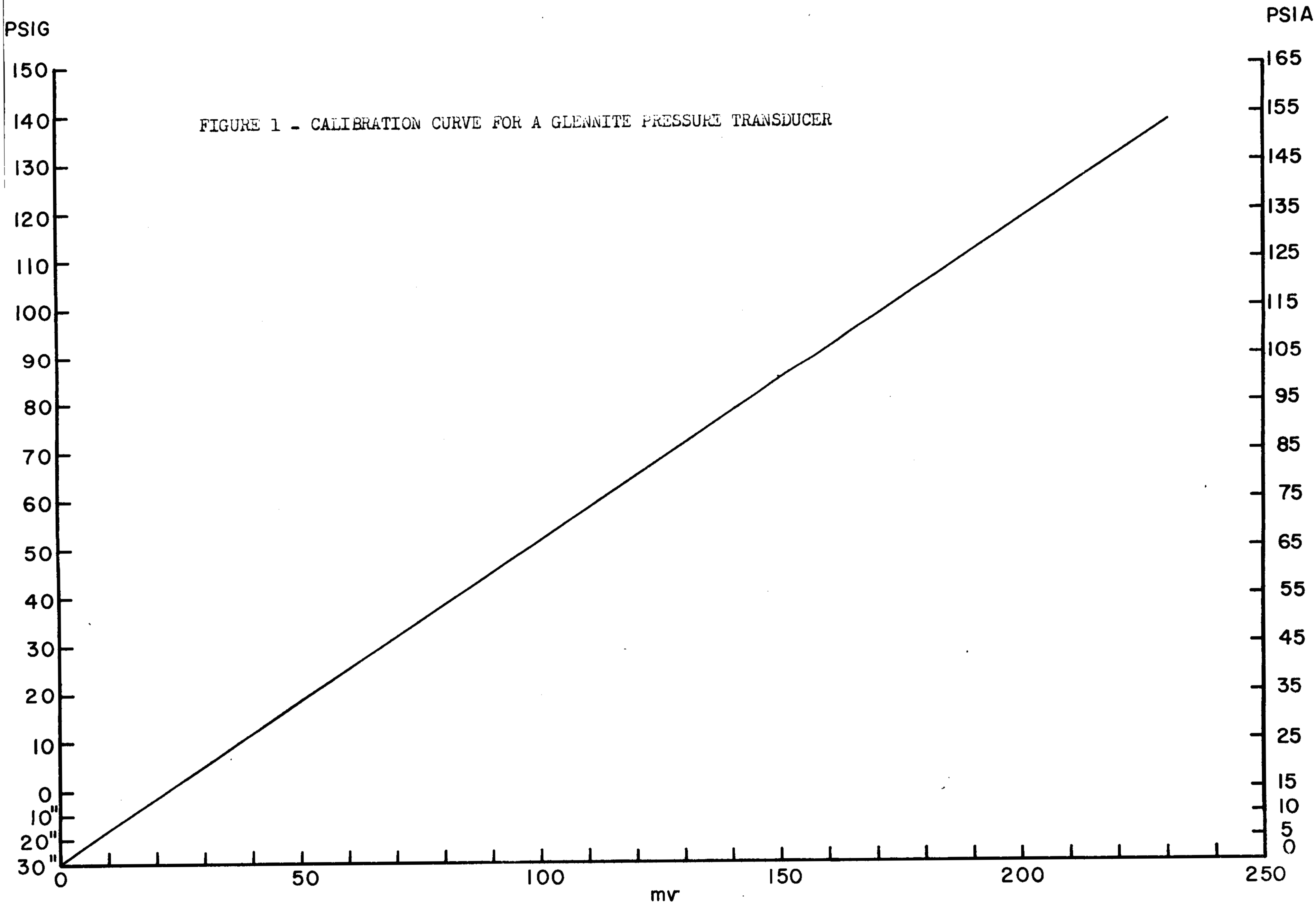

FIGURE 1 - CALIBRATION CURVE FOR A GLENNITE PRESSURE TRANSDUCER

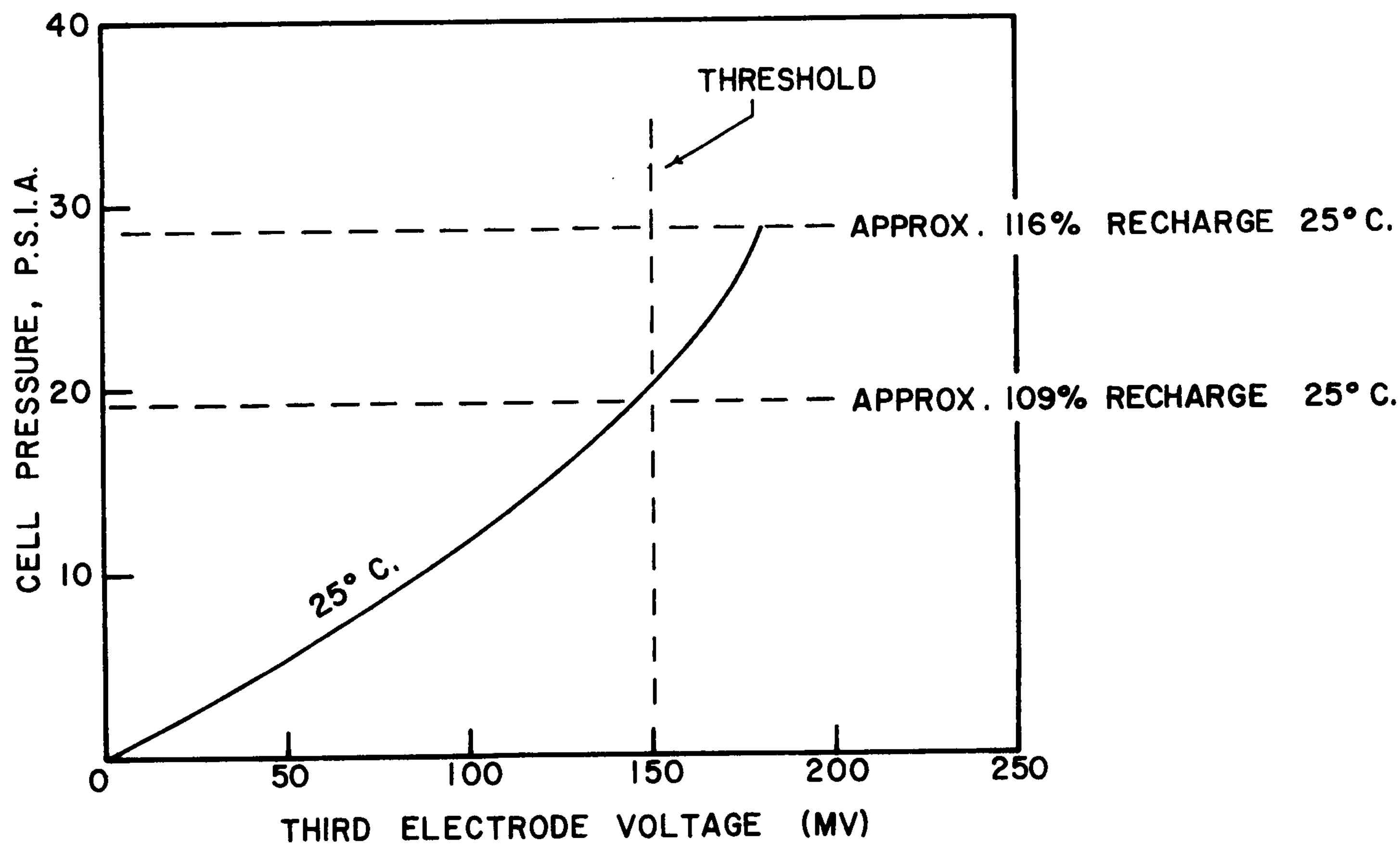

FIGURE 2 - CALIBRATION CURVE FOR THE ADHYDRODE

At the conclusion of each experimental series (approx. 24 hrs.) the cell was discharged to a terminal voltage of zero and then recharged for 16 hrs. at $\frac{C}{10}$ or 0.6 amps.

III. RESULTS AND CONCLUSIONS

1. Cycling Experiments

The final series of cyclic experiments (40% depth of discharge, 110% recharge) to be performed with the six ampere-hour nickel-cadmium cell have been completed. Detailed tables of representative cycles which appear in Appendix 1 describe the thermal output, electrical characteristics, enthalpy changes, and oxygen pressure of the cell at five-minute intervals.

The thermal data were obtained by converting the microvolt signal of the thermopile to watts by means of a calibration curve. The oxygen pressure was indicated by the millivolt output of the Adhydrode control electrode across a 6.8 ohm resistor. This signal was converted to p.s.i.a. of oxygen by means of the calibration curve appearing in Figure 2. Any signal above 181 mv. was recorded as such and cannot at the present time be converted to a p.s.i.a. value since the pertinent relationship has not as yet been derived.

As discussed previously, the enthalpy change (ΔH) calculations of thermodynamic significance are limited to that point of minimum oxygen evolution or reation ($V\Delta P=0$) approximately 35 minutes into the charge cycle. At that point excellent agreement is obtained between the experimentally value of 33.15 kcal/equiv and the calculated value of 33.1 kcal/equiv. At other times, at which the $V\Delta P$ contribution is considerable, the calculated "ΔH" is no longer the true change in enthalpy. Thus, the value is denoted as ΔH^* in the table. This matter will be discussed in more detail in the next report. In Table I is presented a comparison of the oxygen pressure, changes in ΔH^* and thermal data at specific times in each cycle.

TABLE I - Comparison of Thermal, Enthalpy, and Oxygen Pressure Data

Condition	Time (mins.)	Heat (watts)	ΔH* (kcal/equiv.)	O_2 Pressure (P.S.I.A.)	
Discharge	5	-0.58	-35.58	15.3	
Discharge	30	-0.59	-33.70	4.1	
Charge	5	-0.38	+24.66	3.5	Exp. Series A Cycle 18 (25% d.c., 110% recharge)
Charge	35	+0.10	+33.67	1.5	
Charge	60	-0.23	+31.43	13.1	
Discharge	5	-0.40	-36.48	13.1	
Discharge	30	-0.32	-33.38	3.2	Exp. Series B Cycle 18 (15% d.c., 114% recharge)
Charge	5	-0.18	+26.25	3.0	
Charge	35	+0.07	+33.68	1.2	
Charge	60	-0.16	+29.93	10.4	
Discharge	5	-0.74	-36.58	195 mv.	
Discharge	30	-0.60	-33.66	6.5	
Charge	5	-0.38	+25.12	6.0	Exp. Series C Cycle 18 (25% d.c., 114% recharge)
Charge	35	+0.10	+33.44	2.1	
Charge	60	-0.34	+29.36	22.0	
Discharge	5	-0.94	-34.83	240 mv.	
Discharge	30	-1.10	-33.40	11.3	
Charge	5	-0.66	+24.45	10.0	Exp. Series D Cycle 25 (40% d.c., 110% recharge)
Charge	35	+0.13	+33.15	3.5	
Charge	60	-0.40	+28.53	260 mv.	

A graphical presentation of the thermal responses of the six ampere-hour Ni-Cd cell appears in Figure 3. The peak of the exothermic reaction occurs approximately ten minutes into the discharge cycle. The height of the endothermic reaction occurs thirty-five minutes into the charging cycles.

Oxygen generation at a rate faster than that of chemical recombination takes place at approximately fifty minutes into the charge cycles.

In Table II appears a comparison of the maximum thermal data and oxygen pressure for each experimental series. The greatest thermal effect is produced by the deepest discharge cycle, i.e. 40% depth of discharge. Also, the greatest oxygen pressure value is obtained for these same series, i.e. 285 mv.

2. Charge Efficiency Experiments

During this set of experiments the cell's efficiency and rate of heat generation were recorded. This data is summarized in Table III. The cell had been subjected to 325 cycles prior to this study.

The results indicate that this type of cell possesses good stability in the region investigated with the percentage efficiency varying only 3.7%. No significance is read into this variation other than experimental variations. An essentially constant maximum exothermic output was recorded for the discharge process which was always at a constant current of 3.00 amps. The greatest quantity of heat liberated (0.24 watts) by the cell occurred during the $\frac{c}{1.2}$ charge cycle. However, very little change in the cell's efficiency was produced.

The completion of this study marked the first time since July, 1966 that the calorimeter was shut down and the battery removed for visual inspection. The battery by this time had been subjected to 335 cycles

FIGURE 3 - COMPARISON OF THE THERMAL RESPONSES

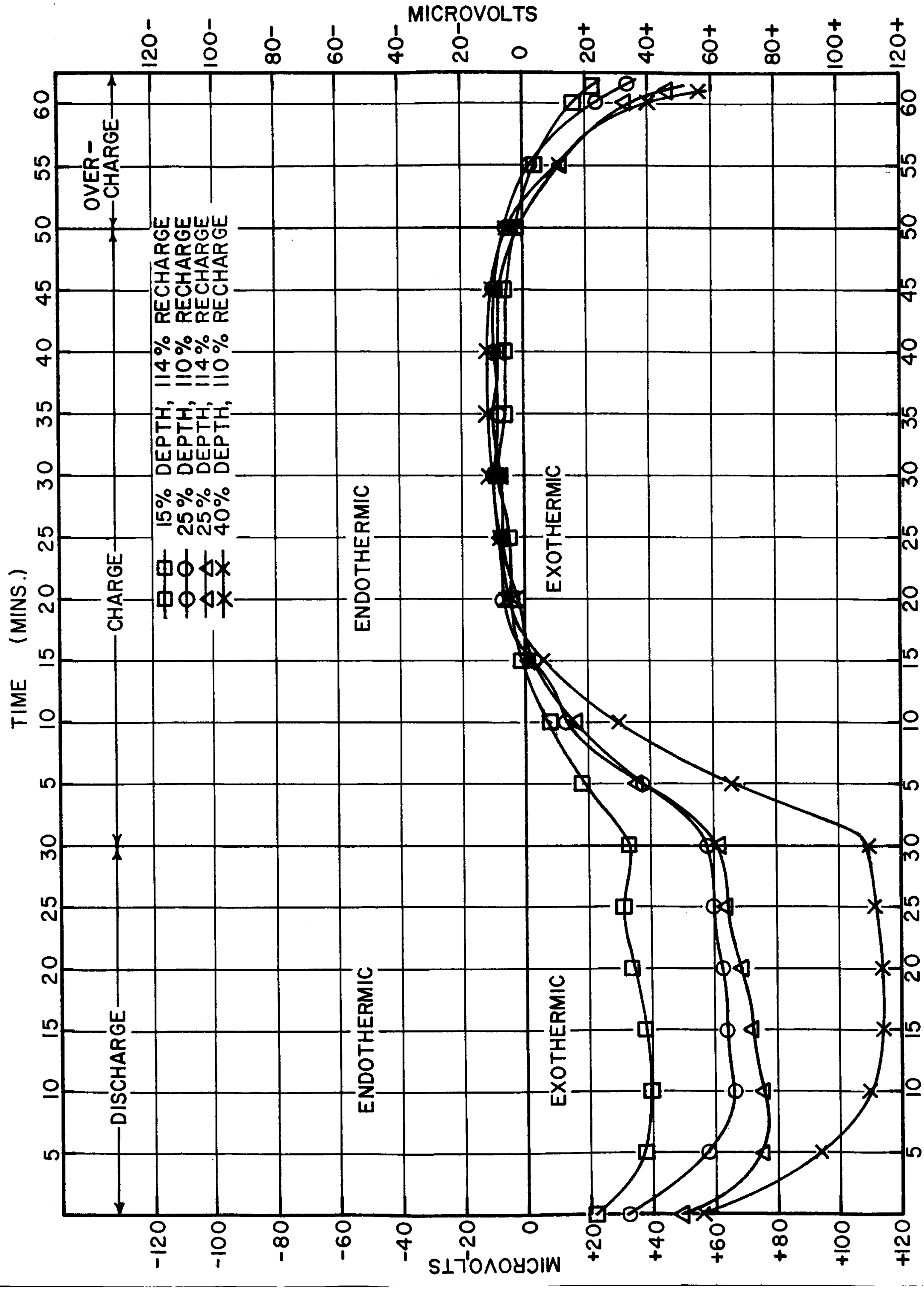

TABLE II - Comparison of Maximum Thermal Effect and Oxygen Pressure For Various Series

	Max. Heat Liberated (watts)	Max. Heat Absorbed (watts)	Max. O_2 Press. (p.s.i.a.)
Exp. Series A (25% d.c., 110% recharge)	-0.66	+0.11	16.1
Exp. Series B (15% d.c., 114% recharge)	-0.44	+0.08	12.6
Exp. Series C (25% d.c., 114% recharge)	-0.77	+0.10	200 mv.
Exp. Series D (40% d.c., 110% recharge)	-1.18	+0.15	285 mv.

TABLE III - Comparison of Efficiency, Charge Rate, and Thermal Response

Charge Rate	AH OUT / AH In	% Eff.	CHARGE: Max. Endothermic Output(Watt)	CHARGE: Max. Exothermic Output(Watt)	DISCHARGE: Max. Exothermic Output(Watt)
C/1.2	6.734/8.134	82.7	+0.10	-0.24	-0.69
C/2	6.835/7.959	85.8	+0.12	-0.12	-0.69
C/4	6.879/8.200	83.8	+0.08	-0.10	-0.68
C/6	6.902/8.237	83.7	+0.07	-0.10	-0.69
C/8	6.943/8.466	82.1	+0.10	-0.10	-0.70
C/10	6.867/8.190	83.8	+0.06	-0.12	-0.72

including all of the following conditions, 15%, 25%, 40% depth of discharge and 110%, 114% recharge. During this testing the battery was not under any form of constraint and upon examination exhibited a very slight bulging which was detectable only with a bubble level. Figure 4 is a photograph of this battery (Gulton Industries Cell No. 256 of the 400T series) as it was mounted in a Lucite fixture containing the battery and calibration heater.

3. Transducer Experiments

The cell fitted with a Glennite pressure transducer for investigating Adhydrode signals above 181 mv. or 28.7 psia of oxygen is shown in Figure 5. Several experiments were run as indicated above. Some uncertainties occurred in the experimental procedure and the interpretation of some of the curves was not too straightforward. For this reason the reporting and discussion of these data is postponed until the next report.

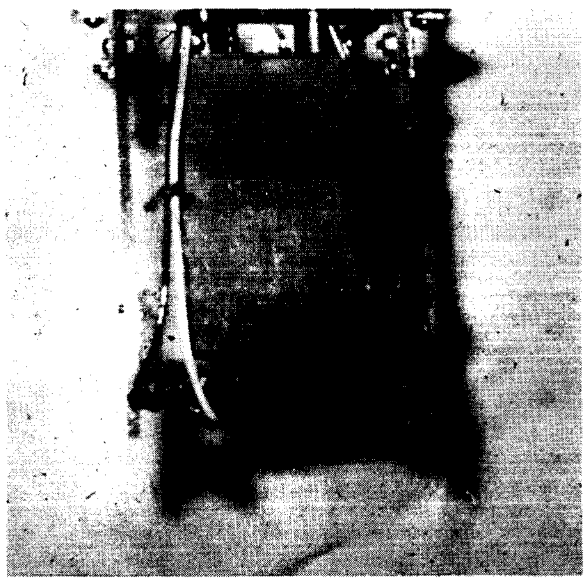

FIGURE 4- PHOTOGRAPH OF SIX'AMPERE GULTON PRISMATIC BATTERY AFTER 335 CYCLES

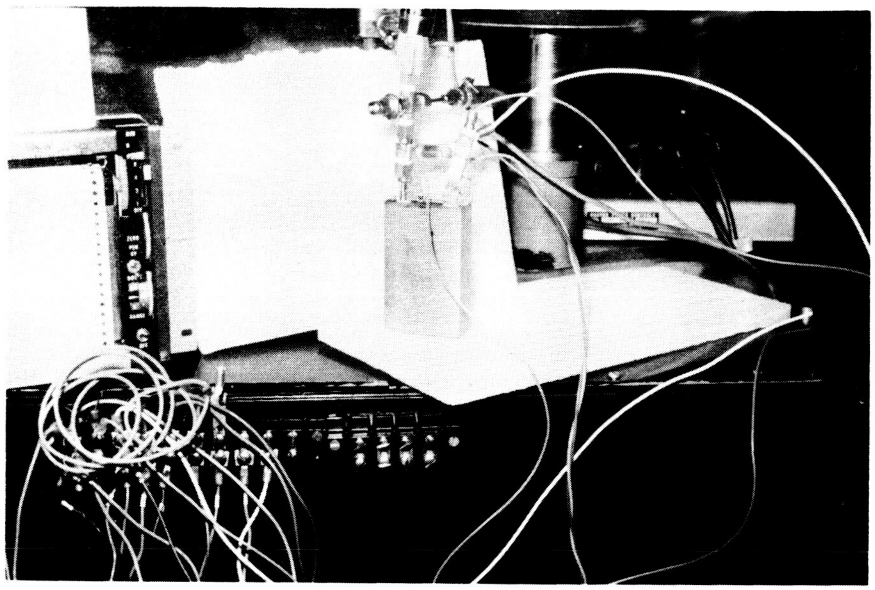

FIGURE 5 - A CELL WITH PRESSURE TRANSDUCER

IV. NEW EQUIPMENT AND FACILITIES

In order to expand the testing capabilities of the calorimeter a Kepco Model 30-36 constant current, constant voltage, power supply has been obtained. This power supply has a range from 0-30 amps and from 0-36 volts with 0.1% regulation. Rewiring of the calorimeter and cycling device to accommodate this new unit has been completed; however, the entire system at this time is limited to twenty amps by the relays in the cycling device. A photograph of the electronic cycling equipment and recorders (center), the console housing the calorimeter and thermal ballast tank (right), and the pipes carrying the oil to the metering pump (foreground) appears as Figure 6.

Also, designed and constructed during this quarter was a special Lucite fixture for positioning the calibration heater and the 12 ampere-hour cell fitted with a pressure transducer and a vacuum cut-off valve in the calorimeter.

During the past month, the Chemistry Department of American University moved into its new building. This project will re relocated in a new electrochemistry laboratory consisting of 1100 sq. ft.

V. FUTURE WORK

Because of the difficulty in placing a 12 ampere-hour cell in the calorimeter (6" high by 4 1/2" I.D.) and the intention to study 20 ampere-hour cells in the future, the design and construction of a calorimeter capable of housing the larger units was initiated.

Following the relocation of the equipment in the new facility it will be necessary to calibrate the calorimeter for the 12 ampere-hour cell.

Upon the successful completion of this, the 12 ampere-hour cell will be subjected to a testing schedule in order that a comparison may be made with the 6 ampere-hour cell and possibly an extrapolation can be made to the performance of a 20 ampere-hour cell.

This testing schedule will be as follows:

1) 15% depth of discharge and 114% recharge
2) 25% depth of discharge and 114% recharge
3) 25% depth of discharge and 110% recharge
4) 40% depth of discharge and 110% recharge

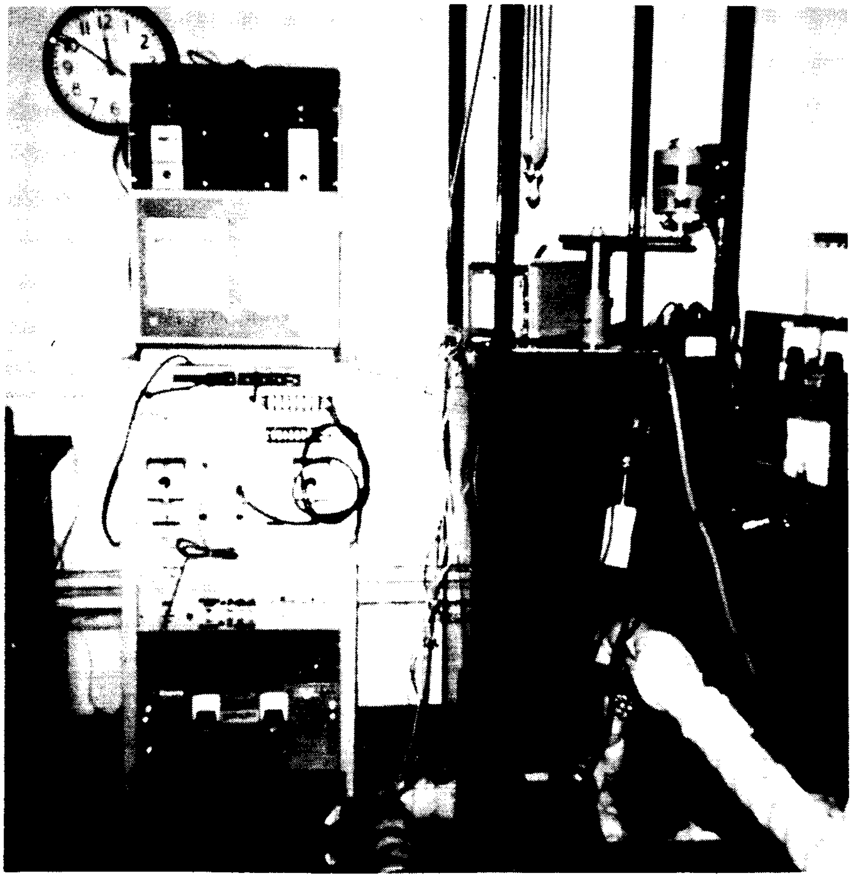

FIGURE 6 - PHOTOGRAPH OF CYCLING EQUIPMENT AND CONSOLE HOUSING THE THERMAL BALLAST TANK AND CALORIMETER

VI. APPENDICES

1. Experimental Series D (40% depth of d.c., 110% recharge)
2. Procedure for Entering a Hermetically Sealed Six Ampere-Hour Gulton Prismatic Ni-Cd Cell.

EXPERIMENTAL SERIES D

25°C — Orbit 24 — Oct. 13, 1966

Orbital Conditions:

1) 31 mins. d.c. at 4.75 amps for 40% Depth of d.c.
2) 61 mins. c. at 2.65 amps for 110% Recharge Rate

	Time (mins.)	q (watts)	E (volts)	I (amps)	W (watts)	ΔH (watt-sec)	ΔH (kcal/equiv)	Adhydrode (mv)	Oxygen Press. (P.S.I.A.)
DISCHARGE									
	5	-0.94	1.31	4.75	-6.22	-7.16	-34.76	242	>29.0
	10	-1.10	1.28	4.75	-6.08	-7.18	-34.85	205	>29.0
	15	-1.14	1.27	4.75	-6.03	-7.17	-34.80	170	25.0
	20	-1.14	1.26	4.75	-5.99	-7.13	-35.12	140	18.1
	25	-1.12	1.25	4.75	-5.94	-7.06	-34.27	120	15.0
	30	-1.10	1.22	4.75	-5.78	-6.88	-34.40	100	11.5
CHARGE									
	5	-0.66	1.31	2.65	+3.47	+2.81	+24.45	88	10.1
	10	-0.28	1.33	2.65	+3.52	+3.24	+28.19	70	7.7
	15	-0.07	1.34	2.65	+3.55	+3.48	+30.28	60	6.5
	20	+0.05	1.36	2.65	+3.60	+3.65	+31.76	50	5.1
	25	+0.10	1.37	2.65	+3.63	+3.73	+32.45	42	4.4
	30	+0.14	1.39	2.65	+3.68	+3.82	+33.23	38	3.9
	35	+0.15	1.39	2.65	+3.68	+3.83	+33.32	35	3.5
	40	+0.12	1.40	2.65	+3.71	+3.83	+33.32	35	3.5
	45	+0.12	1.42	2.65	+3.76	+3.88	+33.76	39	4.0
	50	+0.05	1.46	2.65	+3.87	+3.92	+34.10	55	5.8
	55	-0.12	1.49	2.15	+3.02	+3.08	+33.03	150	20.0
	60	-0.40	1.49	1.50	+2.24	+1.84	+28.28	265	>29.0
	61	-0.56	1.49	1.48	+2.21	+1.65	+25.70	285	>29.0

EXPERIMENTAL SERIES D

25°C   Orbit 25   Oct. 13, 1966

Orbital Conditions:

1) 31 mins. d.c. at 4.75 amps for 40% Depth of d.c.
2) 61 mins. c. at 2.65 amps for 110% Recharge Rate

Time (mins.)	q (watts)	E (volts)	I (amps)	W (watts)	ΔH (watt-sec)	ΔH (kcal/equiv)	Adhydrode (mv)	Oxygen Press. (P.S.I.A.)
DISCHARGE								
5	-0.94	1.31	4.70	-6.16	-7.10	-34.83	240	>29.0
10	-1.10	1.28	4.75	-6.08	-7.18	-34.85	200	>29.0
15	-1.14	1.27	4.75	-6.03	-7.17	-34.80	170	25.0
20	-1.14	1.26	4.75	-5.99	-7.13	-34.16	140	18.1
25	-1.12	1.25	4.75	-5.94	-7.06	-34.27	118	13.8
30	-1.10	1.22	4.75	-5.78	-6.88	-33.40	98	11.3
CHARGE								
5	-0.66	1.31	2.65	+3.47	+2.81	+24.45	86	10.0
10	-0.30	1.33	2.65	+3.52	+3.22	+28.01	70	7.7
15	-0.05	1.34	2.65	+3.55	+3.50	+30.45	59	6.3
20	+0.05	1.36	2.65	+3.60	+3.65	+31.76	49	4.9
25	+0.07	1.37	2.65	+3.63	+3.70	+32.19	41	4.4
30	+0.13	1.39	2.65	+3.68	+3.81	+33.15	37	3.8
35	+0.13	1.39	2.65	+3.68	+3.81	+33.15	32	3.5
40	+0.12	1.40	2.65	+3.71	+3.83	+33.32	32	3.5
45	+0.11	1.42	2.65	+3.76	+3.87	+33.67	38	3.9
50	+0.05	1.46	2.65	+3.87	+3.92	+34.10	60	6.5
55	-0.12	1.49	2.25	+3.35	+3.23	+33.10	145	19.0
60	-0.40	1.49	1.60	+2.38	+1.98	+28.53	260	>29.0
61	-0.56	1.49	1.50	+2.24	+1.68	+25.82	280	>29.0

EXPERIMENTAL SERIES D

25°C — Orbit 26 — Oct. 13, 1966

Orbital Conditions:

1) 31 mins. d.c. at 4.75 amps for 40% Depth of d.c.
2) 61 mins. c. at 2.65 amps for 110% Recharge Rate

	Time (mins.)	q (watts)	E (volts)	I (amps)	W (watts)	ΔH (watt-sec)	ΔH (kcal/equiv)	Adhy-drode (mv)	Oxygen Press. (P.S.I.A.)
DISCHARGE									
	5	-0.94	1.31	4.73	-6.20	-7.14	-34.80	240	>29.0
	10	-1.12	1.28	4.75	-6.08	-7.20	-34.95	200	>29.0
	15	-1.14	1.27	4.75	-6.03	-7.17	-34.80	168	21.7
	20	-1.14	1.26	4.75	-5.99	-7.13	-34.61	140	18.1
	25	-1.12	1.25	4.75	-5.94	-7.06	-34.27	115	14.0
	30	-1.10	1.22	4.75	-5.78	-6.88	-33.40	98	11.3
CHARGE									
	5	-0.66	1.31	2.65	+3.47	+2.81	+24.45	88	10.1
	10	-0.28	1.33	2.65	+3.52	+3.24	+28.19	70	7.7
	15	-0.05	1.35	2.65	+3.58	+3.53	+30.71	57	5.9
	20	+0.05	1.36	2.65	+3.60	+3.65	+31.76	49	4.9
	25	+0.10	1.37	2.65	+3.63	+3.73	+32.45	40	4.1
	30	+0.14	1.39	2.65	+3.68	+3.82	+33.23	35	3.5
	35	+0.15	1.39	2.65	+3.68	+3.83	+33.32	32	3.5
	40	+0.12	1.41	2.65	+3.74	+3.86	+33.58	32	3.5
	45	+0.12	1.42	2.65	+3.76	+3.88	+33.76	35	3.5
	50	+0.05	1.46	2.65	+3.87	+3.92	+34.10	60	6.5
	55	-0.12	1.49	2.25	+3.35	+3.23	+33.10	140	18.1
	60	-0.40	1.49	1.55	+2.13	+1.91	+28.41	260	>29.0
	61	-0.56	1.49	1.50	+2.24	+1.68	+25.82	280	>29.0

EXPERIMENTAL SERIES D

25°C — Orbit 27 — Oct. 13, 1966

Orbital Conditions:

1) 31 mins. d.c. at 4.75 amps for 40% Depth of d.c.
2) 61 mins. c. at 2.65 amps for 110% Recharge Rate

Time (mins.)	q (watts)	E (volts)	I (amps)	W (watts)	ΔH (watt-sec)	ΔH (kcal/equiv)	Adhydrode (mv)	Oxygen Press. (P.S.I.A.)
DISCHARGE								
5	-0.94	1.31	4.75	-6.22	-7.16	-34.75	240	>29.0
10	-1.10	1.29	4.75	-6.13	-7.23	-35.09	200	>29.0
15	-1.14	1.27	4.75	-6.03	-7.17	-34.80	165	23.5
20	-1.14	1.26	4.75	-5.99	-7.13	-34.61	138	17.0
25	-1.12	1.25	4.75	-5.94	-7.06	-34.27	115	14.0
30	-1.10	1.22	4.75	-5.78	-6.88	-33.40	95	10.9
CHARGE								
5	-0.66	1.31	2.65	+3.47	+2.81	+24.45	85	9.7
10	-0.26	1.33	2.65	+3.52	+3.26	+28.36	70	7.7
15	-0.07	1.35	2.65	+3.58	+3.51	+30.54	58	6.2
20	+0.05	1.36	2.65	+3.60	+3.65	+31.76	48	4.8
25	+0.10	1.37	2.65	+3.63	+3.73	+32.45	40	4.1
30	+0.13	1.39	2.65	+3.68	+3.81	+33.15	35	3.5
35	+0.15	1.39	2.65	+3.68	+3.83	+33.32	32	3.5
40	+0.12	1.41	2.65	+3.74	+3.86	+33.58	32	3.5
45	+0.12	1.42	2.65	+3.76	+3.88	+33.76	35	3.5
50	+0.07	1.46	2.65	+3.37	+3.94	+34.28	60	6.5
55	-0.10	1.49	2.20	+3.28	+3.18	+33.33	150	20.0
60	-0.46	1.49	1.55	+2.31	+1.85	+27.52	260	>29.0
61	-0.56	1.49	1.50	+2.24	+1.68	+25.82	280	>29.0

EXPERIMENTAL SERIES D

25°C Orbit 28 Oct. 13, 1966

Orbital Conditions:

1) 31 mins. d.c. at 4.75 amps for 40% Depth of d.c.
2) 61 mins. c. at 2.65 amps for 110% Recharge Rate

Time (mins.)	q (watts)	E (volts)	I (amps)	W (watts)	ΔH (watt-sec)	ΔH (kcal/equiv)	Adhydrode (mv)	Oxygen Press. (P.S.I.A.)
DISCHARGE								
5	-0.97	1.31	4.70	-6.16	-7.13	-34.98	240	>29.0
10	-1.10	1.28	4.75	-6.08	-7.18	-34.85	200	>29.0
15	-1.14	1.27	4.75	-6.03	-7.17	-34.80	168	21.7
20	-1.14	1.26	4.75	-5.99	-7.13	-34.16	140	18.1
25	-1.12	1.25	4.75	-5.94	-7.06	-34.27	115	14.0
30	-1.10	1.22	4.75	-5.78	-6.88	-33.40	95	10.9
CHARGE								
5	-0.66	1.31	2.65	+3.47	+2.81	+24.45	88	10.1
10	-0.26	1.33	2.65	+3.52	+3.26	+28.36	70	7.7
15	-0.07	1.35	2.65	+3.58	+3.51	+30.54	58	6.2
20	+0.05	1.36	2.65	+3.60	+3.65	+31.76	50	5.1
25	+0.10	1.37	2.65	+3.63	+3.73	+32.45	40	4.1
30	+0.14	1.39	2.65	+3.68	+3.82	+33.23	35	3.5
35	+0.15	1.39	2.65	+3.68	+3.83	+33.32	32	3.5
40	+0.15	1.40	2.65	+3.71	+3.86	+33.58	32	3.5
45	+0.12	1.42	2.65	+3.76	+3.88	+33.76	38	3.9
50	+0.05	1.47	2.65	+3.90	+3.95	+34.37	60	6.5
55	-0.10	1.49	2.25	+3.35	+3.25	+33.30	150	20.0
60	-0.43	1.49	1.55	+2.31	+1.88	+27.96	265	>29.0
61	-0.56	1.49	1.50	+2.24	+1.68	+25.82	285	>29.0

EXPERIMENTAL SERIES D

25°C — Orbit 30 — Oct. 13, 1966

Orbital Conditions:

1) 31 mins. d.c. at 4.75 amps for 40% Depth of d.c.
2) 61 mins. c. at 2.65 amps for 110% Recharge Rate

Time (mins.)	q (watts)	E (volts)	I (amps)	W (watts)	ΔH (watt-sec)	ΔH (kcal/equiv)	Adhydrode (mv)	Oxygen Press. (P.S.I.A.)
DISCHARGE								
5	-0.97	1.32	4.74	-6.26	-7.23	-35.17	240	>29.0
10	-1.12	1.28	4.77	-6.11	-7.23	-34.95	200	>29.0
15	-1.17	1.27	4.77	-6.06	-7.23	-34.95	167	23.8
20	-1.17	1.26	4.79	-6.04	-7.21	-34.70	139	17.9
25	-1.12	1.25	4.79	-5.99	-7.11	-34.22	117	14.5
30	-1.10	1.22	4.79	-5.84	-6.94	-33.40	97	11.3
CHARGE								
5	-0.66	1.31	2.68	+3.51	+2.85	+24.52	87	10.0
10	-0.27	1.34	2.68	+3.59	+3.32	+28.56	70	7.7
15	-0.07	1.35	2.68	+3.62	+3.55	+30.54	68	7.5
20	+0.06	1.36	2.68	+3.64	+3.70	+31.83	49	5.0
25	+0.10	1.37	2.68	+3.67	+3.77	+32.43	41	4.4
30	+0.13	1.39	2.68	+3.73	+3.86	+33.21	37	3.8
35	+0.15	1.40	2.67	+3.74	+3.89	+33.59	36	3.6
40	+0.16	1.41	2.67	+3.76	+3.92	+33.85	36	3.6
45	+0.12	1.42	2.67	+3.79	+3.91	+33.76	39	4.0
50	+0.05	1.46	2.67	+3.90	+3.95	+34.11	53	5.6
55	-0.14	1.49	2.10	+3.13	+2.99	+32.82	100	11.5
60	-0.46	1.49	1.55	+2.31	+1.85	+27.52	269	>29.0
61	-0.56	1.49	1.50	+2.24	+1.68	+25.82	280	>29.0

CHAMPION LINE NO. 636

EXPERIMENTAL SERIES D

25°C　　Orbit 40　　Oct. 13, 1966

Orbital Conditions:

1) 31 mins. d.c. at 4.75 amps for 40% Depth of d.c.
2) 61 mins. c. at 2.65 amps for 110% Recharge Rate

	Time (mins.)	q (watts)	E (volts)	I (amps)	W (watts)	ΔH (watt-sec)	ΔH (kcal/equiv)	Adhydrode (mv)	Oxygen Press. (P.S.I.A.)
DISCHARGE									
	5	-0.97	1.31	4.70	-6.16	-7.13	-34.98	238	>29.0
	10	-1.11	1.28	4.75	-6.08	-7.19	-34.90	200	>29.0
	15	-1.16	1.27	4.75	-6.03	-7.19	-34.90	162	22.5
	20	-1.15	1.26	4.75	-5.99	-7.14	-34.66	135	17.1
	25	-1.12	1.25	4.75	-5.94	-7.06	-34.27	112	13.1
	30	-1.13	1.22	4.75	-5.80	-6.93	-33.64	95	11.0
CHARGE									
	5	-0.06	1.31	2.65	+3.47	+2.81	+24.45	82	9.0
	10	-0.27	1.33	2.65	+3.52	+3.25	+28.23	68	7.5
	15	-0.08	1.35	2.65	+3.58	+3.50	+30.45	57	5.9
	20	+0.04	1.36	2.65	+3.60	+3.64	+31.67	48	4.8
	25	+0.10	1.37	2.65	+3.63	+3.73	+32.45	40	4.1
	30	+0.10	1.38	2.65	+3.66	+3.76	+32.71	37	3.8
	35	+0.15	1.40	2.65	+3.71	+3.86	+33.58	34	3.4
	40	+0.12	1.40	2.65	+3.71	+3.83	+33.32	33	3.3
	45	+0.13	1.42	2.65	+3.76	+3.89	+33.34	38	3.9
	50	+0.06	1.46	2.65	+3.87	+3.93	+34.19	54	5.8
	55	-0.12	1.49	2.20	+3.28	+3.16	+33.12	140	18.1
	60	-0.36	1.49	1.60	+2.38	+2.02	+29.11	155	21.0
	61	-0.56	1.49	1.55	+2.31	+1.75	+26.03	177	26.9

CHAMPION LINE NO. 636

EXPERIMENTAL SERIES D

25°C | Orbit 50 | Oct. 13, 1966

Orbital Conditions:

1) 31 mins. d.c. at 4.75 amps for 40% Depth of d.c.
2) 61 mins. c. at 2.65 amps for 110% Recharge Rate

	Time (mins.)	q (watts)	E (volts)	I (amps)	W (watts)	ΔH (watt-sec)	ΔH (kcal/equiv)	Adhydrode (mv)	Oxygen Press. (P.S.I.A.)
DISCHARGE									
	5	-0.98	1.31	4.70	-6.16	-7.14	-35.03	232	>29.0
	10	-1.11	1.28	4.75	-6.08	-7.19	-34.90	190	>29.0
	15	-1.17	1.27	4.75	-6.03	-7.20	-34.95	158	21.8
	20	-1.18	1.26	4.75	-5.99	-7.17	-34.80	130	16.1
	25	-1.14	1.25	4.75	-5.94	-7.08	-34.37	108	12.8
	30	-1.11	1.22	4.75	-5.80	-6.91	-33.54	90	10.4
CHARGE									
	5	-0.67	1.30	2.65	+3.45	+2.78	+24.19	80	8.9
	10	-0.26	1.33	2.65	+3.52	+3.26	+28.36	65	7.1
	15	-0.09	1.35	2.65	+3.58	+3.49	+30.36	53	5.6
	20	+0.05	1.36	2.65	+3.60	+3.65	+31.76	47	5.0
	25	+0.09	1.37	2.65	+3.63	+3.72	+32.36	40	4.1
	30	+0.11	1.38	2.65	+3.66	+3.77	+32.80	35	3.5
	35	+0.14	1.40	2.65	+3.71	+3.85	+33.50	32	3.5
	40	+0.14	1.41	2.65	+3.74	+3.88	+33.76	32	3.5
	45	+0.12	1.42	2.65	+3.76	+3.88	+33.76	37	3.8
	50	+0.07	1.46	2.65	+3.87	+3.94	+34.28	56	5.9
	55	-0.14	1.49	2.13	+3.17	+3.03	+32.80	136	17.5
	60	-0.45	1.49	1.70	+2.53	+2.08	+28.21	250	>29.0
	61	-0.54	1.49	1.60	+2.38	+1.84	+26.51	274	>29.0

EXPERIMENTAL SERIES D

25°C Orbit 60 Oct. 13, 1966

Orbital Conditions:

1) 31 mins. d.c. at 4.75 amps for 40% Depth of d.c.
2) 61 mins. c. at 2.65 amps for 110% Recharge Rate

Time (mins.)	q (watts)	E (volts)	I (amps)	W (watts)	ΔH (watt-sec)	ΔH (kcal/equiv)	Adhydrode (mv)	Oxygen Press. (P.S.I.A.)
DISCHARGE								
5	-0.99	1.31	4.70	-6.16	-7.15	-35.08	230	>29.0
10	-1.15	1.28	4.74	-6.07	-7.22	-35.12	190	>29.0
15	-1.18	1.27	4.74	-6.02	-7.20	-35.02	157	21.6
20	-1.18	1.25	4.75	-5.94	-7.12	-34.56	128	15.9
25	-1.14	1.25	4.75	-5.94	-7.08	-34.37	117	14.5
30	-1.11	1.21	4.75	-5.75	-6.86	-33.30	88	10.1
CHARGE								
5	-0.66	1.30	2.65	+3.45	+2.79	+24.27	77	11.3
10	-0.27	1.32	2.65	+3.50	+3.23	+28.10	63	6.9
15	-0.09	1.34	2.65	+3.55	+3.46	+30.10	52	5.4
20	+0.04	1.36	2.65	+3.60	+3.64	+31.67	45	4.6
25	+0.09	1.37	2.65	+3.63	+3.72	+32.36	40	4.1
30	+0.10	1.38	2.65	+3.66	+3.76	+32.71	34	3.4
35	+0.15	1.39	2.65	+3.68	+3.83	+33.32	31	3.1
40	+0.11	1.40	2.65	+3.71	+3.82	+33.23	30	3.0
45	+0.13	1.42	2.65	+3.76	+3.89	+33.84	35	3.5
50	+0.05	1.46	2.65	+3.87	+3.92	+34.10	53	5.6
55	-0.10	1.49	2.15	+3.20	+3.10	+33.24	130	16.1
60	-0.45	1.49	1.65	+2.46	+2.01	+28.09	250	>29.0
61	-0.55	1.49	1.60	+2.38	+1.83	+26.37	270	>29.0

EXPERIMENTAL SERIES D

25°C Orbit 71 Oct. 13, 1966

Orbital Conditions:

1) 31 mins. d.c. at 4.75 amps for 40% Depth of d.c.
2) 61 mins. c. at 2.65 amps for 110% Recharge Rate

Time (mins.)	q (watts)	E (volts)	I (amps)	W (watts)	ΔH (watt-sec)	ΔH (kcal/equiv)	Adhy-drode (mv)	Oxygen Press. (P.S.I.A.)
DISCHARGE								
5	-0.99	1.31	4.73	-6.20	-7.19	-35.04	230	>29.0
10	-1.16	1.28	4.75	-6.08	-7.24	-35.14	190	>29.0
15	-1.18	1.27	4.75	-6.03	-7.21	-35.00	155	21.0
20	-1.18	1.25	4.75	-5.94	-7.12	-34.56	129	15.9
25	-1.16	1.23	4.76	-5.85	-7.01	-33.95	106	12.5
30	-1.13	1.21	4.76	-5.76	-6.89	-33.37	88	10.1
CHARGE								
5	-0.65	1.30	2.67	+3.47	+2.82	+24.35	77	11.3
10	-0.27	1.32	2.67	+3.52	+3.25	+28.06	61	6.8
15	-0.09	1.34	2.65	+3.55	+3.46	+30.10	51	5.2
20	+0.05	1.36	2.65	+3.60	+3.65	+31.76	45	4.6
25	+0.10	1.37	2.65	+3.63	+3.73	+32.45	39	4.0
30	+0.11	1.38	2.65	+3.66	+3.77	+32.80	35	3.5
35	+0.15	1.40	2.65	+3.71	+3.86	+33.58	31	3.1
40	+0.14	1.41	2.65	+3.74	+3.88	+33.76	30	3.0
45	+0.11	1.42	2.65	+3.76	+3.87	+33.67	34	3.4
50	+0.05	1.46	2.65	+3.87	+3.92	+34.10	55	5.8
55	-0.14	1.49	2.20	+3.28	+3.14	+32.91	130	16.1
60	-0.51	1.49	1.75	+2.61	+2.10	+27.67	250	>29.0
61	-0.56	1.49	1.66	+2.47	+1.91	+26.53	270	>29.0

Procedure For Entering a Hermetically Sealed

6 A-H Gulton Prismatic Ni-Cd Cell

This procedure is to be used on a hermetically sealed cell which has not been fitted initially by the manufacturer with an appropriate device for measuring internal gas pressure. The procedure is such that it allows the very minimum of foreign material and atmosphere to enter the cell.

1) With a #44 drill (0.086" dia.) center drill the negative terminal of the cell to a depth of 5/8".
2) With a 3-56 tap, thread this hole to a depth of 0.50".
3) At this point, clean the hole of all metal turnings and excessive grease and cutting fluid.
4) Now, place the entire cell and drill press in an argon atmosphere.
5) Continue to center drill the negative terminal for approximately 3/32" with a #72 drill (0.025" dia.), backing out the drill every few seconds to remove any metal turnings while a stream of argon gas plays on the hole.
6) After drilling approximately 3/32", the interior of the cell will be reached without damage to the cell.

Into this threaded hole (3-56) place a stainless steel (Type 316) adapter, shown in Figure 7. The adapter in turn will connect to a 1/8 Swagelok Tee containing a pressure transducer and a stainless steel valve through which a vacuum may be applied.

After all of the above components are assembled in an argon atmosphere and the valve closed, the entire system can be removed from the argon chamber. All fittings and threads are sealed with Teflon tape.

Finally, a vacuum line is attached to the valve and with the aid of a water aspirator a vacuum is pulled on the cell thus removing the argon and returning the cell to its initial condition. It is important not to go below 24 mm. of pressure. At the lower pressure the electrolyte in the cell will be vaporized.

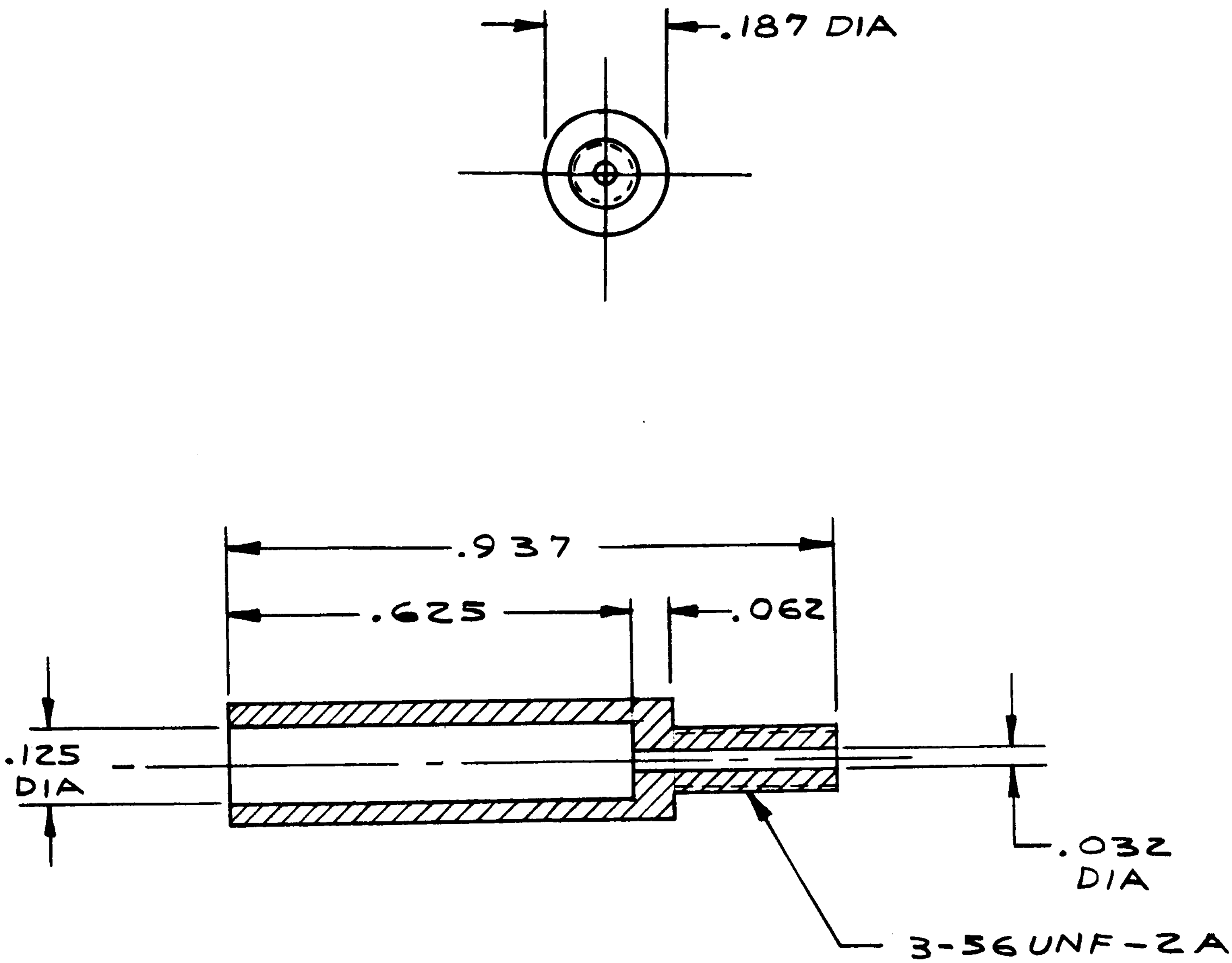

FIGURE 7 - STAINLESS STEEL ADAPTER