NASA CR-135200

FABRICATION AND TESTING OF

LARGE SIZE NICKEL-ZINC CELLS

by Martin Klein

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16. Abstract

The program involves the design and construction of 100 to 300 Ah nickel-zinc cells. All the cells constructed contain GFE sintered nickel electrodes and GFE asbestos coated inorganic separator material.

Negative electrodes were prepared by a dry pressing process in accordance with a NASA process specification. The cells utilized various inter-separators on the positive electrodes, consisting of non-woven nylon, non-woven polypropylene, and asbestos.

Initially, three experimental 100 Ah cells were build for test evaluation. Based on the results of these cells, six 300 Ah cells were constructed and evaluated. A second generation design was prepared and additional experimental cells built and evaluated in the GFE molded glass filled Norel cell jar and cover.

In the program initially seven, and then subsequently 135, 300 Ah cells were constructed and delivered to NASA-Lewis Research Center for test and evaluation.

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FABRICATION AND TESTING OF LARGE SIZE NICKEL-ZINC CELLS

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1.0 INTRODUCTION

The nickel-zinc battery system offers potential advantages for electric vehicles and other applications. This program was directed at the construction and limited testing of 100 to 300 ampere-hour nickel-zinc cells. The program was divided into the following tasks:

Task I	-	3 experimental 100 ampere-hour cells
TASK II A	-	6 experimental 300 ampere-hour cells
B	-	4 second generation experimental 300 ampere-hour cells
TASK III	-	Test and evaluation of the above cells
TASK IV	-	Fabrication of 7,300 ampere-hour cells for delivery for NASA
TASK V	-	Reports
TASK VI	-	Fabrication and delivery of 135, 300 ampere-hour cells

All the cells were constructed with Government furnished inorganic separator material, and sintered nickel positive electrodes. The cells constructed for Task II B and Task VI utilize a Government furnished injection molded cell case and cover. The cell design and fabrication procedure for the zinc negative electrodes utilized in all the cells was specified in the contract.

TASK I - Fabrication of 3 experimental 100 ampere-hour nickel-zinc cells

The 100 ampere-hour cells were constructed in accordance with the specification listed in Table I. The cell containers were fabricated from 3/8" thick polysulfone plastic. The negative electrodes were prepared according to the NASA fabrication procedure, attached is Appendix A. The separator bags for the negative electrode which utilize the inorganic separator were prepared by epoxy bonding; an ABS plastic frame to two layers of the sepatator material as shown in Figure 1. This technique was utilized for all the cells constructed in the program. The ABS frame thickness was selected to be equal to the nickel or zinc electrodes thickness and its absorbent separator layer.

The three 100Ahr cells were filled each with 500 cc of 31, 33 and 35% KOH containing 1% LiOH and then placed in an oven at 150°F. for 16 hours to complete the wetting cycle. After an additional 48 hours of soaking they were charged at 5.3A for 24 hours. They were then discharged at 120A, to 1.50 volts followed by draining at 10A to 1.50 volts. The charge rate was kept at 5.3A for 24 hours or to a voltage cut-off of 1.92 volts. No cell reached this cut-off during charge. Table II summarizes the results.

TABLE I

100AH Cell Specifications

Cell Dimensions		100 Amp. Hr.
Overall Height		13.0 in.
Case Height		12.25 in.
Case Width		7.0 in.
Case Depth		1.062 in.
No. of Electrodes		5 Pos/4 Neg
Electrode Sizes		
Inside Positive	5.875 x 9.62 x 0.070 in.	
Outside Positive	5.875 x 9.62 x 0.035 in.	
Negative	6.125 x 9.87 x 0.067 in.	
Negative Electrode Material	113-115 grams	

Note - Negative electrode thickness dependent upon absorber mat thickness.

Separator Bag Size 6.50 x 10.25 in.

Absorber Materials on Positive 2530 Polypropylene .012" thick

Absorber Material on Negative

ERC prepared KT (potasium titanate sheet) .010 in thick

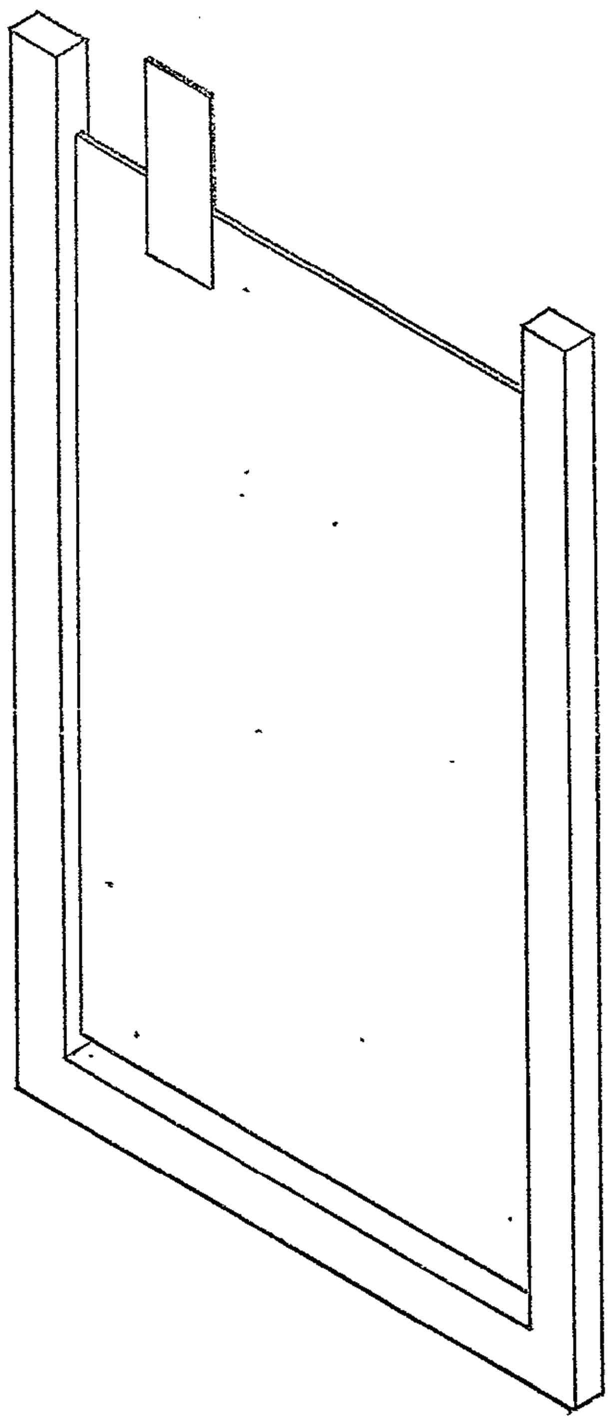


Figure 1

SEPARATE FRAME

TABLE II

100Ahr Results

Cell No.	Elec. Conc.	Capacities - Ahr		
		**120A/*10A	60A/*10A	30A/*10A
100 - 1	31%	60.3/108	90/109	110/110
100 - 2	33%	60.3/109	90/111	110/115
100 - 3	35%	60.3/108	90/113	110/117

*Represents the sum of the two capacities

**Discharge carried out to 1.40 volts

Based on the results obtained during the initial tests, these cells were subjected to a pulse discharge cycle regime.

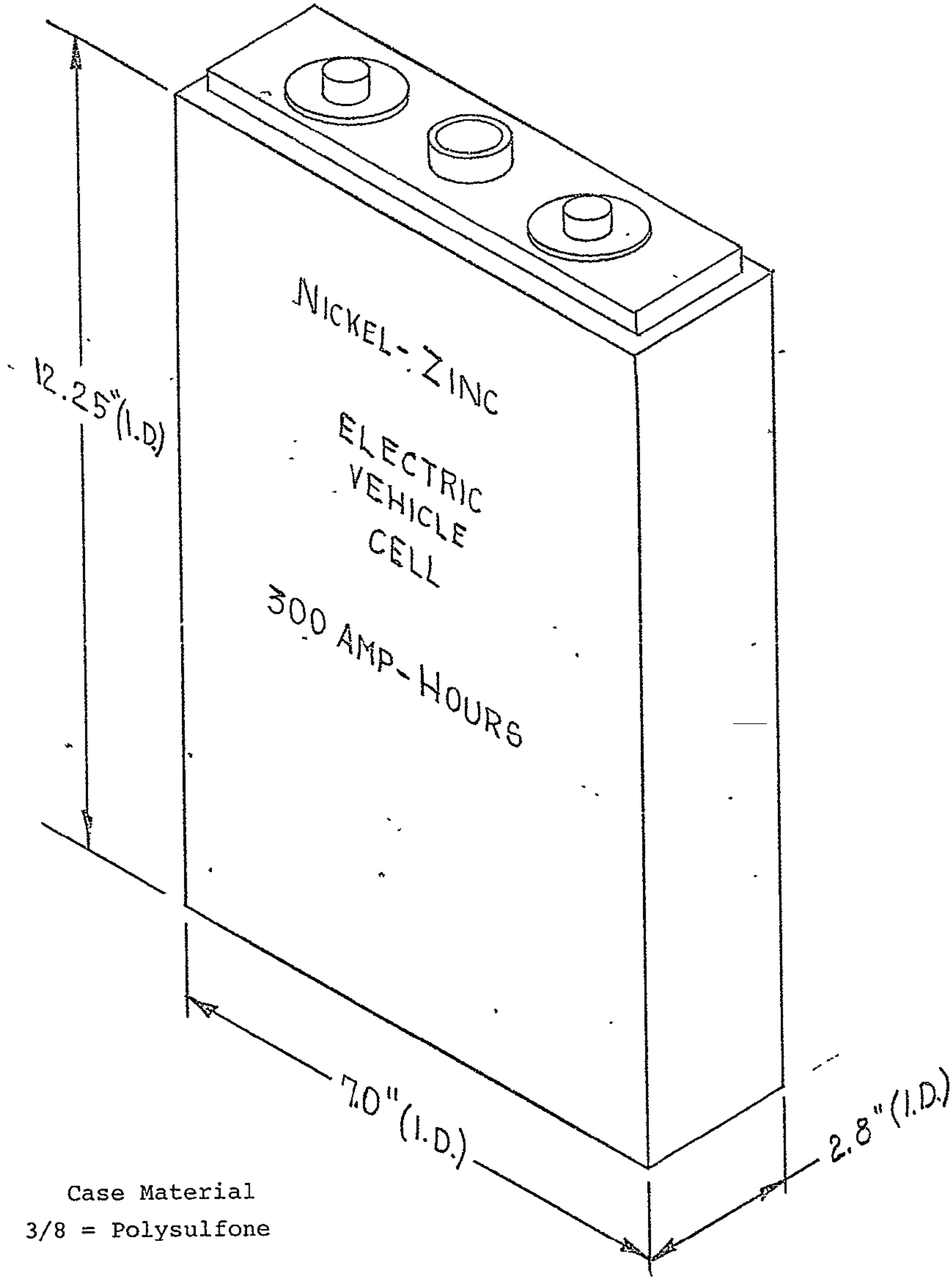
After 4 pulse cycles were completed, the cells developed shorts and the testing was discontinued.

Dissection of the cells showed that zinc had penetrated through the bottom portion of the sealed inorganic separator bag. Evidence of zinc shorting could also be seen at the edges of the bag seal as well. Some evidence of positive plate wrapping was also seen.

The cause of the shorting in the 100Ahr cells was traced to use of inorganic separator materials from the beginning of the separator roll which had only been coated once. The normal material is prepared with a double dip coating.

TASK II A - Construction of 6, 300 ampere-hour cells

The six experimental 300 ampere-hour cells were constructed using 3/8" thick polysulfone fabricated cell cases as shown in Figure 2. The cell design is shown in Table III. Figure 3 shows the positive electrode utilized. The first 300 ampere-hour cell was subjected to testing and dissection before the balance of the cells were completed. The cell contained non-woven polypropylene as the separator material on the positive electrodes. Dissection of this cell revealed that the positive electrode tended to dish placing a compressive load on the separator edges. To overcome this all subsequent cells of the program contained positive electrode that had the screen side inward to reverse the bow.



Case Material
3/8 = Polysulfone

Figure 2
300 Ah CELL

TABLE III

300AH Cell Specifications

Cell Dimensions		300 Amp. Hr.
Overall Height		13.0 in.
Case Height		12.25 in.
Case Width		7.0 in.
Case Depth		2.812 in.
No. of Electrodes		14 Pos/13 Neg.
Electrode Sizes		
Inside Positive	5.875 x 9.62 x 0.070 in.	
Outside Positive	5.875 x 9.62 x 0.035 in.	
Negative	6.125 x 9.87 x 0.067 in.	
Negative Electrode Material	113-115 grams	
Separator Bag Size	6.50 x 10.25 in.	
Absorber Materials on Positive		
2530 Polypropylene	2 x .006 (Cells - 1 - 4)	
Fuel Cell Asbestos	0.010 in. thick (Cell 5 & 6)	

*As manufactured by the Pellon Corporation.

Absorber Material on Negative	
ERC KT	.010 in thick

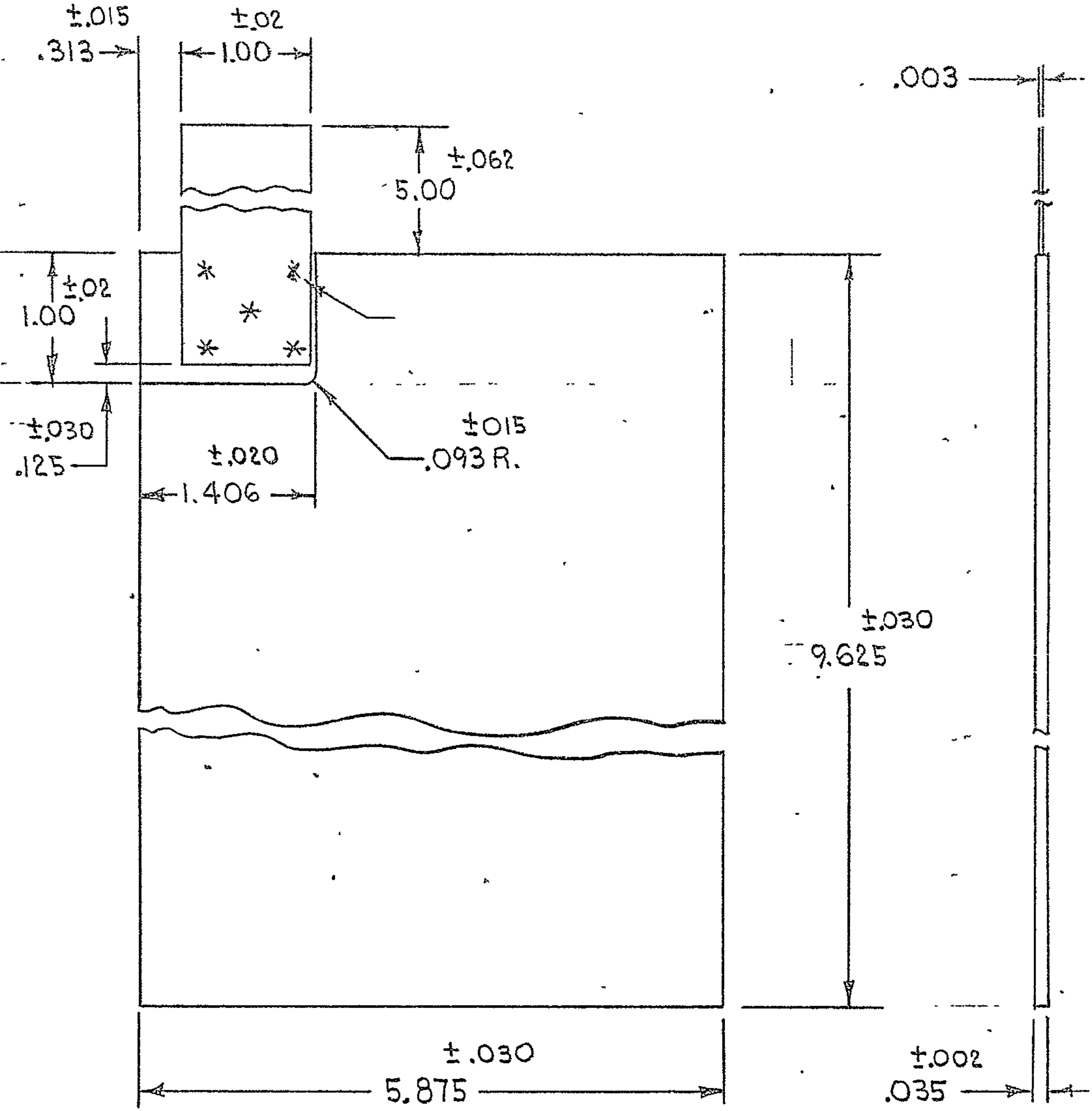


Figure 3

NICKEL ELECTRODE

This was accomplished by removing the tabs on half the positive electrodes and placing new tabs on the opposite corner. To place the new tabs it was necessary to grind off the nickel sintered active material to spot weld the tabs directly to the screen.

A further observation made on the first cells was the inorganic separator material tended to delaminate from the frame in the layers of the asbestos. To overcome this all subsequent cells contained an ABS frame around the positive electrode to provide some compression on the edge seal of the inorganic separator material. Cells 2, 3, and 4 contained two layers of 6 mil polypropylene wrapped around a positive electrode with the ABS frame. Cells 5 and 6 contained untreated asbestos absorber around the positive electrodes which was epoxy bonded to an ABS frame of equal thickness to the positive electrode.

TASK III - Testing and evaluation of the 6 experimental 300Ahr Cells

Table IV shows the test procedure used to test the cells.

The first 300Ahr nickel-zinc cell was filled with 1500 cc of 31% KOH + 1% LiOH and allowed to soak for 72 hours including 16 hours at 150°F prior to placing the cell on charge.

TABLE IV

TEST PROCEDURES

A. Cell Formation Procedures

The cells shall be formed and tested as detailed herein.

Formation Cycle No. 1 - Charge the cells at 16 amperes to 1.91-1.92 volts or for 24 hours whichever occurs first. Discharge the cells at 135 amperes (1.5ma/sq. cm) to 150 volts, then at 30 amperes to 1.50 volts.

Formation Cycle No. 2 - Same as Formation Cycle No. 1.

B. Performance-Characterization Test

Following the second formation discharge, the cells shall be charged at 16 amperes to 1.92 volts or for 24 hours whichever occurs first. The cells shall then be discharged at 360 (40ma/sq.cm), 180 (20ma/sq.cm), and 90 (10ma/sq.cm) amperes to 1.50 volts, followed by draining at 30 amperes to 1.50 volts after each test. Cells shall be charged at 16 amperes to 1.92 volts between discharges. The discharge voltage shall be continuously recorded as a function of time at the constant current drain rates.

C. Cycle Life Testing

The 300-ampere-hour cells shall be cycled continuously on the regime outlined below:

TABLE IV
(continued)

Charge Schedule:

The cells shall be charged at 20 amps until the cell voltage reads 1.92 volts. By means of a manual timer on the cycling equipment, the Contractor shall charge the cell so that on each cycle the input shall be approximately 105% of the output of the previous cycle.

Discharge Schedule:

(a) Discharge at 30 amps for 1 second

(b) Discharge at 200 amps for 4 seconds

(c) Stand on open circuit for 7 seconds

Items (a) through (c) together shall constitute one discharge pulse. The discharge pulses shall be repeated until the load voltage of any cell falls to 1.5 volts.

The cell was charged at 16A for 24 hours and then discharged at 135A, 360A, 180A and 90A to 1.50 volts on each of 4 deep discharge cycled followed by draining at 30A to 1.50 volts after each cycle.

Table V shows the results of these discharges.

Following the deep discharges, the cell was placed on a pulse cycle regime. The results are shown in Table VI.

At cycle 6, the low voltage cut-off was lowered to 1.40 volts. After 3 discharge pulse cycles the cell was reaching the high voltage cut-off on charge at 1.92 volts. After 20 cycles, the ECV cut-off was raised to 2.00 volts.

Cell No. 1 failed after 43 pulse cycles and testing was discontinued. Capacity began dropping after 33 cycles and at cycle 43 capacity had fallen to 91.5Ahr. At cycle 43, the charge voltage rose to only 1.82V and after 24 hours of stand the voltage dropped to 0.1V. The cell had developed internal shorts.

Cells 2 - 6 were filled with 1550 cc of 31% KOH heat treated and placed on test. Cell #2 was initially placed on the pulse cycle test. Table VII shows the discharge results of this cell. The end of charge voltage declined after cycle 20 indicating a short. The testing was terminated after cycle 26. Cell 3-6 were initially discharged at 135 and 90 amps as shown in Table VIII - XI and then placed on cycle test.

Cell #3 shorted after 9 cycles and was dissected. The data is presented in Table XII.

Cell #3 was placed on charge stand after cycling for three days after which time the open circuit voltage dropped to 1.78 volts

TABLE V

TEST RESULTS OF CELL #1

												(AH)
Time (min)	5	30	60	110	120	150	190	215	240	250		
Volts (135 Amp)	1.625	1.575	1.55	1.50								
(30 Amp)					1.63	1.624	1.60	1.58	1.56	1.50		(278.5)
Time (min)	2	5	10	15	20	60	180	300	420	450		
Volts (360 Amp)	1.47	1.45	1.42	1.40								
(30 Amp)					1.62	1.68	1.66	1.63	1.57	1.50		(336)
Time (min)	5	10	20	55	65	90	120	180	240	300	370	
Volts (180 Amp)	1.60	1.56	1.54	1.52	1.50							
(30 Amp)						1.66	1.66	1.64	1.63	1.60	1.50	(357)
Time (min)	5	60	120	180	205	240	265					
Volts (90 Amp)	1.69	1.62	1.60	1.54	1.50							
(30 Amp)						1.55	1.50					(338)

TABLE VI

Ni-Zn 300Ah Cell No. 1

Pulse Discharge

30A for 1 sec. 0.231Ah/pulse
200A for 4 sec. (to 1.500V)
open for 7 sec.

CYCLE NO.	CHARGE	ECV	No. PULSE	CAPACITY Ah	
1	16A for 24 hrs	1.885	945	218	
2	16A for 16 hrs	1.900	1359	314	
3	16A for 22 1/4	1.920	1349	311	
4	16A for 20 1/2	1.920	1306	303	
5	16A for 20 3/4	1.920	1232	284	
6	16A for 18 1/4	1.920	1527	354	Low limit is changed to 1.400V
7	16A for 21 3/4	1.920	1214	280	1.495V stop discharging manually
8	16A for 18	1.920	1390	322	
9	16A for 21 1/2	1.920	1367	316	
10	16A for 21 1/4	1.920	1357	313	
11	16A for 21	1.920	1332	308	
12	16A for 20 1/2	1.920	1355	313	
13	16A for 21 1/4	1.920	1375	318	
14	16A for 19	1.920	1335	309	input 304Ah
15	16A for 19	1.920	1313	303	
16	16A for 19	1.920	1334	308	
17	16A for 18 1/2	1.920	1272	294	input 296Ah
18	16A for 17	1.920	1156	267	input 272Ah
19	16A for 17	1.920	1212	279	
20	16A for 24	1.940	1360	314	High limit is changed to 2.000V input 383Ah
21	16A for 24	1.960	1371	316	
22	16A for 20 1/4	1.970	1278	295	
23	16A for 18	2.003	1249	289	input 288Ah
24	16A for 18	2.003	1228	284	
25	16A for 17 1/6	2.003	1206	278	input 274Ah
26	16A for 16 3/4	2.000	1137	262	input 268Ah
27	16A for 16 1/2	2.00	1113	257	input 264Ah

TABLE VI

(Continued)

CYCLE NO.	CHARGE	ECV	No. PULSE	CAPACITY Ah	
28	16A for 15 5/6	2.00	1096	253	255Ah input
29	16A for 15 1/4	2.00	1075	248	244Ah input 30A fully discharge to 0.5V 75Ah Total 323Ah
30	16A for 20 1/2	2.00	1103	255	328Ah input
31	16A for 15 1/2	2.00	1083	250	
32	16A for 15	2.00	1045	242	
33	16A for 15	2.00	686	158	Cell No. 2 Start
34	16A for 15	2.00	771	178	
35	16A for 15	2.00	890	205.	
36	16A for 15	2.00	716	165	
37	16A for 15	2.00	743	171	
38	16A for 15	2.00	716	165	
39	16A for 15	2.00	798	184	
40	16A for 15	2.00	637	147	
41	16A for 17	2.00	500	115	
42	16A for 17	2.00	326	75.4	
43	16A for 24	1.820	395	91.5	

TABLE VII

NICKEL-ZINC 300Ahr CELL NO. 2

Pulse Discharge

CYCLE NO.	CHARGE	ECV	NO. PULSE	CAPACITY Ahr	END OF DISCHARGE VOLTAGE 1.4V
1	16A for 12 hrs.		686	158	
2	16A for 12 hrs.		771	178	
3	16A for 12 hrs.		890	205	
4	16A for 12 hrs.		716	165	
5	16A for 12 hrs.		743	171	
6	16A for 17 hrs.		716	165	
7	16A for 17 hrs.		798	184	
8	16A for 17 hrs.		637	147	
9	16A for 17 hrs.		500	115	
10	16A for 17 hrs.		326	75.4	
11	16A for 24 hrs.		395	91.5	
12	16A for 18 hrs.		714	164	
13	16A for 12 hrs.	2.00	840	194	
14	16A for 11 1/4	2.00	777	179	
15	16A for 16 hrs.	2.016	1029	238	valve open
16	16A for 16 hrs.	2.015	869	201	
17	16A for 15 1/2	2.018	796	184	
18	16A for 15 1/2	2.01	938	217	
19	16A for 15 1/2	2.01	859	199	valve closed
20	16A for 16 hrs.	2.02	867	200	
21	16A for 16 hrs.	1.94	578	134	
22	16A for 16 hrs.	1.90	909	210	
23	16A for 16 hrs.	1.91	781	180	
24	16A for 11 1/6	2.00	544	126	Check Shorting
25	16A for 7 1/2	2.00	500	116	
26	16A for 7 hrs.	2.00	448	103	

TABLE VIII

TEST RESULTS OF CELL #3

Time (min)	10	20	40	60	63	90	120	160	195		(AH)
Volts (135 Amp)	1.56	1.54	1.53	1.51	1.50						
30 Amp)						1.63	1.59	1.53	1.50		(239.5)

Time (min)	30	60	90	120	180	200	230	270	320	350	
Volts (90 Amp)	1.56	1.58	1.58	1.56	1.54	1.50					
(30 Amp)							1.54	1.57	1.50	1.50	(375)

Time (min)	30	60	90	120	150	180	210	225			
Volts (90 Amp)	1.60	1.60	1.57	1.54	1.50						
(30 Amp)						1.59	1.58	1.50			(260)

TABLE IX

TEST RESULTS OF CELL #4

Time (Min)	10	20	40	50	60	63	90	180	240	300	
Volts (135 Amp)	1.56	1.54	1.52	1.52	1.51	1.50					
(30 Amp)							1.63	1.60	155	1.50	(245)

Time (Min)	30	60	90	120	180	200	230	290	320	350	
Volts (90 Amp)	1.60	1.58	1.57	1.56	1.54	1.50					
(30 Amps)							1.58	1.56	155	1.50	(375)

Time (Min)	30	60	90	105	120	150	180	195	200		
Volts (90 Amp)	1.60	1.60	1.57	1.54	1.52	1.50					
(30 Amp)							1.59	1.56	150		(260)

TABLE X

TEST RESULTS OF CELL #5

Time (min)	10	20	30	40	50	60	82	140	290	380	425	(AH)
Volts (135 Amps)	1.56	1.54	1.54	1.53	1.53	1.52	1.50					
(30 Amps)									1.60	1.58	1.50	(356)

TIME (Min)	30	120	180	200	290	305	360	420	440	
Volts (90 Amps)	1.60	1.57	1.56	1.50						
(30 Amps)					1.62	1.62	1.60	1.53	1.50	(400)

Time (Min)	30	60	90	120	135	180	240	250	
Volts (90 Amps)	1.60	1.59	1.56	1.52	1.50				
(30 Amps)						1.61	1.54	1.50	(242)

TABLE XI

TEST RESULTS OF CELL #6

Time (min)	30	45	65	80	135	180	340	370	470	(AH)
Volts (135 Amp)	1.52	1.52	1.51	1.50						
(30 Amp)					1.65	1.64	1.60	1.58	1.50	(375)

Time (min)	30	60	90	120	180	200	230	260	
Volts (90 Amps)	1.59	1.58	1.57	1.56	1.54	1.50			
(30 Amps							1.58	1.5	(360)

TABLE XII

NICKEL-ZINC 300 Ahr CELL NO. 3

Cycle No.	Charge	ECV	No. Pulse	Capacity Ahr	End of Discharge Voltage 1.4V
1	16A for 19 hrs.	1.935	1090	252	
2	16A for 20 1/2	2.02	962	222	
3	16A for 18 hrs.	2.00	812	187	
4	16A for 15 1/2	2.00	755	175	Valve Closed
5	16A for 16 hrs.	1.95	912	211	
6	16A for 16 hrs.	1.90			·shorted· OCV 1.800V 3 days standing to 1.78 volts
7	16A for 16 hrs.	1.88	909	210	
8	16A for 16 hrs.	1.90	971	224	
9	16A for 14 hrs.	2.0	109	25	Check shorting

When current was applied, the cell voltage dropped to 1.40 volts. Zinc penetration could be seen in many areas over the separator face, but was most prominent along the bottom portion of the separator. Zinc was also seen growing through the epoxy sealed separator frames along the edges. Considerable zinc erosion was noted along the top portions of the negative plate and shape change was estimated at about 25% which is high considering the short cycle life.

Cycle testing was terminated on Cell #4 after the capacity decayed below 150Ahr as shown in Table XIII. Disection of this cell also showed zinc shape change and zinc penetration through the separator.

Cells #5 & 6 with the asbestos on the positive electrode exhibited better performance and were cycled 39 times. A gradual capacity decay was observed as shown in Tables XIV and XV.

TASK IV - Fabrication of 7, 300Ahr Cells for Delivery to NASA

Seven cells were fabricated for delivery to NASA-LEWIS in polysulfone fabricated cases with asbestos absorbers on the positives. Additional epoxy was placed along the edges of the separator frame to prevent zinc growth along the seal area. The cells were filled with 1550 cc of 31% KOH.

TABLE XIII

NICKEL-ZINC 300Ahr CELL NO. 4

Cycle No.	Charge	ECV	No. Pulse	Capacity Ahr	End of Discharge Voltage 1.4V
1	16A for 19 hrs.	1.920	1033	238	
2	16A for 18 1/2	2.01	1131	261	
3	16A for 18 hrs.	2.00	1013	233	
4	16A for 15 1/2	2.00	817	189	Valve closed
5	16A for 16 hrs.	2.00	1152	266	
6	16A for 16 hrs.	2.00	780	180	
7	16A for 16 hrs.	2.00	1187	274	
8	16A for 16 hrs.	2.01	971	224	
9	16A for 14 hrs.	2.01	769	178	
10	16A for 14 1/2	2.00	755	174	
11	16A for 15 2/3	2.00	688	159	
12	16A for 10 hrs.	2.00	641	148	

TABLE XIV

NICKEL-ZINC 300Ahr CELL NO. 5

Cycle No.	Charge	ECV	No. Pulse	Capacity Ahr	End of Discharge Voltage 1.4V
1	16A for 19 hrs.	1.93	1090	252	
2	16A for 24 hrs.	1.96	1518	351	
3	16A for 20 hrs.	1.92	1413	326	
4	16A for 19 hrs.	1.90	1324	306	Valve Closed
5	16A for 19 hrs.	1.92	1339	310	
6	16A for 19 hrs.	1.95	1222	282	
7	16A for 16 hrs.	1.89	1200	277	
8	16A for 16 hrs.	1.90	1105	255	
9	16A for 19 hrs.	1.94	1286	297	
10	16A for 17 1/2	1.98	1105	255	
11	16A for 15 1/4	2.00	1200	277	
12	16A for 11 hrs.	1.90	743	172	
13	16A for 17 hrs.	2.00	1131	261	
14	16A for 16 hrs.	2.00	1129	261	
15	16A for 16 hrs.	2.00	1157	267	
16	16A for 18 3/4	2.00	1218	281	
17	16A for 17 1/4	2.00	1156	267	
18	16A for 16 3/4	2.00	1108	255	
19	16A for 15 1/2	2.00	1088	251	
20	16A for 15 hrs.	2.00	991	229	
21	16A for 14 hrs.	2.00	1019	235	
22	16A for 14 3/4	2.00	1015	234	
23	10A for 18 hrs.	1.95	831	192	Accident at Power Supp.
24	16A for 16 hrs.	2.00	1008	233	
25	16A for 15 hrs.	2.00	968	224	
26	16A for 13 1/2	2.00			
27					

TABLE XIV
(continued)

Cycle No.	Charge	ECV	No. Pulse	Capacity Ahr	End of Discharge Voltage 1.4V
28	16A for 15 1/2	2.01	896	229.6	
29	16A for 15 1/2	2.10	816	188.5	
30	16A for 11	2.00	200A 696 30A 471 130A 30A	232.8	160.8Ah + 232.8 72 Ah
31	16A for 11 hrs.	2.00	666	153.8	
32	16A for 10 1/2	2.10	530	122.4	
33	16A for 10 1/4	2.10	516	119.2	
34	16A for 8 hrs.	2.10	631	145.76	
35	16A for 9 1/2	2.10	522	120.58	
36	16A for 8 hrs.	2.10	492	113.7	
37	16A for 8 1/4	2.10	448	103.48	
38	16A for 16 hrs.		508	117.3	shorted voltage didn't get 2.00V, on charge

TABLE XV

NICKEL-ZINC 300Ahr CELL NO. 6

Cycle No.	Charge	ECV	No. Pulse	Capacity Ahr	End of Discharge Voltage 1.4V
1	16A for 19 hrs.	1.91	1271	294	
2	16A for 24 hrs.	1.92	1581	351	
3	16A for 20 hrs.	1.92	1413	326	
4	16A for 19 hrs.	1.89	1324	306	Valve closed
5	16A for 19 hrs.	1.90	1339	310	
6	16A for 19 hrs.	1.91	1222	282	
7	16A for 16 hrs.	1.89	1200	277	
8	16A for 16 hrs.	1.89	1105	255	
9	16A for 19 hrs.	1.94	1286	297	
10	16A for 17 1/2	1.93	1105	255	
11	16A for 15 2/3	1.94	1200	277	
12	16A for 11 hrs.	1.90	743	172	
13	16A for 17 hrs.	1.95	1131	261	
14	16A for 16 hrs.	1.95	1109	256	
15	16A for 20 hrs.	2.00	1341	309	
16	16A for 18 3/4	1.98	1250	289	
17	16A for 17 1/4	1.97	1156	267	
18	16A for 17 3/4	1.98	1105	255	
19	16A for 15 1/2	1.96	1088	251	
20	16A for 15 hrs.	1.96	991	229	
21	16A for 16 hrs.	2.00	1019	235	
22	16A for 15 hrs.	2.00	1180	273	
23	10A for 18 hrs.	1.95	831	192	Accident at Power Supp.
24	16A for 16 hrs.	2.00	1008	233	
25	16A for 15 hrs.	2.00	968	224	
26	16A for 13 1/2	2.00			
27					

TABLE XV
(continued)

Cycle No.	Charge	ECV	No. Pulse	Capacity Ahr	End of discharge Voltage 1.4V
28	16A for 15 1/2	2.01	896	229.6	
29	16A for 15 1/2	2.10	816	188.5	
30	16A for 11 hrs.	2.00	696	160.8	
31	16A for 11 hrs.	2.00	666	153.8	
32	16A for 13 hrs.	2.10	634	146.5	
33	16A for 9 1/2	2.10	612	141.4	
34	16A for 12 1/2	2.10	654	151.07	
35	16A for 9 1/2	2.10	585	135.13	
36	16A for 8 hrs.	2.10	492	113.7	
37	16A for 8 1/4	2.10	448	103.48	
38	16A for 16 hrs.		508	117.3	Shorted, voltage didn't get to 2.0V on charge
39	16A for 16 hrs.			OUT	

TASK II B - 2nd Generation Test Cells

Based on the dissection analysis of cells number 1 to 6, it was decided to modify the design somewhat from the 7 cells delivered to NASA. To evaluate these charges, 4 additional cells were assembled and tested prior to the completion of the Final 135 cells.

The new design featured the following modifications:

1. The use of the molded cell case and cover with a 12 negative, 13 positive electrode configuration.
2. Two layers of 6 - 7 mil thick Pellon 2533 polypropylene on the positive electrodes in place of the untreated asbestos. This material was heat sealed along 2 vertical edges to form open top bags.
3. The frame thickness on the positive electrodes were decreased by .02" to compensate for thickness build-up due to epoxy on the negative plate frames.

The four cells were filled with 1450 cc of electrolyte subjected to four characterization cycles and then put on life test on the pulsed discharge. The charge and discharge results are presented in Table XVI. The four cells were run in series on discharge and the discharge was stopped when one cell reached 1.4V.

The cells were cycled on the normal pulse discharge regime for a total of 34 cycles. The results of this testing is shown in Table XVII. Cells were recharged and given one discharge at 90 amps at cycle 18 and 35 as shown in Table XVIII and IXX. Discussions with NASA Technical Representatives revealed that there may have been a problem with the pellon polypropylene

TABLE XVI

INITIAL CYCLE RESULTS OF CELLS 8-11

Cell Type: 300Ah Ni-Zn
Contract No.:
Name of Test: Formation
Cycle No.: 1

Charge Date: 3/23 ∿ 3/24
Charge Current: 16A

Discharge Date. 3/25 ∿ 3/26/76
Discharge Current: 135A
30A
V-Reading Interval:
Cutt Off Voltage: 1.50V

Cell No.	8		9		10		11					
Charge Time	24 hrs.		24 hrs.		24		24					
C: (Ah)	384		384		384		284					
ECV (V)	1.900		1.899		1.898		1.902					
OCV (V)	1.848		1.850		1.850		1.850					
Time												
Strt at: 9·28												
IDV 9.28	1.684		1.681		1.681		1.679					
9:38	1.548		1.545		1.548		1.546					
9.48	1.523		1.520		1.525		1.522		135A		40 min.	
9·58	1.515		1.510		1.517		1.513				90Ah	
10:08	1.494		1.487		1.497		1 491					
10:11	1.633		1.631		1.636		1.633					
11:15	1.651		1.651		1.653		1.650					
12:15	1.645		1.645		1.648		1.644					
13:15	1.640		1.640		1.642		1.639					
14:16	1.629		1.628		1.631		1.627					
15.11	1.619		1.619		1.623		1.618					
16:11	1.579		1.592		1.598		1.593		30A			
16:26	1.559		1.585		1.591		1.587					
3/26 7·51	1.608		1.635		1.640		1.640					
8 03	1.501		1.569		1.576		1.577					
8·21			1.542		1.550		1.553					
8:36			1.498		1.511		1.524					
8·43					1.495		1.524					
	6.22 hrs.		7 hrs.		7.12 hrs.		7.12 hrs.					
	183Ah		210Ah		213Ah		213Ah					
Discharge Time												
Co (Ah)	273		300		303		303					
Va (V)												

TABLE XVI
(continued)

Cell Type: 300Ah Ni-Zn
Contract No.:
Name of Test: Formation
Cycle No.: 2

Charge Date: 3/29 ∿ 3/30
Charge Current: 16A

Discharge Date: 3/30 ∿ 3/31/76
Discharge Current: 360A → 1.4V
30A → 1.5V
V-Reading Interval: 60 min.
Cutt Off Voltage:

Cell No.		8	9	10	11		
Charge Time		24 hrs.	24 hrs.	24 hrs.	24 hrs.		
C: (Ah)		384	384	394	384		
ECV (v)		1.905	1.904	1.902	1.908		
OCV (v)		1.875	1.874	1.872	1.877		
Time							
Strt at	9:23						
IDV	09:23	1.480	1.482	1.481	1.470	360A	2 min.
	09:25	1.387	1.391	1.394	1.384		12Ah
	09:26	1.686	1.689	1.690	1.690		
	10:26	1.675	1.677	1.679	1.676		
	11:26	1.663	1.665	1.666	1.663		
	12·26	1.660	1.662	1.664	1.660		
	13:26	1.655	1.657	1.659	1.655		
	14.26	1.653	1.653	1.655	1.652		
	15:26	1.647	1.648	1.650	1.646		
	16:26	1.640	1.640	1.643	1.639	30A	628 min.
3/31	08 00	1.692	1.691	1.692	1.691		314Ah
	08:32	1.626	1.623	1.626	1.624		
	09:32	1.606	1.603	1.606	1.603		
	10·32	1.580	1.577	1.580	1.576		
	11:02	1.534	1.549	1.549	1.547		
	11:28	0.272	1.484	0.227	1.493		
Discharge Time							
Co (Ah)		326	326	326	326		
Va (V)							

TABLE XVI
(continued)

Cell Type 300Ah Ni-Zn
Contract No.:
Name of Test: V + Cap. determ.
Cycle No.: 3

Charge Date: 3/31 ∿ 4/1/76
Charge Current: 16A

Discharge Date: 4/2/76
Discharge Current: 180A
30A
V-Reading Interval:
Cutt Off Voltage: 1.50V

Cell No.		8		9		10		11					
Charge Time		24 hrs.		24 hrs.		24		24					
Ci (Ah)													
ECV (v)		1.920		1.915		1 913		1.921					
OCV (v)		1.818		1.817		1.817		1.817					
Time													
Strt at	8:40												
IDV	8:40	1.627		1.600		1.613		1.620		180A		10 min.	
	8:50	1.501		1.483		1.496		1.501				30Ah	
	8:51	1.647		1.645		1.649		1.649					
	9:51	1.661		1.658		1.664		1.663					
	10:51	1.657		1.653		1.660		1.659					
	11:51	1.655		1.650		1.657		1.655					
	12 51	1.651		1.646		1 653		1.651					
	13:51	1.648		1.642		1.650		1.648					
	14.51	1.640		1.635		1.642		1.640					
	15 51	1.631		1.622		1.633		1.630					
	16:21	1.621		1.621		1.621		1.621		30A			
4/5	8.30	1.676		1.674		1.676		1.675			595 min. 297.5Ah		
	8 50	1.608		1.612		1.648		1.612					
	9·10	1.593		1.592		1.590		1.592					
	9 25	1.586		1.582		1.586		1.532					
	9 50	1.576		1.573		1.576		1.571					
	10:20	1.458		1.508		1.508		1 496					
Discharge Time													
Co (Ah)		327.5		327.5		327.5		327.5					
Va (v)													

TABLE XVI
(continued)

Cell Type 300Ah Ni-Zn
Contract No.:
Name of Test: V + Cap. determ.
Cycle No.: 4

Charge Date. 4/5 ∿ 4/6/76
Charge Current: 16A

Discharge Date. 4/6/76
Discharge Current: 90A
30A
V-Reading Interval:
Cutt Off Voltage: 1.50V

Cell No.	8		9		10		11					
Charge Time	24 hrs.		24		24		24					
Ci (Ah)	384		384		384		384					
ECV (v)	1.930		1.927		1.927		1.935					
OCV (v)	1.873		1.872		1.872		1.877					
Time												
Strt at 11:50												
IDV 11:50	1.763		1.758		1.756		1.754					
12.20	1.599		1.601		1.606		1 601					
12:50	1.582		1.584		1.589		1.582					
13:20	1.578		1.581		1.586		1 578		90A		3 hrs +	20 min.
13:50	1.572		1.576		1.581		1.579				300Ah	
14.20	1.561		1.565		1.572		1.562					
14:50	1.538		1.540		1.551		1.535					
15·10	1.506		1.507		1.527		1.503					
30A 15:10	1.580		1.583		1.596		1.582					
15:40	1.605		1.607		1.614		1.602					
16:30	1.582		1.586		1.593		1.578	30A			100 min.	
4/7 8:05	1.633		1.630		1.631		1.622				50Ah	
8.35	1.525		1.532		1.538		1.522					
8:45	1.476		1.506		1.514		1.485					
Discharge Time												
Co (Ah)	350		350		350		350					
Va (v)												

TABLE XVII

Ni-Zn 300Ah CELL NO. 8-11

Cycle No.	Charge	ECV	No. Pulse	Capacity Ah
1	16A, 24 hrs.	7.824	1486	343.3
2	16A, 24 hrs.	7.795	1460	337.2
3	16A, 24 hrs.	7.822	1415	326.8
4	16A, 24 hrs.	7.824	1400	323.4
5	16A, 24 hrs.	7.85V	1394	322.0
6	16A, 24 hrs.	7.82V	1381	319.0
7	16A, 24 hrs.	7.911	1371	316.70
8	16A, 21.25	8.02	1354	312.8
9	16A, 18.75	8.00	1242	286.9
10	19 hrs.	8.00	1355	313
11	19.41 hrs.	8.055	1212	273.9
12	18.75 hrs.	8.065	1213	280.2
13	18 hrs.	8.321	1105	255.2
14	17.75hrs.	8.102	1105	255.2
15	15.33 hrs.	8.183	1096	253.1
16	15.4 hrs.	8.10	1061	245.0
17	14.75 hrs.	8.09	935	215.9
18	13.58 hrs.	8.05	90A discharge manually	

TABLE XVII
(continued)

Cycle No.	Charge	ECV	No. Pulse	Capacity Ah
19	pulse discharge reading individually			
20	15.5 hrs.	8.10	952	219.9
21	14.12	8.00	936	216.2
22	13.50	8.05	884	204.2
23	13.00hrs.	8.00	874	201.8
24	13 1/4	8.00	923	213.21
25	13 hrs.	8.00	884	204.2
26	13 1/2 hrs.	8.046	879	203
27	12 1/4 hrs.	8.00	796	183.87
28	12 hrs.	8.00	799	184.56
29	11 1/4 hrs.	8.00	667	154
30	10 1/4 hrs.	8.00	680	157
31	9 3/4 hrs.	8.00	669	154.5
32	9 3/4 hrs.	8.00	617	142.5
33	9 1/4 hrs.	8.00	570	131.67
34	8 1/4 hrs.	8.00	590	136.2

TABLE XVIII

Cell Type: 300Ah Ni-Zn (4 cells)
Contract No.:
Name of Test:
Cycle No.: 18

Charge Date: 5/19 - 5/20/76
Charge Current: 16A
90A discharge
record each cell individually

Discharge Date. 5/20/76
Discharge Current. 90A
V-Reading Interval: 15 min.
Cutt Off Voltage: 1.30 V

Cell No.	8		9		10		11					
Charge Time	13.58 hrs		13.58 hrs		13.58 hrs.		13.58 hrs.					
c: (Ah)	217.2		217.2		217.2		217.2					
ECV (v)	2.01		2.01		2 01		2 01					
OCV (v)	1.85		1.85		1 86		1.86					
Time												
Strt at 9·05												
IDV 9:05	1.727		1 735		1.734		1.721					
9:20	1.603		1.614		1.616		1 606					
9.35	1.571		1.583		1.581		1.567					
9·50	1.561		1.576		1 574		1 560					
10:35	1.505		1.548		1.540		1 485					
11:00	1.376		1.525		1.511		1.275					
11.05	1.301		1 501		1.466							
11.15			1.542		1.540							
11 30			1.489		1.471							
11:45			1.415		1.242							
11 55			1.285									
	2hrs. 180Ah		2.66 hrs. 239.4Ah		2.5 hrs. 225Ah		1.91 hrs. 171.9 hrs.					
Discharge Time												
Co (Ah)	180		239.4		225		171.9					
Va (v)												

TABLE IXX

Cell Type: 300Ah Ni-Zn (4 cells)
Contract No.
Name of Test:
Cycle No.: 35

Charge Date: 7/13 ∿ 7/14/76
Charge Current: 16A
for 10 hrs.

Discharge Date 7/15/76
Discharge Current: 90A
V-Reading Interval. 15 min.
Cutt Off Voltage 1.30V

Cell No.	8		9		10		11					
Charge Time	10 hrs.		10 hrs.		10 hrs.		10 hrs.					
C: (Ah)	160		160		160		160					
ECV (v)	2.00		2.00		2.00		2.00					
OCV (v)	1.819		1.817		1.818		1.818					
Time												
Strt at 08:39												
IDV 08.39	1.694		1.700		1 700		1 688					
08.54	1.584		1.595		1.595		1.582					
09:09	1.550		1.564		1.564		1.548					
09:24	1.548		1.554		1.564		1.545					
09 39	1.530		1.551		1.548		1.514					
09 54	1.485		1.532		1.509		1.292					
10:09	1.274		1.526		1.276							
	135Ah				135Ah		112.5Ah					
Discharge Time												
Co (Ah)												
Va (v)												

material utilized in these cells. Apparently the non-woven polypropylene material contained some wetting agents that could be dilatorius to cell performance. On the basis of this, it was decided to hot water wash the pellon prior to incorporation in the final cells.

Leak testing of the molded 300Ahr cell cases revealed approximately a 50% leakage rate at the ultrasonic welded plugs in the bottom of the cell cases. It was therefore, decided to sandblast and place epoxy sealing cement over the plugs in all of the cell containers.

TASK VI - 135 Deliverable Cells

The final cells were constructed in two groups. The first 65 cells contained NASA IO separator material. The second group of 75 cells was constructed with a new more flexible asbestos coated separator material also supplied by NASA designated K19. All the cells were filled with 1450 cc of 31% KOH and shipped to NASA LEWIS.

OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: PROCEDURE FOR ANALYSIS OF MERCURIC OXIDE CONTENT OF NEGATIVE ELECTRODE POWDER MIXES

1. EQUIPMENT REQUIRED

1.1 100 ml pyrex beaker.

1.2 Triple beam balance, Sargent S-3435, or equal.

1.3 Drying oven, electric, thermostatically controlled, 105° C.

1.4 Plain Scheibler Desiccators with active desiccant.

1.5 Stainless steel spatula.

1.6 250 cc narrow neck Erlenmeyer flask, pyrex.

1.7 Burette clamp and stand.

1.8 25 ml capacity Geissler burette.

2. MATERIALS REQUIRED

2.1 0.1 normal standard potassium thiocyanate solution (KCNS).

2.2 Ferric indicator solution (saturated solution of Iron (ic) ammonium sulfate.

2.3 7.5 molar solution of nitric acid (HNO_3) (1:1).

3. ANALYTICAL PROCEDURE

3.1 Using a triple beam balance weigh out 10 grams ±1 gram of the negative electrode mix to be analyzed for mercuric oxide content into a 100 ml pyrex beaker.

3.2 Transfer the sample in the beaker to a thermostatically controlled electric oven set at 105° C. Allow the sample to remain in this oven for at least 4 hours.

3.3 Remove the sample from the oven and transfer rapidly to a desiccator with active desiccant. Allow to cool off in the desiccator.

3.4 Weigh out 5.00 ± 0.01 grams of the dried sample using a triple beam balance and transfer all of the sample to a 250 cc Erlenmeyer flask.

OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: PROCEDURE FOR ANALYSIS OF MERCURIC OXIDE CONTENT OF NEGATIVE ELECTRODE POWDER MIXES

3.5 Add 50 cc of 7.5 molar nitric acid (1:1) to the Erlenmeyer flask and gently swirl the liquid until the sample has dissolved. It is important that all of the sample be completely dissolved.

3.6 Add distilled water to the solution in the Erlenmeyer flask so that the entire amount of liquid in the flask is approximately 100 cc.

3.7 Add 1.5 cc of Ferric indicator solution to the solution in the flask.

3.8 Cool the contents of the flask to 12° C. This may be done by immersing the flask in water at 50° F, that may be obtained from refrigerated drinking fountains.

3.9 Keeping the solution temperature lower than 15° C, titrate with 0.1 N potassium thiocyanate standard solution, proceeding very slowly near the endpoint, until a distinct reddish brown color persists on vigorous shaking. Use a 25 cc Geissler burrette for this titration.

3.10 Record the number of cc of 0.1 N KCNS required to completely react with the mercury in the sample.

4. CALCULATIONS

4.1 One cubic centimeter of 0.1 normal KCNS solution is equivalent to 0.010830 gram of mercuric oxide (H_gO).

4.2 a) cc of 0.1 N KCNS x 0.010830 = grams H_gO in sample.

b) $$\frac{\text{grams } H_gO \text{ in sample} \times 100}{5.00 \text{ grams}} = \% \ H_gO \text{ in sample.}$$

5. REFERENCES

5.1 "Treatise on Analytical Chemistry" by Kolthoff and Elving, Part II, Volume 3, pp 306-308.

OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: PROCEDURE FOR PREPARATION OF NEGATIVE MIX

1. OBJECTIVE OF OPERATION

The purpose of this operation is to blend together desired quantities of zinc oxide and mercuric oxide powders to form a homogeneous material for use in the fabrication of zinc electrodes.

2. MATERIALS REQUIRED

2.1 Zinc oxide - Horsehead® U.S.P. - 12 grade; New Jersey Zinc Company; in 50 lb. cartons.

2.2 Mercuric oxide - Analytical Reagent grade; Mallinckrodt; in 1 lb. bottles.

3. EQUIPMENT REQUIRED

3.1 Balance, 20 kg. capacity, Ohaus Model 1119 or equivalent.

3.2 Balance, triple beam, Sargent S-3435 or equivalent.

3.3 Mixer, U.S. Stoneware "Universal" lab mixer, with rotohedral mixing units.

3.4 Drying oven, Despatch, Model LDB-1-67 or equivalent.

3.5 Tray, stainless steel, 12" x 20" x 2-1/2".

3.6 Spatula, stainless steel.

3.7 Scoop. plastic.

3.8 Beaker, plastic, 100 ml. capacity.

3.9 Jars; one gallon capacity; brown glass.

4. DETAILED OPERATIONAL PROCEDURE

4.1 Place a stainless steel tray on the 20 kg. balance and tare it.

4.2 Using a plastic scoop, transfer 3920 g. of zinc oxide from its container to the tray.

4.3 Place a plastic beaker on the triple beam balance and tare it.

OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: PROCEDURE FOR PREPARATION OF NEGATIVE MIX

4.4 Using a stainless steel spatula, transfer 80 g. of mercuric oxide from its container to the beaker.

4.5 Add both the zinc oxide and the mercuric oxide to one side of the rotohedral blender, alternating small amounts of each so that the mercuric oxide is somewhat dispersed throughout the zinc oxide.

4.6 Put the top on the blender and turn the blender on. Let it run for 15 minutes, then turn it off.

4.7 Carefully remove the blender cover, and with a stainless steel spatula gently scrape any powder which had adhered to the blender walls off the walls. Replace the blender cover.

4.8 Turn the blender on and let it run for 45 minutes. Turn it off.

4.9 Remove the blender cover and transfer the contents of the blender to a stainless steel tray.

4.10 Place the tray containing the mixture on a shelf in the Despatch oven and allow it to dry overnight at approximately 70° C. Transfer the material to one gallon brown glass jars. Place caps on the jars.

5. DISPOSITION OF PRODUCT

The negative mix is now ready for analysis according to BFDO 1001. If mercury content is correct the mix is ready for use in electrode fabrication.

6. SAFETY CONSIDERATIONS

Mercuric oxide is an accumulative poison and should not be ingested. The operator must keep this material off his skin, and must wash his hands and arms thoroughly after exposure to mercuric oxide.

OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: MOLD PRESSING OF NEGATIVE ELECTRODES

1. OBJECTIVE

To make a negative electrode of a given size, weight and thickness by pressing mix around a collector grid.

2. MATERIAL REQUIREMENTS

2.1 Negative mix from BFDO #1013.

2.2 Welded negative electrode grid from BFDO #1012.

2.3 Potassium titanate absorbers from BFDO #1011.

2.4 P.V.A. solution from BFDO #1017.

3. EQUIPMENT REQUIREMENTS

3.1 Three-piece mold.

3.2 Hydraulic press, Wabash Model #100-15 SMAC or equivalent.

3.3 Tamping tool.

3.4 Shim stock.

3.5 Burgess Sprayer, Model VS-855.

3.6 Spray hood.

3.7 Kimwipes.

3.8 Acetone.

3.9 Vernier calipers, Helios.

3.10 Throw-away filter mask, 3M brand.

3.11 Rubber or plastic gloves.

3.12 Kimtowels.

4. OPERATIONAL DETAILS

4.1 Clean base plate with Kimwipe and place on work table.

OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: MOLD PRESSING OF NEGATIVE ELECTRODES

4.2 Wipe surface of base plate that will come in contact with mix with piece of Kimwipe dipped in acetone.

4.3 Clean mold with Kimwipe and position on base plate, matching base plate pins with pin holes in mold.

4.4 Tab slot in mold should be positioned toward operator.

4.5 Place one piece of potassium titanate on Kimtowel against back-board of spray hood.

4.6 Spray P.V.A. solution from BFDO #1017 on one surface of potassium titanate paper.

4.7 Remove piece of potassium titanate paper from spray hood and position in bottom of mold, wet side up.

4.8 Pour 1/2 of prepared cup of negative mix into mold on top of potassium titanate paper.

4.9 Spread mix evenly with tamping tool. The care taken in the even spreading of the mix is directly related to the final thickness and quality of the finished electrode.

4.10 Prepare collector grid assembly by handforming the grid so that it will lie flat.

4.11 Place collector grid assembly carefully on mix in mold, threading tab through tab slot. It is important that grid lie flat on mix.

4.12 Pour remainder of mix into mold on top of collector grid assembly. Material weighed per BFDO #1013.

4.13 Spread mix evenly over grid assembly with tamping tool. The care taken in the even spreading of the mix is directly related to the final thickness and quality of the finished electrode.

4.14 Repeat 4.5 - 4.6.

4.15 Remove second piece of potassium titanate paper from spray hood and place on top of mix in mold, wet side down.

4.16 Clean punch with Kimwipe. Wipe surface of punch that will come in contact with mix with Kimwipe dipped in acetone.

4.17 Insert punch very slowly into mold, to prevent blowout of mix.

OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: MOLD PRESSING OF NEGATIVE ELECTRODES

4.18 Place mold assembly in center of bottom platen of press.

4.19 Place 0.339 shims on each side of mold.

4.20 To turn on press throw main switch on back right side of press. Push power on button at front right side of press.

4.21 Set pressure gauge to 40 tons.

4.22 Set timer to 35 seconds.

4.23 Press two green buttons marked "close" simultaneously to close press. Do not release the green buttons until the press stops. The pre-selected pressure will stop the press automatically and then the green buttons must be released. After the pre-set time interval the press will open.

4.24 When press opens, let the lower platen travel down a workable distance then stop by pressing green buttons once simultaneously.

4.25 Remove shims from mold and place on platens.

4.26 Remove mold assembly and place on work table in an inverted position.

4.27 Remove base plate by carefully lifting off of mold and electrode.

4.28 Place heel and thumb of each hand on either side of mold and press down, being careful not to touch edge of electrode. Mold will drop leaving electrode free on top of punch.

4.29 Pick up electrode by tab and check thickness with Vernier calipers.

4.30 Place electrode flat on area set aside for the drying of the electrode.

4.31 Before the next step the electrode must dry overnight at room temperature.

5. DISPOSITION OF PRODUCT

The electrodes are now ready for the inspection operation per BFDO #1015

OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: MOLD PRESSING OF NEGATIVE ELECTRODES

6. SAFETY CONSIDERATIONS

6.1 The two palm buttons are designed to prevent any injury to the operator's hand and arms since the press stops if both palm buttons are not pressed simultaneously.

6.2 A filter mask and rubber or plastic gloves should be worn during this operation.

OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: INSPECTION OF NEGATIVE ELECTRODES

1. OBJECTIVE

The objective of this operation is to insure that negative electrodes are mechanically acceptable and are 2.80" ± 0.015" in width and 3.625" ± 0.015" in length (excluding the tab extension). The measurement of thickness and the weighing of each electrode will be described in BFDO #1016.

2. MATERIAL REQUIREMENTS.

Negative electrodes from operation BFDO #1014.

3. EQUIPMENT REQUIREMENTS

Vernier calipers.

4. OPERATIONAL DETAILS

4.1 There will be 100% inspection of electrodes for mechanical acceptability. Every tenth electrode will be checked for width and length.

4.2 Inspection for mechanical acceptance.

4.2.1 Damaged or crushed edges are not acceptable.

4.2.2 There shall be no evidence of separation of the prepared mix from the DISTEX collector grid.

4.2.3 The KT paper absorber shall lie flat on each wide outer surface of the electrode and there shall be evidence of reasonable adherence of the KT paper to the electrode.

4.3 Measure width of every tenth electrode with Vernier calipers. The width should be 2.80 ± 0.015.

4.4 Measure length of every tenth electrode with Vernier calipers. The length should be 3.625 ± 0.015.

5. DISPOSITION OF PRODUCT

The electrodes are now ready for weighing, thickness measurements, and serializing per BFDO #1016.

OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: SLEEVING AND SERIALIZING OF NEGATIVE ELECTRODES (INCLUDING WEIGHING)

1. OBJECTIVE

1.1 To record and ensure proper weight and thickness of each electrode.

1.2 To apply insulation sleeving to each electrode.

1.3 To give each electrode a traceable serial number.

2. MATERIALS REQUIRED

2.1 Pressed and inspected negative electrode.

2.2 Heat shrinkable FEP spaghetti FEP HST. #8 (precut to 1/2" lengths).

2.3 White coding tapes with consecutive numbers starting with 0001, EZ Code.

2.4 Traceability and inspection form.

3. EQUIPMENT REQUIREMENTS

3.1 Triple beam balance, Sargent S-3435 or equivalent.

3.2 Vernier Calipers, 6" helios.

3.3 Black ink pen.

4. OPERATIONAL DETAILS

4.1 Set balance to zero.

4.2 Pick up electrode by tab or edge and place on balance tray.

4.3 Adjust balance weights until pointer swings an equal distance on either side of zero mark.

4.4 Record weight on traceability and inspection form.

4.5 The electrode weight must fall in the range of 37.8 to 39.0 grams.

4.6 Remove electrode from balance and slide precut spaghetti down over tab until it contacts negative plate.

4.7 Attach numbered tape to end of tab.

OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: SIEEVING AND SERIALIZING OF NEGATIVE ELECTRODES (INCLUDING WEIGHING)

4.8 Record number in serial number column on same line as recorded weight of electrode.

4.9 Check thickness of electrode over its entire area with a Vernier Caliper and record the average thickness on the traceability and inspection form on same line as serial number.

4.10 The electrode thickness must fall within the range of 86 to 90 mils.

4.11 All traceability data on form must correspond with actual data of electrode.

4.12 Electrodes are now stored in plastic boxes.

5. DISPOSITION OF PRODUCT

Electrodes are now ready for use in unit sub-assemblies. Refer to section 3.1.

OPERATIONAL WORK INSTRUCTION SHEET

Operat. Title: PREPARATION OF PVA SOLUTION

1. OBJECTIVES OF OPERATION

The purpose of this operation is to prepare a 1% solution of polyvinyl alcohol in water for use in the fabrication of zinc oxide electrodes.

2. MATERIAL REQUIRED

2.1 Polyvinyl alcohol - DuPont "Elvanol" Grade 51-05; in 50 lb. bags.

2.2 De-ionized water.

3. EQUIPMENT REQUIRED

3.1 Triple beam balance, Sargent S-3435 or equivalent.

3.2 Graduated cylinder, 500 ml. capacity.

3.3 Beaker, 800 ml. capacity.

3.4 Beaker, 100 ml. capacity.

3.5 Stainless steel spatula.

3.6 Magnetic stirrer, Sargent Model H or equivalent.

3.7 Stirring bar, teflon coated, 1-1/2 in. long.

4. DETAILED OPERATIONAL PROCEDURE

4.1 Place a 100 ml. beaker on the triple beam balance and tare it.

4.2 Weigh out 5.0 grams of Elvanol, using a stainless steel spatula to transfer the material from its bag to the beaker.

4.3 Pour 495 ml. of de-ionized water into a 500 ml. graduated cylinder.

4.4 Empty the graduated cylinder into an 800 ml. beaker.

4.5 Place the beaker containing the water on a magnetic stirrer and drop a teflon coated stirring bar into the water.

4.6 Turn the stirrer on and adjust it to a medium stirring speed.

4.7 Slowly pour the Elvanol from its beaker into the water.

OPERATIONAL WORK INSTRUCTION SHEET

Operation Title: PREPARATION OF PVA SOLUTION

4.8 Allow the mixture to stir until all of the Elvanol has been dissolved.

4.9 Turn the stirrer off.

5. DISPOSITION OF PRODUCT

The product may be stored in glass jars with plastic lined lids, or it may be poured directly into the reservoir of the spray gun, where it will be ready for use in electrode manufacture.

6. SAFETY CONSIDERATIONS

Normal laboratory safety practices should be observed during this operation.

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