N71-15746
NASA CR-115788

EVALUATION PROGRAM for SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
GULTON INDUSTRIES
5.0 AMPERE-HOUR NICKEL-CADMIUM
SPACECRAFT CELLS WITH COBALT ADDITIVE
prepared for
GODDARD SPACE FLIGHT CENTER

CONTRACT W12,397

QUALITY EVALUATION LABORATORY
NAD CRANE, INDIANA

DEPARTMENT OF THE NAVY
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CRANE, INDIANA 47522

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QE/C 70-692 22 October 1970

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Enclosure (1)

REPORT BRIEF
GULTON INDUSTRIES
5.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
WITH COBALT ADDITIVE

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) NASA Lewis Work Sheet of 11 September 1969

I. TEST ASSIGNMENT BRIEF

A. In compliance with references (a) and (b), evaluation of Gulton 5.0 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. Fifty cells were purchased from Gulton Industries, Metuchen, New Jersey. These cells are rated at 5.0 ampere-hours. They consisted of four groups: (1) Twelve cells contained cobalt additive and Pellon separator and were designated Cobalt-Pellon; (2) Thirteen cells contained cobalt additive and Polypropylene (PPL) separators and were designated Cobalt-PPL; (3) Twelve cells contained pellon separators with no cobalt additive and were designated Control-Pellon; and (4) Thirteen cells contained Polypropylene separarators with no cobalt additive and were designated Control-PPL.

II. RESULTS

A. The data substantiates the following summary of results:

1. The preconditioning cycle showed no cell to exceed a charge voltage of 1.45 volts during the 48-hour charge. The discharge during preconditioning showed the capacity of the cells to range from 4.79 to 7.68 ampere-hours for an average of 6.31 ampere-hours.

2. Following preconditioning, the average capacity for three capacity checks is as follows:

	Cobalt-Pellon	Cobalt-PPL	Control-Pellon	Control-PPL
Avg ah	5.50	5.26	5.64	6.07

The control-pellon group steadily dropped capacity over the three capacity checks: (1st) avg, 6.50 ah (2nd) avg, 5.75 ah (3rd) avg, 4.67 ah. During the third capacity check all control-pellon cells delivered less than 5.00 ah.

3. The recovery voltage for both groups with cobalt additive was less that 1.15 volts during the cell short test.

	Cobalt-Pellon	Cobalt-PPL	Control-Pellon	Control-PPL
Avg Recovery Volts	1.09	1.07	1.16	1.22
Range Volts	1.09-1.14	1.04-1.11	1.13-1.22	1.21-1.22

The control-pellon group contained only four cells whose recovery voltage exceeded 1.15 volts.

4. The end-of-overcharge voltage did not vary appreciably among the groups or the two rates--c/10 and c/20. The average for the different groups and rates of charge ranged from 1.43 to 1.47 volts.

5. The internal resistance did not vary appreciably among the groups. The overall average was 2.82 millohms.

6. The capacity to 1.00 volt following the overcharge was as follows:

	Cobalt-Pellon	Cobalt-PPL	Control-Pellon	Control-PPL
Avg ah	4.93	4.81	6.58	6.81
Range ah	4.70-5.30	4.68-4.95	6.45-6.75	7.08-6.45

7. The ceramic seals of these cells are satisfactory as evidenced by no leakers around the seals of the 50 cells tested.

III. CONCLUSIONS

A. From comparative graphs of discharge and overcharge, it can be concluded that:

1. Cobalt additive suppresses voltage on charge and discharge.

2. Cells with cobalt additive deliver less capacity by 0.8 to 1.2 ampere-hours.

RESULTS OF ACCEPTANCE TEST OF 5.0 AMPERE-HOUR NICKEL-CADMIUM SECONDARY SPACECRAFT CELLS MANUFACTURED BY GULTON INDUSTRIES FOR THE EVALUATION OF COBALT ADDITIVE TO POSITIVE PLATES

I. INTRODUCTION

A. On 6 June 1970, acceptance tests were begun on 50 cells manufactured by Gulton Industries, Metuchen, New Jersey. These tests were completed on 15 July 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. Conditioning Cycle.

3. Capacity Tests.

4. Cell Short Test.

5. Leak Test.

6. Overcharge Test.

7. Internal Resistance Measurement.

8. 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 number. They were divided into four groups: (1) Twelve cells contained cobalt additive and pellon separator and were designated Cobalt-Pellon with serial numbers from 1865 to 1876 consecutively. (2) Thirteen cells contained cobalt additive and polypropylene (PPL) separator and were designated Cobalt-PPL with serial numbers from 1880 to 1892 consecutively. (3) Twelve cells contained pellon separator with no cobalt additive and were designated Control-Pellon with serial numbers from 1895 to 1906 consecutively. (4) Thirteen cells contained polypropylene separator with no cobalt additive and were designated Control-PPL with serial numbers 1909 to 1921 consecutively.

B. The cells were divided into five 10-cell packs for acceptance testing. This activity assigned the following acceptance pack numbers:

Pack Number	F-1-0	F-2-0	F-3-0
Group	Cobalt-Pellon	Cobalt-PPL	Control-Pellon
Serial No. Range	1865-1874	1880-1889	1895-1904

Pack Number	F-4-0	F-5-0
Group	Control-PPL	Mixed
Serial No. Range	1904-1918	--

Pack F-5-0 consisted of a mixture of cells from the four groups with the following serial numbers:

Group	Cobalt-Pellon	Cobalt-PPL	Control-Pellon	Control-PPL
Serial Numbers	1875,1876	1890, 1891 1892	1905, 1906	1919, 1920 1921

Because Pack F-5-0 is a mixture of the four groups, the data for this pack has not been averaged in Table I as it was for the other four packs.

C. These 5.0 ampere-hour cells are rectangular with an average height (base to top of positive terminal), length and width of 3.693, 0.822 and 2.104 inches respectively. The average weight is 268.7 grams. The individual cell dimensions and weight are given in Table I.

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

E. The 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. There were no signs of leakage on any of the 50 cells subjected to the leak test.

B. Conditioning Cycle:

1. In compliance with the manufacturer's specifications, a c/20 charge for 48 hours was performed on these 50 cells, where c is the manufacturer's rated capacity. During this charge, a voltage limit of 1.50 volts per cell was observed. The end-of-charge voltage for each cell is tabulated in Table I. This data shows that no cell reached the 1.50 volt limit on the charge portion of the conditioning cycle.

2. Following the charge, each cell was discharged at c/3, in series, to an individual cutoff voltage of 1.0 volt per cell. The individual and average capacities for each group are shown in Table I. The averages are:

Group	Cobalt-Pellon	Cobalt-PPL	Control-Pellon	Control-PPL
Capacity ah	5.87	5.89	6.35	7.15

C. Capacity Test:

1. The capacity test is a determination of the cell capacity at the c/2 discharge rate, 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 in series to 1.00 volt per cell. At this voltage, each cell was manually switched to open circuit while the remaining cells continued to discharge to the 1.00 volt limit.

2. The individual cell capacities to 1.00 volt are given in Table I. The range and the average capacity for each group (first capacity check) is tabulated on the following page.

Group	Cobalt-Pellon	Cobalt-PPL	Control-Pellon	Control-PPL
Avg Capacity ah	5.32	5.37	6.50	6.36
Capacity Range ah	5.18-5.45	5.20-5.58	6.45-6.55	4.18-6.80

Characteristic 2-hour rate discharge curves for high, average and low capacity cells of each group (first capacity check) are shown in Figures 1 and 2.

a. A comparison of Figures 1 and 2 shows that the discharge voltage of the cells with cobalt additive starts dropping below that of the control cells during the first 10 minutes of discharge. This trend continues throughout discharge and results in less capacity for the cobalt cells.

D. 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 testing.

3. Table I indicates 31 of the 50 cells failed to recover to the 1.15 volt level. The Technical Monitor of NASA Goddard and the project engineer of NASA Lewis were notified of these results. The dicision was made to allow these cells to go on life cycling test since such results were felt due to the cobalt additive.

E. High Vacuum Leak Test

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

2. The cells were subjected to a vacuum of 40 microns of mercury or less for 24 hours. At the end of this period they were removed and sprayed with phenolphthalein solution. If the indicator turned pink or red, the location was noted and the cell was identified as a leaker.

3. None of the 50 cells tested failed the leak test prior to overcharge.

F. Overcharge Test:

1. The purpose of this test is basically threefold:

a. To determine the degree to which a pack of cells maintains 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 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.

3. The steady state voltage of each cell at the end of each 16-hour charge rate test is shown in Table I. This data indicates good cell balance and an equilibrium voltage ranging from 1.44 to 1.47 volts for the different cell groups and overcharge rates. Figure 3 shows the characteristic overcharge curves for the different groups and overcharge rates.

a. Notice that the graph of Figure 3 shows the voltage of the cobalt cells to start low and rise rapidly during the 16-hour, c/10 overcharge. The control cells start higher and rise much more gradually when subjected to the same test. Thus the cobalt additive indicates an initial suppression of cell voltage on charge.

4. None of the cells required removal from this portion of testing.

G. Internal Resistance Measurement:

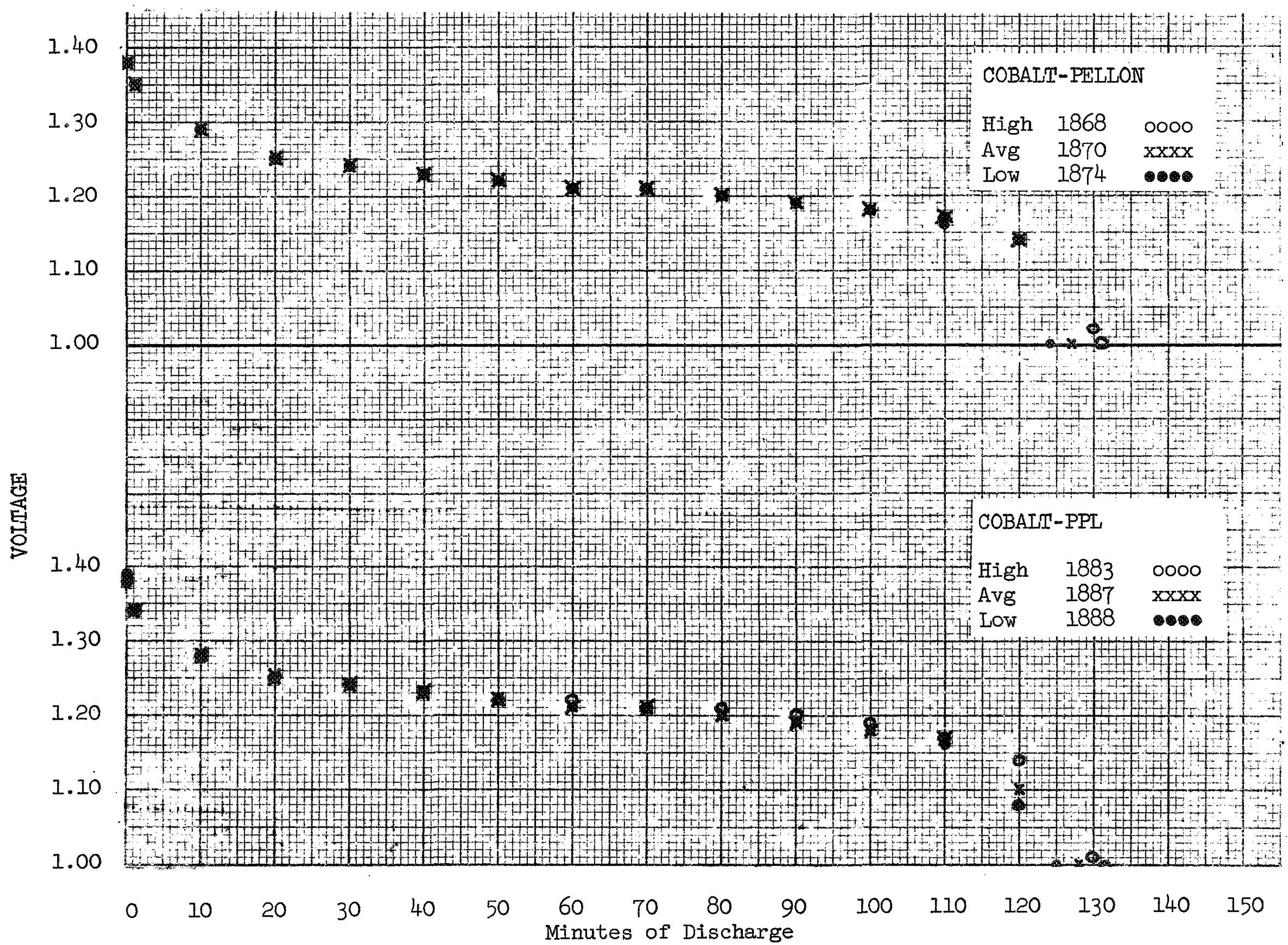
1. Immediately following the overcharge test, the internal resistance of each cell was measured with a Hewlett-Packard milliohm-meter (Model 4328A).

2. The internal resistance for each cell is shown in Table I. The resistance values ranged from 2.53 to 3.70 milliohms for an average of 2.82 milliohms.

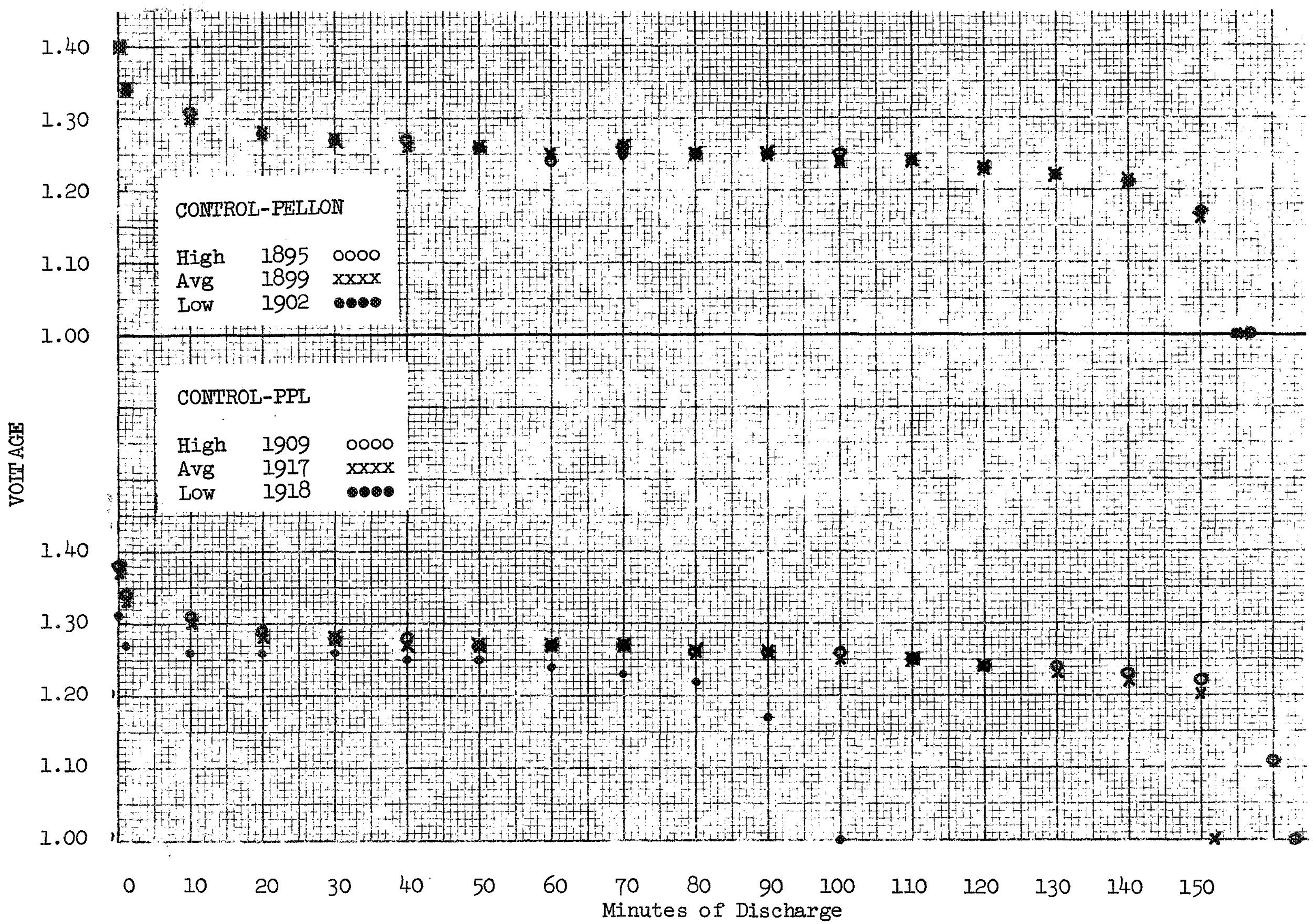
H. Leak Test:

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 prior to the 0.00 volt cutoff 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.E.2 was repeated.

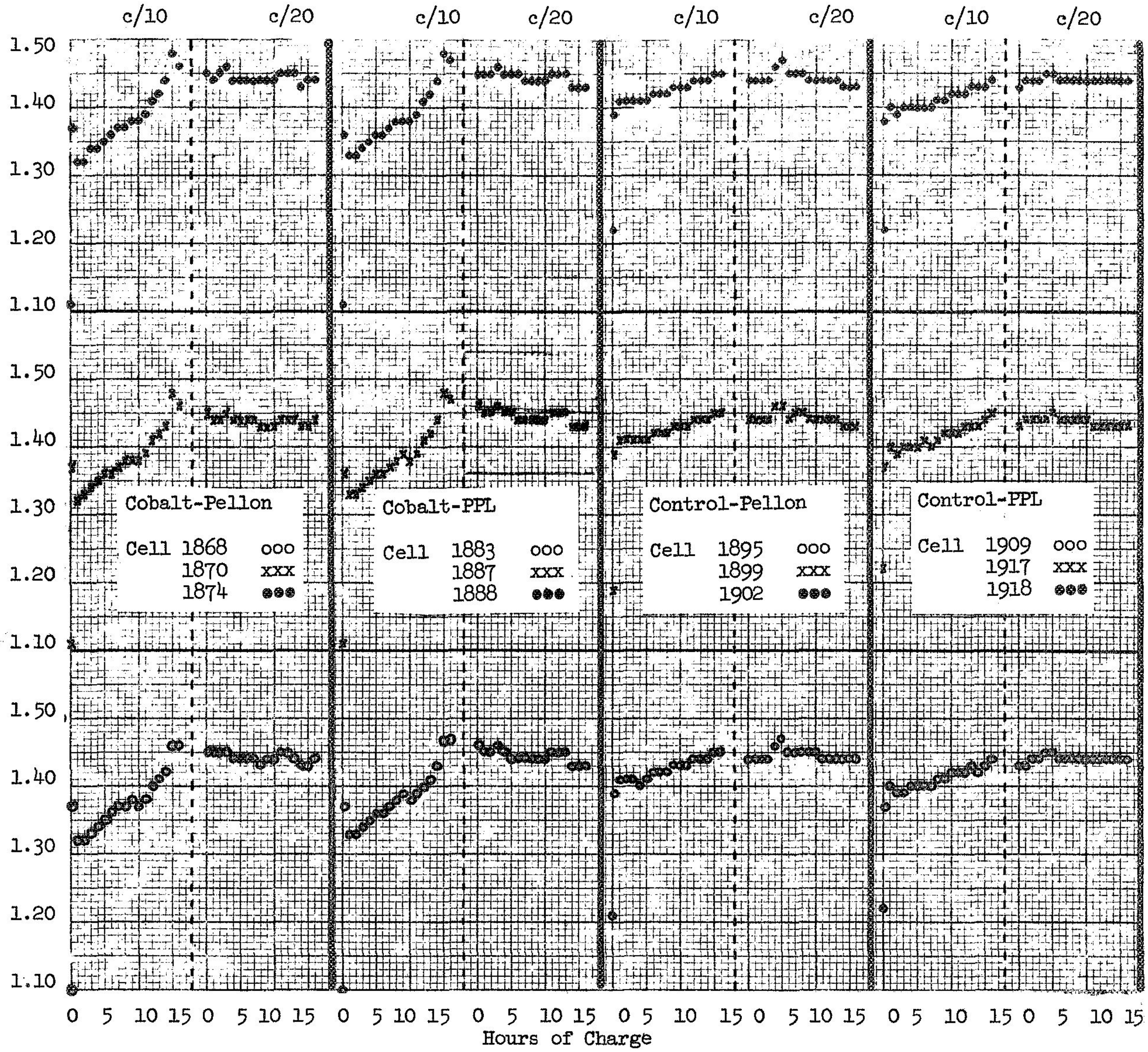
2. None of the 50 cells failed this final leak test.



CHARACTERISTIC 2-HOUR RATE DISCHARGE CURVES
(HIGH, AVERAGE AND LOW FOR COBALT-PELLON AND COBALT PPL)
GULTON 5.0 AMPERE-HOUR NICKEL-CADMIUM CELLS
FIGURE 1



CHARACTERISTIC 2-HOUR RATE DISCHARGE CURVES
(HIGH, AVERAGE AND LOW FOR CONTROL-PELLON AND CONTROL PPL)
GULTON 5.0 AMPERE-HOUR NICKEL-CADMIUM CELLS
FIGURE 2



CHARACTERISTIC 16-HOUR OVERCHARGE CURVES
GULTON 5.0 AMPERE-HOUR NICKEL-CADMIUM CELLS

FIGURE 3

TABLE I

Cell Serial No.	Weight (Grams)	Height (In)	Length (In)	Width (In)	Conditioning Cycle End 48-Hr Chg (V)	Conditioning Cycle End c/3 Disch (AH)	Capacity Checks (AH) No. 1	Capacity Checks (AH) No. 2	Capacity Checks (AH) No. 3	Cell Short Test	Overcharge (Volts) c/10	Overcharge (Volts) c/20	Internal Resistance (Milliohms)	c/2 Disch following Overcharge
F-1-0 - Cobalt-Pellon														
1865	268.3	3.693	0.822	2.104	1.43	5.63	*	5.93	5.38	1.14	1.47	1.44	3.70	5.30
1866	267.0	3.690	0.817	2.100	1.43	5.91	5.18	5.70	5.33	1.10	1.47	1.44	2.72	4.93
1867	267.8	3.697	0.817	2.100	1.43	6.13	5.38	5.93	5.55	1.09	1.46	1.44	2.59	4.95
1868	267.0	3.692	0.815	2.103	1.42	6.13	5.45	6.00	5.63	1.06	1.46	1.44	2.64	5.05
1869	265.8	3.692	0.820	2.110	1.42	5.91	5.30	5.80	5.43	1.09	1.46	1.44	2.72	4.88
1870	267.6	3.690	0.822	2.102	1.42	5.91	5.30	5.70	5.30	1.09	1.46	1.44	2.67	4.88
1871	268.3	3.692	0.824	2.100	1.42	6.13	5.43	5.80	5.43	1.08	1.46	1.43	2.63	4.88
1872	268.1	3.690	0.823	2.103	1.42	6.10	5.33	5.83	5.43	1.09	1.46	1.44	2.68	4.88
1873	266.1	3.689	0.822	2.100	1.43	6.06	5.33	5.70	5.30	1.09	1.46	1.44	2.64	4.83
1874	268.3	3.691	0.819	2.105	1.44	4.79	5.18	5.55	5.08	1.09	1.46	1.44	2.78	4.70
AVG	267.4	3.692	0.820	2.103	1.43	5.87	5.32	5.79	5.39	1.09	1.46	1.44	2.78	4.93
F-2-0 - Cobalt-Polypropylene														
1880	269.9	3.692	0.823	2.102	1.43	5.73	5.30	5.58	5.13	1.05	1.47	1.44	2.91	4.75
1881	270.0	3.680	0.822	2.105	1.42	5.85	5.33	5.68	5.20	1.06	1.47	1.43	2.88	4.80
1882	270.2	3.692	0.818	2.104	1.43	5.88	5.25	5.58	5.25	1.09	1.47	1.44	2.90	4.75
1883	270.1	3.685	0.820	2.100	1.43	5.88	5.50	5.80	5.38	1.04	1.47	1.43	2.96	4.95
1884	272.1	3.691	0.822	2.104	1.43	5.88	5.43	5.80	5.25	1.07	1.47	1.43	2.79	4.83
1885	266.8	3.696	0.821	2.100	1.43	5.88	5.30	5.68	5.30	1.05	1.47	1.43	3.03	4.75
1886	271.5	3.689	0.821	2.102	1.43	6.06	5.58	5.95	5.50	1.05	1.47	1.43	2.96	4.95
1887	269.9	3.695	0.823	2.100	1.43	5.88	5.33	5.63	5.25	1.10	1.47	1.43	3.03	4.75
1888	268.7	3.706	0.822	2.108	1.43	5.81	5.20	5.63	5.05	1.11	1.47	1.43	2.89	4.68
1889	273.0	3.694	0.823	2.103	1.43	6.05	5.50	1.38	5.33	1.09	1.47	1.44	2.96	4.93
AVG	270.2	3.692	0.822	2.103	1.43	5.89	5.37	5.27	5.26	1.07	1.47	1.43	2.93	4.81

* Reversed

TABLE I (Contd)

Cell Serial No.	Weight (Grams)	Height (In)	Length (In)	Width (In)	Conditioning Cycle End 48-Hr Chg (V)	Conditioning Cycle End c/3 Disch (AH)	Capacity Checks (AH) No. 1	Capacity Checks (AH) No. 2	Capacity Checks (AH) No. 3	Cell Short Test	Overcharge (Volts) c/10	Overcharge (Volts) c/20	Internal Resistance (Milliohms)	c/2 Disch following Overcharge
F-3-0 - Control-Pellon														
1895	265.0	3.695	0.820	2.107	1.41	6.76	6.55	5.93	4.95	1.19	1.45	1.44	2.75	6.63
1896	265.4	3.685	0.820	2.100	1.40	6.30	6.50	5.75	4.68	1.19	1.45	1.44	2.68	6.58
1897	269.4	3.680	0.820	2.106	1.40	6.38	6.50	5.68	4.55	1.14	1.45	1.44	2.53	6.75
1898	267.5	3.695	0.825	2.103	1.40	6.10	6.50	5.68	4.50	1.13	1.45	1.43	2.60	6.70
1899	265.4	3.700	0.822	2.106	1.40	6.21	6.50	5.80	4.75	1.13	1.45	1.43	2.61	6.45
1900	266.3	3.690	0.822	2.100	1.40	6.10	6.50	5.68	4.55	1.13	1.45	1.43	2.67	6.58
1901	266.4	3.691	0.822	2.108	1.40	6.26	6.50	5.70	4.58	1.14	1.45	1.43	2.60	6.50
1902	266.6	3.695	0.819	2.104	1.40	6.21	6.45	5.75	4.63	1.20	1.45	1.43	2.71	6.45
1903	265.7	3.700	0.820	2.105	1.41	6.46	6.50	5.80	4.80	1.13	1.45	1.43	2.58	6.70
1904	261.5	3.689	0.820	2.100	1.41	6.68	6.45	5.70	4.70	1.22	1.46	1.44	2.62	6.50
AVG	268.4	3.692	0.821	2.104	1.40	6.35	6.50	5.75	4.67	1.16	1.45	1.43	2.64	6.58
F-4-0 - Control-Polypropylene														
1909	267.9	3.695	0.820	2.104	1.45	7.35	6.80	6.20	6.20	1.22	1.44	1.44	2.79	7.00
1910	268.7	3.700	0.820	2.105	1.44	7.31	6.80	6.13	5.68	1.22	1.44	1.44	2.78	7.08
1911	270.0	3.703	0.829	2.104	1.44	7.21	6.68	6.05	5.55	1.21	1.44	1.43	2.86	6.68
1912	268.7	3.705	0.825	2.106	1.45	6.90	6.55	6.18	6.20	1.22	1.46	1.44	3.02	6.45
1913	269.4	3.696	0.828	2.103	1.44	7.21	6.68	6.13	5.68	1.22	1.44	1.43	2.99	6.70
1914	265.4	3.692	0.825	2.105	1.44	6.68	6.45	6.20	5.88	1.22	1.47	1.44	3.02	6.45
1915	269.2	3.696	0.820	2.103	1.44	7.40	6.70	5.95	5.45	1.21	1.44	1.43	2.89	6.93
1916	270.4	3.698	0.824	2.105	1.44	7.40	6.45	6.00	5.43	1.21	1.44	1.43	3.03	7.00
1917	268.0	3.684	0.824	2.107	1.44	7.68	6.33	6.13	5.58	1.22	1.45	1.43	3.01	6.88
1918	265.2	3.700	0.821	2.106	1.45	6.31	4.18	6.20	5.70	1.22	1.44	1.44	2.81	6.93
AVG	268.3	3.697	0.824	2.105	1.44	7.15	6.36	6.12	5.74	1.22	1.45	1.44	2.92	6.81

TABLE I (Contd)

Cell Serial No.	Weight (Grams)	Height (In)	Length (In)	Width (In)	Conditioning Cycle End 48-Hr Chg (V)	Conditioning Cycle End c/3 Disch (AH)	Capacity Checks (AH) No. 1	No. 2	No. 3	Cell Short Test	Overcharge (Volts) c/10	c/20	Internal Resistance (Milliohms)	c/2 Disch following Overcharge
F-5-0														
Cobalt-Pellon														
1875	266.9	3.695	0.819	2.111	1.45	6.21	5.83	5.70	5.58	1.11	1.46	1.44	2.79	5.38
1876	267.3	3.694	0.824	2.100	1.45	6.31	6.13	6.05	5.95	1.10	1.46	1.44	2.74	5.68
Cobalt-Polypropylene														
1890	269.4	3.688	0.822	2.105	1.45	5.98	5.63	5.58	5.55	1.09	1.47	1.44	3.03	5.33
1891	268.9	3.696	0.825	2.100	1.45	6.05	5.63	5.68	5.63	1.10	1.47	1.44	3.01	5.38
1892	270.0	3.689	0.821	2.102	1.45	6.10	5.75	5.58	5.50	1.11	1.47	1.44	3.02	5.30
Control-Pellon														
1905	266.9	3.689	0.824	2.110	1.44	7.35	6.45	5.80	5.00	1.23	1.44	1.42	2.69	6.68
1906	267.0	3.700	0.821	2.104	1.44	7.35	6.55	5.93	5.13	1.16	1.44	1.43	2.76	6.83
Control-Polypropylene														
1919	268.0	3.688	0.824	2.105	1.44	7.46	6.43	6.00	5.25	1.20	1.44	1.43	2.93	6.83
1920	265.8	3.698	0.824	2.105	1.44	7.52	6.50	5.88	5.18	1.22	1.45	1.44	2.91	6.80
1921	264.1	3.700	0.824	2.108	1.45	6.85	6.45	6.18	5.70	1.22	1.45	1.44	2.89	6.45

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