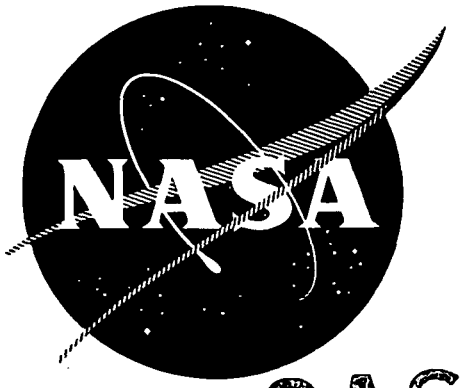

EVALUATION PROGRAM

for

SECONDARY SPACECRAFT CELLS

ACCEPTANCE TESTS
OF
EAGLE–PICHER 20.0 AMPERE–HOUR
NICKEL–CADMIUM CELLS
WITH AUXILIARY ELECTRODES

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT S–23404–G

QUALITY EVALUATION AND ENGINEERING LABORATORY
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EVALUATION PROGRAM FOR SECONDARY SPACECRAFT CELLS

ACCEPTANCE TESTS OF EAGLE-PICHER 20.0 AMPERE-HOUR NICKEL-CADMIUM CELLS WITH AUXILIARY ELECTRODES

QEEL/C 72-127 21 MARCH 1972

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Enclosure (1)

REPORT BRIEF
EAGLE-PICHER COMPANY
20.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS WITH AUXILIARY ELECTRODES

Ref: (a) NASA P. O. S-23404-G
(b) Acceptance Test Procedure for Nickel-Cadmium Cells: NAD 3052-TP304 Rev A, 14 May 1970

I. TEST ASSIGNMENT BRIEF

A. 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 1.150 volts on the cell short test.

B. The 29 cells were purchased by National Aeronautics and Space Administration, Goddard Space Flight Center, from Eagle-Picher Company, Joplin, Missouri. These cells are rated at 20.0 ampere-hours and they consisted of three groups: (1) 11 cells had the fuel cell auxiliary electrode (Aux E) (2) 9 cells contained the teflon rolled captured platinum auxiliary electrode and (3) 9 cells contained the teflonated sintered nickel plaque auxiliary electrode. All the cells contained double ceramic seals. The testing was funded in accordance with reference (a).

II. SUMMARY OF RESULTS

A. The capacity of the 29 cells ranged from 21.7 to 28.8 ampere-hours. All cells exceeded the rated capacity on all three capacity checks.

B. Five cells failed to recover to 1.150 volts: serial number 18 of the teflon rolled, captured platinum group and serial numbers 7, 8, 9 and 10 of the teflonated, sintered nickel plaque group.

C. During the overcharge tests, 15 of the 29 cells had to be removed from charge before completion of the respective tests due to high pressure.

TYPE OF AUXILIARY ELECTRODE	SERIAL NUMBERS OF CELLS REMOVED
Fuel Cell	5, 11, 12, 15, 21, 22
Teflon Rolled, Captured Platinum	6, 7, 8, 10, 16, 17, 18, 19, 20
Teflonated, Sintered Nickel Plaque	none

D. Auxiliary electrode characterization tests were conducted to determine the maximum signal power across the electrodes. The auxiliary electrode resistance corresponding to maximum signal power for the respective auxiliary electrode types is tabulated as follows:

TYPE OF AUXILIARY ELECTRODE	AVERAGE RESISTANCE VALUE
Fuel Cell	1.0 ohm
Teflon Rolled, Captured Platinum	0.5 ohm
Teflonated, Sintered Nickel Plaque	2.0 ohms

E. Eleven of the 29 cells gave indication of leakage during one of the three leak tests. Most of the indications were around the fill tube and negative terminals following the second and third leak tests.

III. RECOMMENDATIONS

A. It is recommended that these Eagle-Picher cells undergo life cycling test to gain more knowledge of their performance on life testing. This recommendation takes into account the difficulties with over-charge.

RESULTS OF ACCEPTANCE TEST OF 20.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS WITH AUXILIARY ELECTRODES MANUFACTURED BY EAGLE-PICHER COMPANY

I. TEST CONDITIONS AND PROCEDURE

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

1. Phenolphthalein Leak Test.
2. Three Capacity Checks.
3. Cell Short Test.
4. Phenolphthalein Leak Test.
5. Overcharge Tests, c/20 and c/10 Rates.
6. Special Resistance Test of Auxiliary electrodes (between c/20 and c/10 overcharge rates).
7. Internal Resistance.
8. Phenolphthalein Leak Test.

See Appendix I for detailed test procedure.

II. CELL IDENTIFICATION AND DESCRIPTION

A. The cells were identified by the manufacturer's serial numbers and by group according to the type auxiliary electrode they contained. This latter information was supplied by Goddard Space Flight Center.

TYPE OF AUXILIARY ELECTRODE	MANUFACTURER'S SERIAL NUMBER
Fuel Cell	2, 3, 4, 5, 11, 12, 13, 14, 15, 21, 22
Teflon Rolled, Captured Platinum	6, 7, 8, 10, 16, 17, 18, 19, 20
Teflonated, Sintered Nickel Plaque	1, 2, 4, 5, 6, 7, 8, 9, 10

B. The 20.0 ampere-hour is rectangular with the average physical weights and dimensions tabulated below.

TYPE OF AUXILIARY ELECTRODE	WEIGHT (g)	HEIGHT (in)	LENGTH (in)	WIDTH (in)
Fuel Cell	918.6	6.245	1.100	3.223
Teflon Rolled, Captured Platinum	923.9	6.232	1.221	3.219
Teflonated, Sintered Nickel Plaque	899.1	7.133	0.907	3.006

C. The cell containers and the c ell covers are made of stainless steel. The positive and negative terminals are insulated from the cell covers by ceramic seals and protrude through the cover as solder type terminals. The auxiliary electrode terminal consists of a stainless steel tab welded to the cell cover.

III. RESULTS--The following data was condensed from Tables II through IV.

A. Average Capacity (ampere-hours)

TYPE OF AUXILIARY ELECTRODE	CAPACITY CHECK 1	CAPACITY CHECK 2	CAPACITY CHECK 3
Fuel Cell	25.5	26.6	24.1
Teflon Rolled, Captured Platinum	24.1	27.7	25.3
Teflonated, Sintered Nickel Plaque	24.6	26.9	25.4

B. Average Recovery Voltage

TYPE OF AUXILIARY ELECTRODE	24-HOUR RECOVERY FROM DEAD SHORT
Fuel Cell	1.177 volts
Teflon Rolled, Captured Platinum	1.176
Teflonated, Sintered Nickel Plaque	0.662

C. Average End-of-Overcharge Voltage:

TYPE OF AUXILIARY ELECTRODE	c/10		c/20		c/10	
	Cell	Aux. E.	Cell	Aux. E.	Cell	Aux. E.
Fuel Cell	1.438	1.043	1.399	1.006	1.416	0.894
Teflon Rolled, Captured Platinum	1.431	1.059	1.420	1.063	1.437	1.067
Teflonated, Sintered Nickel Plaque	1.424	0.731	1.438	0.731	1.456	0.685

1. All cells of the teflon rolled, captured platinum group and six of the fuel cell type auxiliary electrode were removed early from overcharge due to high pressure.

D. Special Test for Determining the Resistance Giving Maximum Signal Power From the Auxiliary Electrode.

1. This test was conducted following the c/20 overcharge and prior to the c/10 overcharge on 15 of the 29 cells. The 15 cells were all equipped with gauges. The c/20 rate had to be reduced stepwise (halving each time) to c/80 to keep the pressures from rising on all cells except the group having the teflonated, sintered nickel plaque.

TYPE OF AUXILIARY ELECTRODE	RESISTANCE FOR MAXIMUM POWER
Fuel Cell	1.0 ohm
Teflon Rolled, Captured Platinum	0.5 ohm
Teflonated, Sintered Nickel Plaque	2.0 ohms

E. Average Internal Resistance:

TYPE OF AUXILIARY ELECTRODE	CELL	AUXILIARY ELECTRODE
Fuel Cell	2.2 milliohms	56.9 milliohms
Teflon Rolled, Captured Platinum	2.7 milliohms	32.8 milliohms
Teflonated, Sintered Nickel Plaque	1.6 milliohms	12.7 milliohms

F. Each cell was subjected to three leak tests. On these tests, 11 cells gave indication of leakage. Most leaks were visible around the fill tube and negative terminal following the second and third leak tests.

APPENDIX I

I. TEST PROCEDURE

A. Phenolphthalein 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.

B. Capacity Tests:

1. The capacity test is a determinatior 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.

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 cell was loaded with a 0.5 ohm, 3 watt resistor for 16 hours. At the end of 16 hours, the shorting resistors were removed and the cells were placed on open circuit stand for 24 hours. Any cell whose voltage did not recover to 1.150 volts or higher was considered as failing this portion of the acceptance test.

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 ther removed from the vacuum chamber and sprayed with phenolphthalein. Pink or redish discolorations would indicate leakage.

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/10, c/20 and c/10 for a minimum of 16 hours at each charge rate. The first c/10 rate serves to establish a condition of overcharge.

3. The cells were monitored hourly throughout the test. Charging was to be discontinued on cells which exceeded 1.500 volts or 100 psig.

4. The special resistance characterization tests for the auxiliary electrodes were conducted following the c/20 overcharge and prior to the c/10 overcharge. The cells were maintained on charge at c/20 provided the voltage and pressure limits were not exceeded. Goddard Space Flight Center specified that the pressure be maintained as near 0 psig as possible and still charge the cells.

a. A decade resistance box was hooked across the auxiliary electrode of each cell (auxiliary electrode terminal to negative terminal) such that the resistance could be conveniently and precisely varied.

b. The sequence of resistance changes (ohms) were: 10,000, 5000, 2000;1000, 500, 200;100, 50, 20;10, 5, 2;1, 0.5, 0.2;and 0.1. A period of approximately 5 minutes was allowed for the equilibrium of the auxiliary electrode voltage to re-establish itself after each resistance change. This equilibrium was verified by observation of a strip chart recorder monitoring the auxiliary electrode voltage of each cell.

c. Data thus obtained was converted to power units in milliwatts as illustrated at the foot of Table IV. The resistance value giving the maximum power of the auxiliary electrode signal is thus chosen for the auxiliary electrode resistance.

F. Internal Resistance:

1. Immediately following the overcharge test, the internal resistance was measured across the cell terminals and across the auxiliary electrodes (from auxiliary electrode terminal to negative terminal). These measurements were made with a Hewlett-Packard milliohmmeter (Model 4328A).

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 volt and shorted prior to the final leak test. The shorted cells were then placed in a vacuum chamber and the procedure described in paragraph I.D.2. was repeated.

TABLE I

SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)	WIDTH (Inches)	LEAK TESTS											
					Initial (Phenol Spray)				After Capacity Tests (Hi Vac & Phenol Spray)				After Overcharge Test (Hi Vac & Phenol Spray)			
					Terminals		Fill Tube	Other	Terminals		Fill Tube	Other	Terminals		Fill Tube	Other
					+	-			+	-			+	-		
2	918.8	6.248	1.070	3.215	L	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	ak.	o.k.	o.k.
3	917.8	6.221	1.268	3.187	o.k.	"	"	"	"	"	"	"	"	"	"	"
4	916.4	6.244	1.069	3.215	"	"	"	"	"	"	"	"	"	"	"	"
5	920.2	6.212	1.162	3.200	"	"	"	"	"	"	"	"	"	"	"	"
11	932.4	6.245	1.065	3.229	"	"	"	"	"	"	"	"	"	"	"	"
12	934.4	6.255	1.088	3.235	"	"	"	"	"	"	"	"	"	"	"	"
13	935.3	6.246	1.061	3.243	"	"	"	"	"	"	"	"	"	"	"	"
14	934.2	6.249	1.076	3.245	"	"	"	"	"	"	"	"	"	"	"	"
15	931.6	6.246	1.075	3.236	"	"	"	"	"	"	"	"	"	"	"	"
21	884.0	6.253	1.084	3.220	"	"	"	"	"	"	"	"	"	"	"	"
22	879.3	6.272	1.080	3.224	"	"	"	"	"	V.S.	"	"	"	"	"	"
Average	918.6	6.245	1.100	3.223												

L = Leaker

v.s. = very slight leak

These cells contained the fuel cell type auxiliary electrode.

TABLE I

SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)	WIDTH (Inches)	LEAK TESTS											
					Initial (Phenol Spray)				After Capacity Tests (Hi Vac & Phenol Spray)				After Overcharge Test (Hi Vac & Phenol Spray)			
					Terminals		Fill Tube	Other	Terminals		Fill Tube	Other	Terminals		Fill Tube	Other
					+	-			+	-			+	-		
6	913.7	6.210	1.080	3.217	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.
7	915.8	6.232	1.158	3.191	"	"	"	"	"	"	"	"	"	"	"	"
8	915.7	6.241	1.153	3.200	"	"	"	"	"	"	"	"	"	"	"	"
10	913.4	6.230	1.176	3.194	"	"	"	"	"	"	"	"	"	"	"	"
16	930.7	6.241	1.085	3.247	"	"	"	"	"	"	"	"	"	"	"	"
17	930.8	6.234	1.064	3.247	"	"	"	"	"	"	"	"	"	"	"	"
18	929.6	6.227	1.123	3.222	"	"	"	"	"	"	"	"	"	"	"	"
19	933.4	6.235	1.073	3.230	"	"	"	"	"	V.S.	"	"	"	"	"	"
20	932.0	6.237	1.080	3.227	"	"	"	"	V.S.	o.k.	"	"	"	"	"	"
Average	923.9	6.232	1.221	3.219												
1	898.0	7.140	0.898	3.009	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	V.S.	o.k.
2	900.0	7.130	0.910	3.001	"	"	"	"	"	"	"	"	"	"	V.S.	"
4	895.3	7.125	0.905	3.010	"	"	"	"	"	"	"	"	"	"	o.k.	"
5	895.9	7.141	0.915	2.999	"	"	"	"	"	"	"	"	"	"	V.S.	"
6	900.2	7.118	0.914	2.997	"	"	"	"	"	"	"	"	"	"	L	"
7	900.5	7.140	0.909	3.023	"	"	"	"	"	"	"	"	"	"	o.k.	"
8	900.4	7.135	0.907	3.005	"	"	"	"	"	L	"	"	"	"	"	"
9	901.8	7.134	0.912	3.005	"	"	"	"	"	o.k.	L	"	"	"	"	"
10	899.6	7.133	0.896	3.008	"	"	"	"	"	"	"	"	"	"	"	"
Average	899.1	7.133	0.907	3.006												
	The first group of cells (6-20) contained the teflon rolled, captured platinum type of auxiliary electrode.															
	The second group of cells (1-10) contained the teflonated, sintered nickel plaque type of auxiliary electrode.															

TABLE II
CAPACITY CHECK DATA

SERIAL NUMBER	FIRST CAPACITY CHECK						SECOND CAPACITY CHECK						THIRD CAPACITY CHECK					
	END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE		
	CELL (Volts)	AUX ELECT (Volts)	PRESS *	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS *	CELL (Volts)	AUX ELECT (Volts)	PRESS *	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS *	CELL (Volts)	AUX ELECT (Volts)	PRESS *	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS *
2	1.419	0.984		25.2	0.746		1.442	1.045		27.7	0.775		1.426	1.053		23.7	0.845	
3	1.423	0.992		24.7	0.749		1.440	1.003		26.8	0.218		1.425	1.015		23.0	0.752	
4	1.420	0.995		25.2	0.744		1.448	1.060		27.5	0.783		1.431	1.066		23.8	0.875	
5	1.419	0.989		25.2	0.745		1.457	1.041		27.7	0.780		1.444	1.054		25.0	0.899	
11	1.417	1.016	-25	24.7	0.788	-26	1.438	1.008	+23	27.2	0.697	+15	1.446	1.032	+75	25.8	0.743	+63
12	1.418	1.024	-9	23.3	0.761	-9	1.441	1.043	+31	27.2	0.750	+17	1.447	1.066	+66	26.7	0.797	+46
13	1.418	1.030	-20	24.8	0.773	-21	1.443	1.047	+38	26.8	0.802	+28	1.430	1.056	+88	23.5	0.845	+81
14	1.418	1.015	+1	25.0	0.758	-25	1.444	1.027	+29	27.7	0.741	+22	1.426	1.046	+77	24.0	0.913	+70
15	1.416	1.026	-18	26.0	0.796	-20	1.434	1.030	+29	26.3	0.758	+22	1.445	1.061	+100	25.7	0.785	+56
21	1.426	0.989		22.8	0.745		1.448	0.977		24.0	0.734		1.429	0.997		22.2	0.734	
22	1.429	0.990		22.8	0.742		1.447	0.984		23.2	0.736		1.427	1.002		21.7	0.732	
Average				24.5						26.6						24.1		
	These cells contained the fuel cell type auxiliary electrode.																	

* Negative values are interpreted as inches of mercury vacuum, while positive values are psig.

TABLE II
CAPACITY CHECK DATA

QEEL/C 72-127

SERIAL NUMBER	FIRST CAPACITY CHECK						SECOND CAPACITY CHECK						THIRD CAPACITY CHECK					
	END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE		
	CELL (Volts)	AUX ELECT (Volts)	PRESS *	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS *	CELL (Volts)	AUX ELECT (Volts)	PRESS *	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS *	CELL (Volts)	AUX ELECT (Volts)	PRESS *	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS *
6	1.418	0.986		25.8	0.895		1.457	1.087		28.0	0.801		1.435	1.068		25.8	0.797	
7	1.420	1.014		25.7	0.785		1.454	1.089		28.2	0.822		1.428	1.068		25.0	0.946	
8	1.423	1.009		22.8	0.754		1.462	1.087		25.5	0.800		1.456	1.096		23.8	0.821	
10	1.420	1.005		23.2	0.759		1.454	1.080		27.0	0.793		1.456	1.100		25.0	0.820	
16	1.418	1.030	-26	25.5	0.780	-27	1.464	1.075	+42	27.8	0.792	+30	1.440	1.061	+47	25.8	0.721	+42
17	1.420	1.022	-26	24.3	0.766	-27	1.445	1.063	+22	26.8	0.780	+16	1.458	1.091	+85	25.0	0.810	+69
18	1.414	1.002	-29	23.0	0.740	-30	1.444	1.055	+17	28.8	0.780	+10	1.446	1.079	+66	26.0	0.804	+47
19	1.414	1.001	-25	23.3	0.776	-26	1.439	1.065	+21	28.2	0.788	+13	1.444	1.091	+77	25.3	0.816	+60
20	1.412	0.999	-25	23.3	0.777	-26	1.434	1.047	+22	28.8	0.777	+15	1.434	1.067	+78	25.8	0.807	+63
Average				24.1						27.7						25.3		
1	1.415	0.793	-13	24.7	0.440	-16	1.426	0.573	+15	27.7	0.388	+2	1.419	0.731	+44	25.7	0.519	+18
2	1.415	0.777		24.5	0.018		1.427	0.585		28.3	0.349		1.421	0.742		25.7	0.526	
4	1.417	0.750	-27	24.8	0.531	-29	1.432	0.516	+6	27.8	0.377	-16	1.422	0.674	+25	26.2	0.485	+3
5	1.415	0.837		24.8	0.563		1.423	0.596		27.2	0.391		1.417	0.791		24.3	0.562	
6	1.416	0.805	-27	24.8	0.545	-29	1.428	0.558	+12	27.5	0.358	-11	1.421	0.695	+35	25.5	0.495	+9
7	1.414	0.785	-29	24.5	0.511	-29	1.428	0.893	0	27.2	0.434	0	1.424	0.781	+40	26.7	0.557	+11
8	1.415	0.714		24.3	0.498		1.430	0.844		25.8	0.283		1.427	0.696		25.3	0.410	
9	1.414	0.697		24.2	0.486		1.432	0.888		25.8	0.464		1.428	0.825		25.2	0.542	
10	1.413	0.874	-20	24.0	0.534	-24	1.424	0.906	+18	24.7	0.551	+21	1.421	0.844	+86	24.0	0.587	+46
Average				24.6						26.9						25.4		
	The first group of cells (6-20) contained the teflon rolled, captured platinum type of auxiliary electrode.																	
	The second group of cells (1-10) contained the teflonated, sintered nickel plaque type of auxiliary electrode.																	

*Negative values are interpreted as inches of mercury vacuum, while positive values are psig.

TABLE III

SERIAL NUMBER	CELL SHORT TEST Recovery Voltage after 24 Hours (Volts)	END OF CHARGE VOLTAGE AT: c/10 CONDITIONING RATE			c/20 CONDITIONING RATE			c/10 CONDITIONING RATE			INTERNAL RESISTANCE MEASUREMENT (Milliohms)	
		CELL (Volts)	AUX ELECT (Volts)	PRESS *	CELL (Volts)	AUX ELECT (Volts)	PRESS *	CELL (Volts)	AUX ELECT (Volts)	PRESS *	CELL	AUX ELECT
2	1.177	1.440	1.056		1.371	0.984		1.414	1.040		1.3	
3	1.156	1.439	0.994		1.372	0.917		1.411	0.990		1.3	
4	1.169	1.443	1.047		1.374	0.983		1.417	1.040		1.3	
5 ◊	1.185	1.424	1.024		1.425	1.026		1.456	1.044		1.4	16.2
11 **	1.177	1.428	1.004	+44	1.430	0.990	+72	1.396	0.996	+85	7.2	61.0
12 **	1.200	1.434	1.047	+30	1.441	1.034	+39	1.401	1.020	+57	4.8	27.0
13	1.173	1.443	1.113	+58	1.368	1.064	+ 6	1.380	0.425	+16	1.3	
14	1.168	1.440	1.107	+50	1.368	1.068	+ 8	1.422	0.238	+65	1.3	
15 ◊	1.188	1.421	1.100	+54	1.427	1.109	+78	1.457	1.056	+100	1.4	25.4
21 **	1.176	1.455	0.988		1.403	0.945		1.422	0.999		1.7	95.0
22 **	1.180	1.455	0.986		1.400	0.948		1.417	0.995		1.6	116.0
Average	1.177	1.438	1.043		1.399	1.006		1.416	0.899		2.2	56.4
**	The last overcharge rate (c/10) was not completed due to high pressure; off after 2 hours and 45 minutes.											
◊	The first two overcharge rates (c/10 and c/20) were terminated early (either or both) due to high pressure.											
	These cells contained the two cell type auxiliary electrodes.											

* Negative values are interpreted as inches of mercury vacuum, while positive values are psig.

TABLE III

SERIAL NUMBER	CELL SHORT TEST Recovery Voltage after 24 Hours (Volts)	END OF CHARGE VOLTAGE AT: c/10 CONDITIONING RATE			c/20 CONDITIONING RATE			c/10 CONDITIONING RATE			INTERNAL RESISTANCE MEASUREMENT (Millionhms)	
		CELL (Volts)	AUX ELECT (Volts)	PRESS *	CELL (Volts)	AUX ELECT (Volts)	PRESS *	CELL (Volts)	AUX ELECT (Volts)	PRESS *	CELL	AUX ELECT
6 ◇	1.197	1.424	1.074		1.426	1.076		1.456	1.092		1.4	25.7
7 ◇	1.181	1.423	1.061		1.426	1.068		1.456	1.084		1.4	19.4
8 **	1.178	1.433	1.067		1.426	1.050		1.395	1.043		7.4	56.0
10 **	1.174	1.434	1.068		1.427	1.056		1.396	1.044		3.0	63.0
16 ◇	1.204	1.425	1.112	+54	1.427	1.116	+78	1.460	1.086	+84	1.4	19.8
17 **	1.189	1.430	1.051	+43	1.432	1.046	+91	1.413	1.058	+100	5.4	67.0
18 **	1.131 ♦	1.425	1.013	+ 8	1.411	1.050	- 15	1.453	1.060	+78	1.4	14.2
19 **	1.168	1.430	1.051	+30	1.405	1.050	-13	1.453	1.075	+86	1.4	15.0
20 **	1.166	1.452	1.036	+36	1.399	1.052	- 14	1.448	1.059	+88	1.5	14.8
Average	1.176	1.431	1.059		1.420	1.063		1.437	1.067		2.7	32.8
		Cells with serial numbers 6 to 20 contained the teflon rolled, captured platinum auxiliary electrode.										
1	1.170	1.426	0.885	+13	1.437	0.876	+14	1.444	0.636	+19	1.6	8.9
2	1.186	1.427	0.628		1.435	0.619		1.439	0.669		1.6	11.0
4	1.187	1.431	0.875	+2	1.452	0.888	+ 5	1.476	0.642	+15	1.7	11.5
5	1.174	1.430	0.671		1.436	0.630		1.439	0.698		1.7	13.7
6	1.166	1.429	0.895	+6	1.442	0.882	+ 6	1.454	0.626	+12	1.7	12.5
7	0.010 ♦	1.418	0.647	+ 6	1.440	0.672	+9	1.476	0.733	+30	1.7	10.5
8	0.013 ♦	1.419	0.608		1.436	0.589		1.461	0.638		1.6	14.5
9	0.012 ♦	1.419	0.661		1.437	0.659		1.458	0.710		1.6	13.8
10	0.036 ♦	1.415	0.711	+15	1.428	0.761	+24	1.458	0.810	+46	1.6	17.9
Average	0.662	1.424	0.731		1.438	0.731		1.456	0.685		1.6	12.7
		cells with serial numbers 1 to 10 contained the teflonated, sintered nickel plaque type auxiliary electrode.										
	♦ Recovery voltages less than 1.150 volts.											
	** The last overcharge rate (c/10) was not completed due to high pressure: off after 2 hours and 45 minutes.											
	◇ The first two overcharge rates (c/10 and c/20) were terminated (either or both) due to high pressure											

* Negative values are interpreted as inches of mercury vacuum, while positive values are psig.

TABLE IV
SPECIAL RESISTANCE TEST DATA ON THE AUXILIARY ELECTRODES

SERIAL NO.	11		12		13		14		15		AVERAGE	
OHMS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	MILLIWATTS
10,000	1.053	+2	1.050	-11	1.064	+6	1.068	+8	1.078	+29	1.063	0.113
5,000	1.047	+3	1.047	-10	1.061	+6	1.064	+8	1.077	+29	1.059	0.224
2,000	1.025	+3	1.029	-9	1.044	+6	1.045	+8	1.059	+29	1.040	0.541
1,000	1.004	+3	1.014	-9	1.021	+6	1.024	+9	1.040	+29	1.021	1.04
500	0.981	+3	1.033	-8	1.002	+7	1.003	+9	1.019	+28	1.008	2.03
200	0.939	+3	0.979	-7	0.971	+7	0.970	+9	0.982	+28	0.968	4.69
100	0.902	+3	0.960	-6	0.944	+7	0.939	+9	0.945	+28	0.938	8.80
50	0.865	+4	0.941	-5	0.914	+7	0.900	+9	0.901	+30	0.904	16.3
20	0.796	+5	0.904	-2	0.864	+7	0.835	+9	0.829	+30	0.846	35.8
10	0.717	+6	0.863	-1	0.814	+7	0.769	+9	0.749	+30	0.782	61.2
5	0.604	+8	0.799	+1	0.751	+6	0.680	+9	0.641	+30	0.695	96.6
2	0.413	+9	0.605	+2	0.634	+6	0.519	+8	0.447	+30	0.524	137.0
1*	0.274	+10	0.385	+2	0.535	+3	0.392	+6	0.302	+29	0.378	143.0
0.5	0.165	+11	0.224	+2	0.316	+1	0.266	+5	0.192	+28	0.233	109.0
0.2	0.083	+13	0.107	+3	0.132	-2	0.144	+3	0.100	+28	0.113	63.8
0.1	0.049	+14	0.064	+4	0.076	-6	0.086	+2	0.064	+27	0.068	46.2

1. Fuel Cell Type Auxiliary Electrode

*. Resistance producing maximum signal power

$$\text{POWER} = \frac{V^2}{R} \text{ Watts} \quad 10^3 \frac{\text{Milliwatts}}{\text{Watt}} : \text{Milliwatts}$$

TABLE IV
SPECIAL RESISTANCE TEST DATA ON THE AUXILIARY ELECTRODES

SERIAL NO.	16		17		18		19		20		AVERAGE	
OHMS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	MILLIWATTS
10,000	1.076	+4	1.069	+6	1.085	+13	1.095	+13	1.085	+12	1.082	0.117
5,000	1.074	+4	1.065	+6	1.076	+16	1.088	+16	1.080	+16	1.077	0.232
2,000	1.058	+4	1.049	+6	1.068	+19	1.081	+19	1.072	+19	1.066	0.568
1,000	1.043	+4	1.034	+6	1.061	+21	1.074	+21	1.064	+21	1.055	1.11
500	1.025	+4	1.020	+6	1.050	+23	1.064	+23	1.052	+24	1.042	2.17
200	0.998	+4	0.992	+7	1.031	+25	1.044	+26	1.031	+26	1.019	5.19
100	0.974	+4	0.969	+7	1.011	+26	1.023	+27	1.009	+27	0.997	9.94
50	0.945	+5	0.942	+8	0.986	+27	0.997	+28	0.982	+29	0.970	18.8
20	0.900	+5	0.900	+9	0.939	+28	0.947	+29	0.932	+30	0.924	42.7
10	0.852	+5	0.857	+11	0.892	+28	0.897	+29	0.882	+31	0.876	76.7
5	0.792	+6	0.797	+12	0.892	+28	0.832	+29	0.816	+31	0.813	132.0
2	0.674	+5	0.681	+13	0.723	+27	0.724	+28	0.701	+30	0.701	246.0
1	0.541	+3	0.561	+14	0.606	+24	0.603	+26	0.578	+29	0.577	332.0
0.5*	0.366	+2	0.406	+14	0.449	+21	0.429	+23	0.433	+26	0.417	348.0
0.2	0.156	+1	0.208	+13	0.201	+17	0.204	+20	0.244	+22	0.204	208.0
0.1	0.079	0	0.122	+13	0.099	+12	0.103	+14	0.130	+16	0.107	114.0

1. Teflon Rolled, Capture Platinum auxiliary electrode

*. Resistance producing maximum signal power

$$\text{POWER} = \frac{V^2}{R} \text{ Watts} \quad 10^3 \frac{\text{Milliwatts}}{\text{Watt}} : \text{Milliwatts}$$

TABLE IV
SPECIAL RESISTANCE TEST DATA ON THE AUXILIARY ELECTRODES

SERIAL NO.	1		4		6		7		10		AVERAGE	
OHMS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	MILLIWATTS
10,000	0.874	+14	0.886	+5	0.876	+6	0.886	+9	0.869	+25	0.879	0.077
5,000	0.857	+14	0.865	+5	0.863	+6	0.882	+9	0.871	+25	0.868	0.151
2,000	0.805	+14	0.803	+5	0.799	+6	0.863	+9	0.865	+24	0.827	0.342
1,000	0.740	+14	0.733	+5	0.723	+6	0.821	+10	0.848	+25	0.773	0.598
500	0.661	+14	0.649	+5	0.639	+6	0.742	+9	0.802	+25	0.699	0.977
200	0.544	+14	0.534	+5	0.528	+6	0.614	+9	0.687	+25	0.581	1.69
100	0.466	+14	0.449	+5	0.451	+6	0.518	+9	0.581	+25	0.493	2.43
50	0.395	+14	0.368	+5	0.376	+6	0.424	+9	0.497	+25	0.412	3.40
20	0.312	+14	0.282	+5	0.287	+6	0.325	+9	0.408	+25	0.323	5.22
10	0.256	+14	0.224	+5	0.230	+6	0.266	+9	0.352	+25	0.266	7.08
5	0.206	+14	0.171	+4	0.179	+5	0.210	+9	0.302	+25	0.214	9.16
2*	0.143	+13	0.109	+3	0.119	+5	0.140	+9	0.238	+25	0.150	11.3
1	0.097	+12	0.067	+3	0.080	+5	0.092	+9	0.188	+24	0.105	11.0
0.5	0.062	+12	0.038	+3	0.049	+4	0.056	+9	0.141	+23	0.069	9.52
0.2	0.032	+12	0.018	+3	0.024	+4	0.026	+8	0.087	+20	0.037	6.85
0.1	0.018	+12	0.010	+3	0.013	+4	0.015	+7	0.058	+19	0.023	5.29

1. Teflonated, sintered nickel plaque auxiliary electrode

*. Resistance producing maximum signal power

$$\text{POWER} = \frac{V^2}{R} \text{ Watts} \quad 10^3 \frac{\text{Milliwatts}}{\text{Watt}} : \text{Milliwatts}$$

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