EVALUATION PROGRAM

for

SECONDARY SPACECRAFT CELLS

ACCEPTANCE TESTS
OF
6.0 AMPERE-HOUR NICKEL-CADMIUM CELLS
MANUFACTURED BY
GULTON INDUSTRIES
WITH GULTON PLATES

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT W12,397

QUALITY EVALUATION LABORATORY
NAD CRANE, INDIANA

DEPARTMENT OF THE NAVY
NAVAL AMMUNITION DEPOT
QUALITY EVALUATION DEPARTMENT
CRANE, INDIANA 47522

EVALUATION PROGRAM FOR SECONDARY SPACECRAFT CELLS

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QE/C 70-662 14 August 1970

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QE/C 70-662

REPORT BRIEF
6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS MANUFACTURED BY GULTON INDUSTRIES WITH GULTON PLATES

Ref: (a) National Aeronautics and Space Administration Purchase Order Number W12-397
(b) NASA ltr BRA/VBK/pad of 25 September 1961 w/BUWEPS first end FQ-1:WSK of 2 October 1961 to CO NAD Crane
(c) Preliminary Work Statement for Battery Evaluation Program of 25 August 1961

I. TEST ASSIGNMENT BRIEF

A. In compliance with references (a) and (b), evaluation of Gulton 6.0 ampere-hour secondary spacecraft cells was begun according to the program outline of reference (c).

B. The purpose of this acceptance test program is to insure that all cells put into the life cycle program are of high quality by the removal of cells found to have electrolyte leakage, internal shorts, low capacity, or inability of any cell to recover its open circuit voltage above 1.15 after the cell short test.

C. Thirty cells were purchased from Gulton Industries, Metuchen, New Jersey by National Aeronautics and Space Administration (NASA). These cells are rated at 6.0 ampere-hours by the manufacturer.

II. RESULTS

A. The leak tests before and after overcharge gave no evidence of leakage around the ceramic seals. Following overcharge, there was evidence of a slight leak around the fill tube on one cell.

B. The capacity of the cells (to 1.00 volt) was in the acceptable range of 6.66 to 7.41 ampere-hours with an average of 6.96 for three capacity checks. The high capacity occurred during the first capacity check; the low occurred during the second capacity check.

C. The internal short test showed all cells, except (SN 900), to recover well above the 1.15 volt limit, averaging 1.19 volts.

D. The internal resistance of the 30 cells ranged from 2.78 to 3.39 milliohms for an average of 2.87 milliohms.

E. Discharge to 1.00 volt following overcharge results in capacities ranging from 6.00 to 6.81 ampere-hours for an average of 6.59 ampere-hours. Further discharging to 0.00 volts, prior to shorting, resulted in capacities ranging from 6.39 to 7.29 ampere-hours for an average of 7.10 ampere-hours.

QE/C 70-662

RESULTS OF ACCEPTANCE TESTS OF 6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS MANUFACTURED BY GULTON INDUSTRIES WITH GULTON PLATES

I. INTRODUCTION

A. On 23 April 1970, acceptance tests were begun on 30 cells. These tests were completed on 27 May 1970.

II. TEST CONDITIONS

A. All acceptance tests were performed at an ambient temperature between 23° C and 27° C at existing relative humidity and atmospheric pressure, and consisted of the following:

1. Physical Inspection: Weighing, Measuring and Phenolphthalein Leak Test.

2. Capacity Test.

3. Cell Short Test.

4. Leak Test.

5. Overcharge Test.

6. Internal Resistance Measurement.

7. Leak Test.

B. All charging and discharging was done at constant current (±5 percent). Cells were charged in series but discharged individually.

III. CELL IDENTIFICATION AND DESCRIPTION

A. The cells were identified by the manufacturer's serial numbers. However, there were 2 cells out of the 30 that had the same serial number (914). One of these cells was arbitrarily identified as 914A by this activity. The serial numbers of the 30 cells were from 899 to 934 although not consecutively.

B. The cells were further identified by acceptance pack numbers assigned by this activity. Cells with serial numbers 899 through 909 made up pack D-3-0. Serial numbers 910 through 923 made up pack E-1-0. Serial numbers 924 through 934 made up pack E-2-0. Each pack contained 10 cells.

C. The 6.0 ampere-hour cell is rectangular with an average height (base to top of positive terminal), length and width of 3.692, 0.827, 2.101 inches respectively. The average weight is 284.2 grams. The individual cell dimensions and weight are given in Table I.

D. The cell containers and covers are made of stainless steel. Both terminals are insulated from the cell cover by a ceramic seal and protrude through the cover as solder type terminals.

E. These cells were supplied in a discharged condition.

IV. TEST PROCEDURE AND RESULTS

A. Phenolphthalein Leak Test:

1. The phenolphthalein leak test is a determination of the condition of the welds and ceramic seals on receipt of the cells. This test was performed prior to any other tests, with a phenolphthalein spray indicator solution of one-half of one percent concentration.

2. This initial leak test indicated one cell (SN 905) to have a slight leak at the positive terminal. Another cell (SN 902) indicated a slight leak at the fill tube. A third cell (SN 925) indicated a leak at the fill tube. However, none of these cells showed leaks on later leak tests. Thus, electrolyte contamination prior to shipment accounts for such results.

B. Capacity Test:

1. The capacity test is a determination of the cell capacity at the c/2 discharge rate, where c is the manufacturer's rated capacity to a cutoff voltage of 1.00 volt per cell. The discharge was made after a 1-hour open circuit period following the 16-hour charge at the c/10 rate. A total of three capacity checks was made at this activity. The cells were discharged individually, but were recharged in series.

2. The individual capacities to 1.00 volt ranged from 6.66 to 7.41 ampere-hours for an average of 6.96 ampere-hours. The cell capacities are tabulated in Table I. Characteristic 2-hour rate discharge curves for high, average, and low capacity cells are shown in Figure 1.

C. Cell Short Test:

1. The cell short test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials, or damage to element in handling or assembly.

2. Following completion of the third capacity discharge test, each individual cell was loaded with a 0.5 ohm, 3 watt resistor and allowed to stand 16 hours with the resistor acting as a shorting device. At the end of 16 hours, the resistors were removed and the cells were placed on open circuit stand for 24 hours. Any cell whose voltage did not recover to 1.15 volts or higher was considered as failing this portion of the acceptance test.

3. The open circuit cell voltage, 24 hours after removal of the shorting resistors, ranged from 1.18 to 1.20 volts with one exception. Cell 900 gave a recovery voltage of only 0.40 volts.

D. Leak Test:

1. The leak test is a means of detecting leakage of a seal or weld. The test was performed before and after the overcharge test sequence to determine the presence of leaks.

2. The cells were placed in a vacuum chamber and exposed to a vacuum of 40 microns of mercury or less for 24 hours. The cells were then removed from the vacuum chamber and sprayed with phenolphthalein. Faintly pink areas were designated as slight leakers. Darker, more obvious, discolorations of pink or red were noted as definite leakers.

3. None of the 30 cells failed this portion of testing.

E. Overcharge Test:

1. The purpose of this test is basically threefold:

a. To determine the degree to which a pack of cells maintain a balanced voltage.

b. To determine the cells capability of reaching a point of chemical equilibrium--oxygen recombination with the negative (cadmium) plate.

c. To test the integrity of the seals as the pressure increases.

2. The overcharge tests were performed to determine the steady state voltage at specified rates. The test specified a series of constant current charges at c/20, c/10 and c/5 rates, for a minimum of 48 hours at each charge rate or until the increase of the "on charge" voltage was less than 10 millivolts per day.

3. The cells were monitored hourly throughout the test. Charging was to be discontinued on cells which exceeded 1.50 volts. No cells were removed from the charging sequence.

4. The steady state voltage of each cell at the end of each 48-hour charge rate test is shown in Table I. Characteristic overcharge voltage curves for high, average and low cells are shown in Figure 2.

5. No cells exceeded the 1.50 volt limit.

F. Internal Resistance Test:

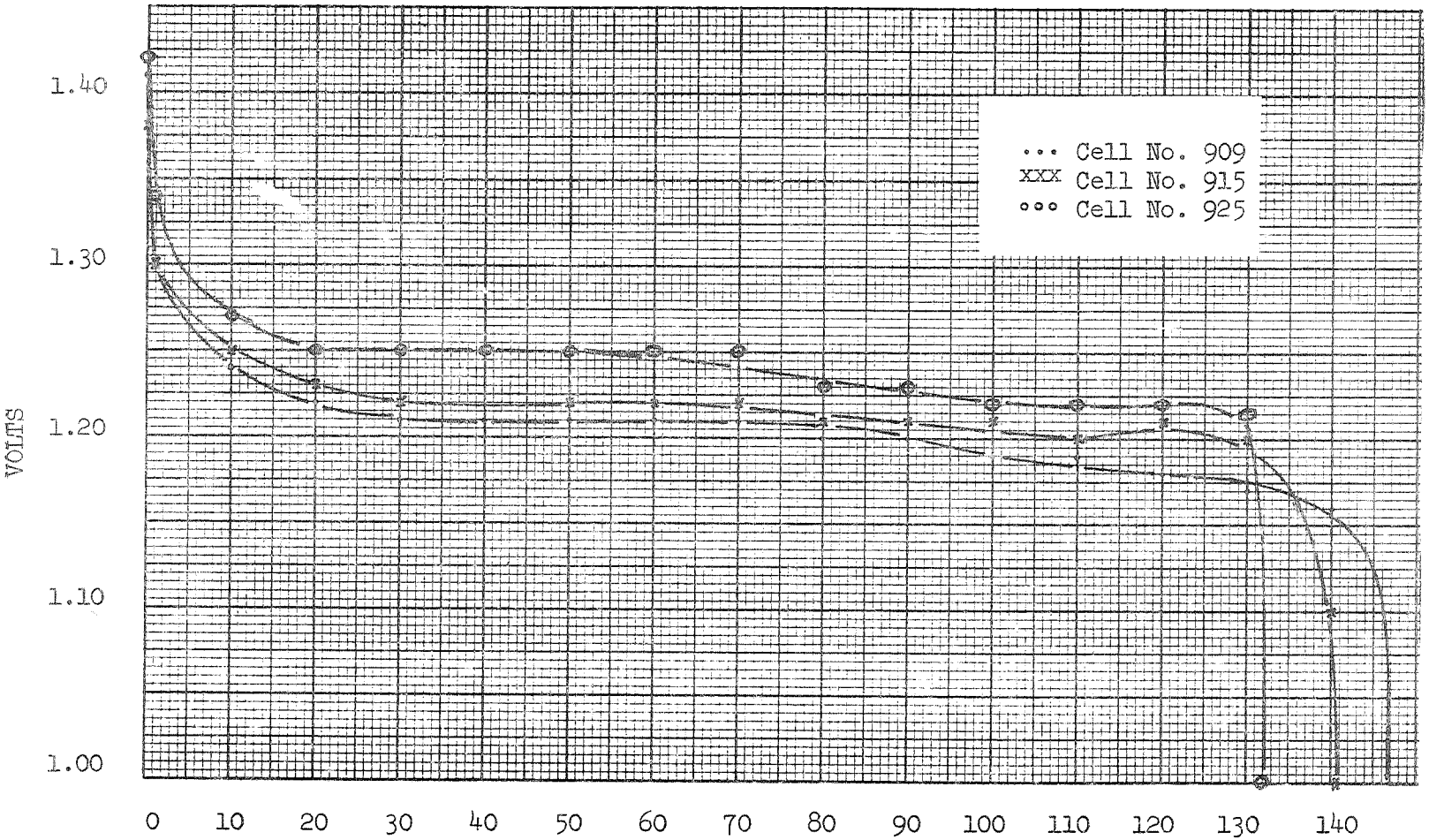
1. Immediately following the overcharge test, the internal resistance of each cell was measured with a Hewlett-Packard milliohmmeter (Model 4328A).

2. The internal resistance for each cell is shown in Table I. The resistance values for the 30 cells range from 2.78 to 3.39 milliohms for an average of 2.87 milliohms.

G. Leak Test:

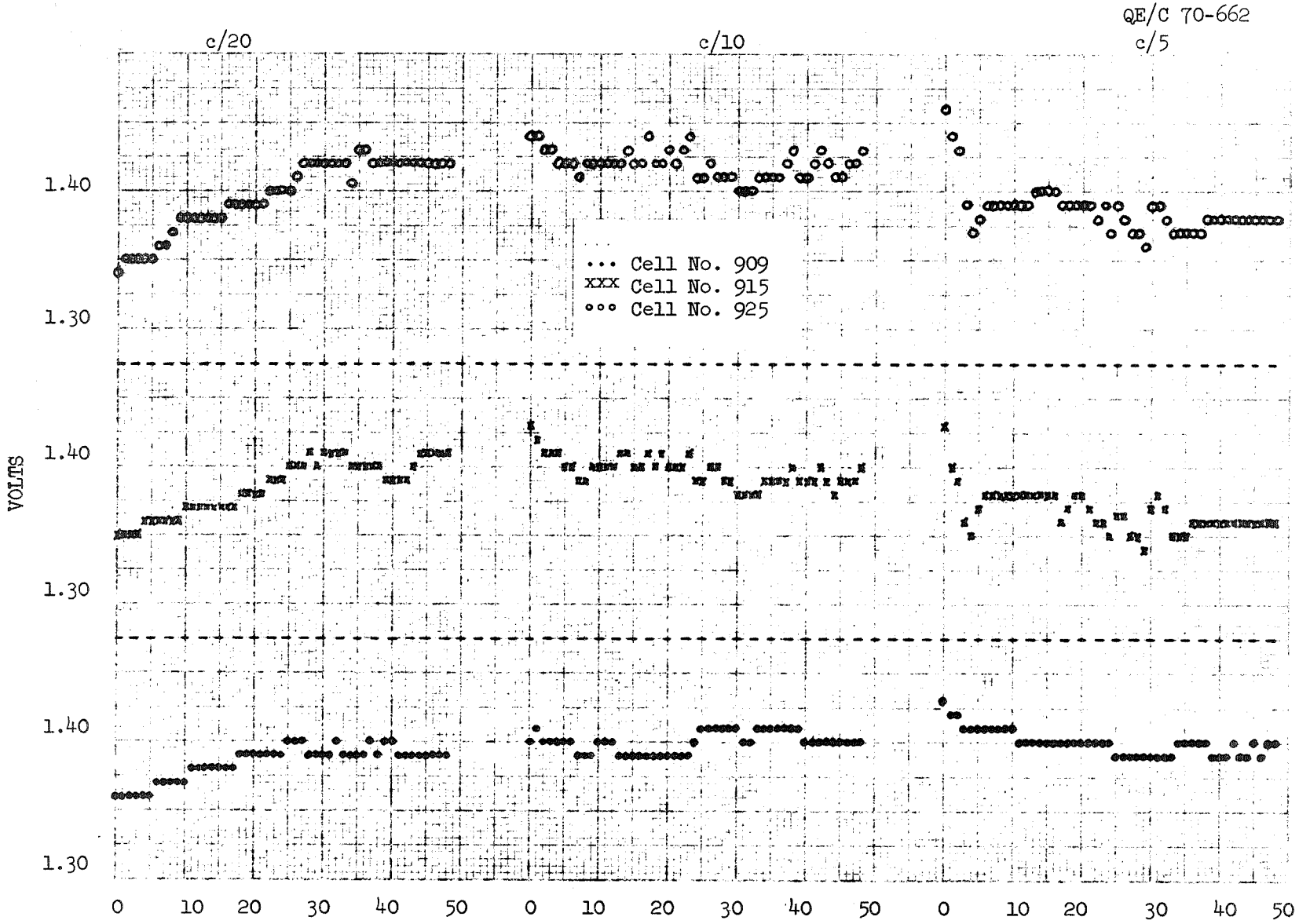
1. Following the internal resistance measurements, the cells were still in a charged state. The cells were discharged at c/2 to 0.00 volts and shorted prior to the final leak test. The capacities to 1.00 volt and 0.00 volts are shown for each cell in Table I. The shorted cells were then placed in a vacuum chamber and the procedure described in paragraph IV.D.2 was repeated.

2. Only one cell (903) gave a slight leak around the fill tube.



CHARACTERISTIC 2-HOUR RATE DISCHARGE CURVES

FIGURE 1



CHARACTERISTIC 48-HOUR OVERCHARGE CURVES

FIGURE 2

TABLE I

GULTON 6.0 AMPERE-HOUR NICKEL CADMIUM

CELL NUMBER	WEIGHT (GRAMS)	HEIGHT (INCHES)	LENGTH (INCHES)	WIDTH (INCHES)	CAPACITY TEST (A.H.)	CAPACITY TEST (A.H.)	CAPACITY TEST (A.H.)	CELL SHORT TEST (VOLTS)	OVERCHARGE c/20 (VOLTS)	OVERCHARGE c/10 (VOLTS)	OVERCHARGE c/5 (VOLTS)	INTERNAL RESISTANCE MEASURED MILLIOHMS	CAPACITY FOLLOWING OVERCHARGE TO 1.00V (A.H.)	CAPACITY FOLLOWING OVERCHARGE TO 0.00V (A.H.)
899	282.7	3.690	0.836	2.100	7.10	6.96	6.84	1.18	1.39	1.41	1.40	2.85	6.60	7.26
900	283.6	3.685	0.830	2.118	7.30	7.11	6.99	*0.40	1.38	1.39	1.38	2.82	6.60	7.26
901	284.1	3.700	0.825	2.100	7.35	7.14	7.11	1.18	1.38	1.39	1.38	2.85	6.66	7.29
902	283.5	3.688	0.828	2.095	7.35	7.11	7.05	1.18	1.38	1.39	1.38	2.86	6.60	7.20
903	285.4	3.707	0.829	2.105	7.35	7.11	7.05	1.18	1.38	1.39	1.37	2.94	6.64	7.11
D-3-O 904	284.5	3.688	0.820	2.110	7.30	7.05	6.99	1.19	1.38	1.39	1.38	2.88	6.64	7.14
905	284.0	3.695	0.845	2.106	7.41	7.20	7.14	1.19	1.37	1.39	1.38	2.83	6.45	7.05
907	284.5	3.708	0.825	2.114	7.35	7.14	7.05	1.18	1.38	1.39	1.38	2.89	6.64	7.11
908	285.3	3.690	0.835	2.098	7.25	7.05	6.96	1.18	1.38	1.39	1.38	2.84	6.64	7.11
909	283.9	3.698	0.824	2.097	7.35	7.20	7.11	1.20	1.38	1.41	1.40	2.79	6.60	7.20
910	285.2	3.700	0.820	2.113	7.20	7.05	7.05	1.19	1.41	1.43	1.41	2.82	6.60	7.20
911	284.2	3.700	0.830	2.100	6.99	6.96	6.96	1.18	1.41	1.42	1.39	3.39	6.51	7.20
912	284.2	3.685	0.820	2.110	6.99	6.99	7.05	1.18	1.41	1.41	1.39	2.82	6.51	6.99
E-1-O 914	284.8	3.690	0.820	2.105	6.99	6.99	6.96	1.18	1.41	1.40	1.36	2.82	6.81	7.26
914A	283.7	3.708	0.825	2.110	6.99	6.90	6.96	1.18	1.41	1.40	1.36	3.16	6.75	7.26

*Low cell not included in average

TABLE I (Cont)

	CELL NUMBER	WEIGHT (GRAMS)	HEIGHT (INCHES)	LENGTH (INCHES)	WIDTH (INCHES)	CAPACITY TEST (A.H.)	CAPACITY TEST (A.H.)	CAPACITY TEST (A.H.)	CELL SHORT TEST (VOLTS)	OVERCHARGE c/20 (VOLTS)	OVERCHARGE c/10 (VOLTS)	OVERCHARGE c/5 (VOLTS)	INTERNAL RESISTANCE MEASURED MILLIOHMS	CAPACITY FOLLOWING OVERCHARGE TO 1.00V (A.H.)	CAPACITY FOLLOWING OVERCHARGE TO 0.00V (A.H.)
	915	284.1	3.708	0.830	2.100	6.99	6.99	6.99	1.18	1.41	1.40	1.36	2.89	6.75	7.26
	916	283.9	3.700	0.825	2.104	6.99	6.96	6.84	1.18	1.41	1.40	1.36	2.84	6.75	7.26
E-1-0	918	283.9	3.700	0.825	2.100	6.99	6.96	6.81	1.19	1.41	1.40	1.36	2.78	6.51	6.99
E-1-0	920	284.7	3.700	0.825	2.100	6.99	6.96	6.96	1.18	1.41	1.41	1.37	2.79	6.69	7.26
	923	284.0	3.635	0.825	2.102	6.99	6.84	6.81	1.19	1.42	1.41	1.39	2.84	6.45	6.84
	924	284.0	3.680	0.825	2.105	6.64	6.75	6.84	1.19	1.43	1.44	1.41	2.88	6.45	6.84
	925	283.5	3.700	0.825	2.100	6.60	6.69	6.75	1.19	1.42	1.43	1.38	2.92	6.45	6.84
	926	284.3	3.695	0.825	2.100	6.64	6.66	6.69	1.19	1.42	1.43	1.37	2.81	6.39	6.90
	927	284.8	3.688	0.825	2.110	6.66	6.84	6.84	1.19	1.42	1.42	1.35	2.79	6.00	6.39
	928	284.6	3.680	0.825	2.110	6.69	6.84	6.90	1.19	1.41	1.41	1.36	2.83	6.81	7.29
E-2-0	929	283.7	3.685	0.829	2.100	6.66	6.90	6.84	1.18	1.42	1.42	1.36	2.81	6.69	7.29
	930	284.6	3.700	0.828	2.100	6.66	6.75	6.81	1.19	1.41	1.41	1.36	2.84	6.61	7.14
	931	284.7	3.680	0.825	2.106	6.60	6.84	6.75	1.18	1.42	1.42	1.36	2.90	6.61	6.99
	932	284.2	3.685	0.825	2.108	6.66	6.81	6.75	1.20	1.42	1.42	1.37	2.81	6.69	6.99
	934	283.2	3.700	0.825	2.000	6.60	6.81	6.90	1.19	1.43	1.43	1.41	2.87	6.61	6.96
	Avg	284.2	3.692	0.827	2.101	6.99	6.95	6.93	*1.19	1.40	1.41	1.38	2.87	6.59	7.10

*Low cell not included in average

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119 Martin-Marietta Corporation (Mr. William B. Collins, M.S. 1620 and Mr. M. S. Imamura, M.S. 8840), P. O. Box 179, Denver, Colorado 80201

120 McDonnell Douglas, Inc. (Mr. A. D. Tonelli, MS 7C), 3000 Ocean Park Boulevard, Santa Monica, California 90406

121 McDonnell Douglas, Inc., Astropower Laboratory (Dr. George Moe), 2121 Campus Drive, Newport Beach, California 92663

122 North American Rockwell Corporation, Rocketdyne Division (Library), 6633 Canoga Avenue, Canoga Park, California 91304

123 Philco-Ford Corporation, Space Power and Propulsion Department (Mr. D. C. Briggs, M.S. W-49), 3825 Fabian Way, Palo Alto, California 94303

124 Portable Power Sources Corporation (Mr. Leon Schulman), 166 Pennsylvania Avenue, Mt. Vernon, New York 10552

125 Power Information Center, University City Science Institute, Room 2107, 3401 Market Street, Philadelphia, Pennsylvania 19104

126 Prime Battery Corporation, 15600 Cornet Street, Santa Fe Springs, California 90670

127 RAI Research Corporation, 36-40 37th Street, Long Island City, New York 11101

128 Southwest Research Institute (Library), 8500 Culebra Road, San Antonio, Texas 78206

129 Stanford Research Institute (Dr. Fritz R. Kalhammer), 820 Mission Street, South Pasadena, California 91030

130 Texas Instruments, Inc., Metals and Controls Division (Dr. E. J. Jost and Dr. J. W. Ross), 34 Forest Street, Attleboro, Massachusetts 02703

131 TRW Systems, Inc. (Dr. W. R. Scott, M 2/2154), One Space Park, Redondo Beach, California 90278

132 TRW Systems, Inc. (Dr. Herbert P. Silverman, R-1/2094), One Space Park, Redondo Beach, California 90278

133 TRW, Inc. (Librarian), 23555 Euclid Avenue, Cleveland, Ohio 44117

134 Tyco Laboratories, Inc. (Dr. A. C. Makrides), Bear Hill, Hickory Drive, Waltham, Massachusetts 02154

135 Union Carbide Corporation, Development Laboratory Library, P. O. Box 5056, Cleveland, Ohio 44101

136 Union Carbide Corporation, Consumer Products Division (Dr. Robert Powers), P. O. Box 6166, Cleveland, Ohio 44101

137 University of Pennsylvania, Electrochemistry Laboratory (Prof. John O'M. Bockris), Philadelphia, Pennsylvania 19104

138 Westinghouse Electric Corporation, Research and Development Center (Dr. C. C. Hein, Contract Admin.), Churchill Borough, Pittsburg, Pennsylvania 15235

139 Whittaker Corporation, Power Sources Division (Mr. J. W. Reiter), 3850 Olive Street, Denver, Colorado 80237