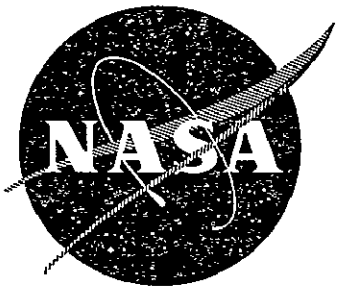

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DEVELOPMENT AND FABRICATION OF LARGE VENTED NICKEL-ZINC CELLS

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prepared for

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16. Abstract A preliminary cell design for a 300AH vented nickel-zinc cell was established based on volume requirements and cell component materials selected by NASA Lewis Research Center. A 100AH cell configuration was derived from the 300AH cell design utilizing the same size electrodes, separators and cell terminal hardware. The first cells fabricated were four (4) groups of three (3) cells each in the 100AH size. These 100AH experimental nickel-zinc cells had as common components the nickel positive electrodes (GFM), flexible inorganic separator (GFM) bags on the negative electrodes, pressed powder zinc oxide electrodes and cell containers with hardware. The variations introduced were four (4) differing electrolyte absorber (interseparator) systems used to encase the nickel positive electrodes of each cell group.

Test equipment was designed and constructed to aid in the evaluation of 100AH or 300AH cells under load conditions similar to those experienced by storage batteries in electric vehicle applications. The four (4) groups of 100AH experimental vented nickel-zinc cells were filled, formed and tested to determine, based on cell performance, the best two (2) interseparator systems.

Using the two (2) interseparator systems selected through 100AH cell testing, two (2) groups of experimental 300AH cells were fabricated. Each group of three (3) cells differed only in the interseparator material used. The six (6) cells were filled, formed and tested to evaluate the interseparator materials and investigate the performance characteristics of the 300AH cell configuration and its components.

Based on the testing of the 300AH cells, the use of a .30mm thick non-woven polyamide material resulted in better cell performance. The use of a .17mm thick non-woven polypropylene material in double layers yielded approximately 10% less energy per cycle during cycle life testing. A problem with the physical stability of the nickel positive electrodes shortened the cycle life of the cells using the polyamide material interseparators while the cells containing the polypropylene material were not affected during the period of testing.

The nickel positive electrodes were modified to minimize the effect of physical instability and seven (7) 300AH cells were constructed using the .30mm thick non-woven polyamide material in the fabrication of the interseparator bags. These seven (7) cells and materials necessary to fill and maintain the cells were shipped to NASA Lewis Research Center for testing and evaluation.

The energy densities of the experimental 300AH cells constructed in this work were in the 21 - 23Wh/lb. range.

A design for molded cases and covers for cells of 250AH to 300AH nominal capacity, based on the configuration developed in the work described above, was prepared and submitted to NASA Lewis Research Center.

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SUMMARY

The intent of this program was to demonstrate the feasibility of the nickel-zinc system. The program, of necessity and to meet overall goals, was accelerated and testing was limited. Judgments were made based on short term cell performance characteristics and life testing, at this point, was not a factor. It was felt that more than 100 cycles could be obtained and that this would illustrate the potential of the system. It was also recognized that there could be problems in the scale-up of this large cell, both electrochemical and mechanical. Some problems were encountered and fixes were introduced which we would like to think will help to insure the integrity of the cell and give us the data needed to show the performance of a vehicle using the nickel-zinc couple.

A preliminary cell design for a 300AH vented nickel-zinc cell was established based on volume requirements and cell component materials selected by NASA Lewis Research Center. A 100AH cell configuration was derived from the 300AH cell design utilizing the same size electrodes, separators and cell terminal hardware. The first cells fabricated were four (4) groups of three (3) cells each in the 100AH size. These 100AH experimental nickel-zinc cells had as common components the nickel positive electrodes (GFM), flexible inorganic separator (GFM) bags on the negative electrodes, pressed powder zinc oxide electrodes and cell containers with hardware. The variations introduced were four (4) differing electrolyte absorber (interseparator) systems used to encase the nickel positive electrodes of each cell group.

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The nickel positive electrodes were modified to minimize the effect of physical instability and seven (7) 300AH cells were constructed using the .30mm thick non-woven polyamide material in the fabrication of the interseparator bags. These seven (7) cells and materials necessary to fill and maintain the cells were shipped to NASA Lewis Research Center for testing and evaluation.

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INTRODUCTION

Growing concern for the conservation of the nation's energy and environment has prompted a revitalized interest in the electric vehicle as an economically advantageous alternate method of moving people or goods over urban routes. More widespread utilization of this transportation mode has been hampered by the restrictions on vehicle range and speed imposed by the relatively low energy density of present commercially available storage batteries. The search for an economically feasible solution to this energy density problem has resulted in a burgeoning interest in the nickel-zinc alkaline storage battery.

The technical problems indigenous to the nickel-zinc couple have been addressed both directly and indirectly by industry and governmental agencies. Advances in nickel electrode technology have been derived from various programs dealing with the nickel-cadmium couple. The development of heat sterilizable silver-zinc cells, sponsored by NASA, spawned both flexible inorganic separators and a zinc electrode of sufficiently improved stability to aid in the evaluation of long life separator materials in battery environments. Company funded and government funded effort continues in the investigation of these problem areas and in establishing the capability to produce, in quantity, improved cell components and battery cells. Combined with this effort are on-going studies of nickel-zinc battery maintenance and cycle management necessary for safe and efficient operation of this couple in daily use.

To date, electric vehicle design has been based on the size and performance of readily available lead-acid storage batteries. As a step toward evaluating the relative merits of a nickel-zinc battery system, NASA Lewis Research Center has funded programs to develop and build prototype nickel-zinc cells of a size which would fit and fill the volume allotted for lead-acid batteries in certain currently available electric vehicles.

It is the purpose of this report to describe the development, fabrication and preliminary testing of a large, vented nickel-zinc cell configuration which could be used in future evaluation of various storage battery couples on a unit volume basis.

TASK I - FABRICATION OF EXPERIMENTAL 100 AMPERE-HOUR NICKEL-ZINC CELLS

1. Objective of Task

The objective of this task was to fabricate 100AH Nickel-Zinc cells in four (4) groups of three (3) cells each. The only difference between the groups was the material used as electrolyte absorber (interseparator) on the nickel positive electrodes.

2. Cell Materials

2.1 The conductor grid material for the negative electrodes was Exmet product 5Ag27-1/0 DISTEX in a roll 15.24cm wide. In fabricating the electrode grid, it was necessary to make only one (1) cut to obtain the grid length of 24.76cm.

2.2 The conductor tab material for the negative conductor grid assemblies was fine silver strip, 2.54cm wide x .10mm thick. Each electrode used a tab strip length of 12.7cm.

2.3 The zinc oxide used for the negative electrode mix was the Horsehead brand manufactured by the New Jersey Zinc Company and conformed to the specifications of USP-12. The zinc oxide was packaged in plastic lined, paperboard boxes containing 22.7 kg. of powder.

2.4 The mercuric oxide used as the inhibitor in the negative electrode mix was analytical reagent grade red mercuric oxide manufactured by Mallinckrodt Chemical Works.

2.5 The material used for the sling to aid in positioning the cell stack inside the cell case was teflon film, .13mm thick x 17.14cm wide.

2.6 The Allbond epoxy used to seal the sides and bottom of the negative electrode separator bags was purchased from Bacon Industries, Inc. in kits containing 0.5 liter of resin and 0.5 liter of activator.

2.7 The cell cases were fabricated by cementing together machined pieces of 0.63cm thick high temperature lucite to create a cavity 17.14cm wide x 2.06cm thick x 30.16cm deep. The top of the cell case was machined to provide a cavity for the cell cover.

2.8 The cell covers were fabricated from machined pieces of 0.63cm thick high temperature lucite.

2.9 The cell pressure relief valve assembly was Yardney Part Number 12984. This valve has an opening pressure of 0.4 - 0.6 Kg/sq.cm.

2.10 The cell terminal assembly was fabricated from tellurium copper, ASTM Spec. B-301, hard temper. The terminal assembly featured a 1/2-20UNF-2A threaded blind terminal post and a bolt-through method of attaching electrode tabs. The terminal assemblies were nickel plated per MIL-F-14072, Finish M312.

2.11 The cell terminal jam nut and metal washer were fabricated from tellurium copper and nickel plated to the same specifications as the cell terminal assemblies.

2.12 The insulation tubing for the electrode tabs was PVC heat shrinkable tubing, 1.9cm diameter, Type RNF100.

2.13 The electrolyte used was a 34 percent (34%) solution of potassium hydroxide. This solution was made by diluting a 45 percent (45%) solution of "Baker Analyzed" reagent grade potassium hydroxide with distilled water.

2.14 The negative electrode absorber pads were cut from potassium titanate material, Type YIFL-II, manufactured by Yardney to conform to Yardney Specification YP-614.

2.15 The nickel positive electrodes were supplied by NASA-Lewis Research Center.

2.16 The flexible inorganic separator material used to fabricate separator bags for negative electrodes was machine coated Type 3420-25FM and was furnished by NASA-Lewis Research Center.

2.17 The electrolyte absorber materials used in the three (3) cells of each group of Task I cells were as follows:

Group 1 Pellon Corporation Type 2530 non-woven polypropylene, .33mm thick.

Group 2 Treated fuel cell asbestos, .25mm thick.

Group 3 Pellon Corporation Type 2506-K4 non-woven polyamide, .15mm thick, and fibrous tubing manufactured by Union Carbide Corporation, .19mm thick.

Group 4 Pellon Corporation Type 2506 non-woven polyamide, .30mm thick.

3. Negative Electrode Fabrication

3.1 The negative conductor grid sub-assembly consisted of expanded silver mesh, Exmet product DISTEX 5Ag27-1/0, cut to 15.24cm x 24.76cm and welded to a fine silver strip tab 2.54cm wide x .10mm thick x 12.7cm long. The expanded silver mesh and fine silver strip pieces were degreased using acetone as the cleaning agent and allowed to air dry. A locating fixture was used to properly position the tab in relation to the grid and the parts were welded together using a 50KVA resistance welder with tungstenite welding tips. Four (4) spot welds 1.58cm in diameter were used to secure the tab to the conductor grid. The completed negative conductor grid sub-assembly was cleaned with acetone and air dried.

3.2 The powder mix used in the negative electrode was prepared in batches containing 3,920 grams of zinc oxide and 80 grams of mercuric oxide. These materials were added to both containers of a twin cone blender, alternating small amounts of each material so that the mercuric oxide was somewhat dispersed throughout the zinc oxide during the loading of the twin cone blender. The material was then mixed in the blender for sixty (60) minutes, removed from the blender and transferred to a stainless steel tray. This was then placed in an oven and allowed to dry overnight at approximately 70°C. A sample of the negative mix was analyzed to determine the actual mercuric oxide content, using a titration method with potassium thiocyanate and ferric indicator solution. All batches used met the requirement of 1.80 - 2.20% mercuric oxide. The exact analytical method is described in "Treatise on Analytical Chemistry" by Kolthoff and Elving, Part II, Volume 3, pages 306 - 308.

3.3 Each negative electrode used two (2) absorber layers of potassium titanate mat manufactured by Yardney Electric Division. Each layer of this material, Yardney product YIFL-II, measured 15.56cm x 25.08cm.

3.4 In fabricating each negative electrode, a 147 gram charge of negative mix was weighed out. One (1) layer of potassium titanate mat was moistened by spraying with a 1% by weight solution of PVA in distilled water. The moistened KT mat was positioned in the bottom of the cavity of a three piece compression mold and covered by half of the charge of negative mix. When the negative mix was spread evenly over KT mat the negative collector grid sub-assembly was positioned in the mold, flat on the mix and centered in the cavity. The balance of the charge of negative mix was then introduced to the cavity and spread evenly over the grid. The second layer of KT mat was moistened and positioned on top of the mix. The mold punch was inserted into the

cavity and the filled mold was pressed between the platens of a hydraulic press at 68,000kg. (indicated) to compact the negative electrode mix around the collector grid. Upon removal from the mold, each electrode was allowed to air dry overnight. Each negative electrode was measured and inspected to ensure conformance with dimensional, weight and physical condition criteria. A 1.90 cm length of plastic tubing was positioned on the tab of acceptable electrodes. The tab was marked with an identification number. The edges of each acceptable negative electrode were reinforced by a light application of a two percent (2%) solution of polyphenylene oxide (PPO) in chloroform to improve the mechanical stability of the edges of the pressed negative electrode.

4. Positive Electrode Preparation

4.1 Each nickel positive plate was inspected for dimensional and physical characteristics and a sample of ten (10) plates was selected for performance evaluation. The sample plates were given charge-discharge cycles using 152mm nickel plaque counter electrodes encased in a heat sealed bag of non-woven nylon. Each nickel positive plate and its bagged counter electrodes were assembled in a cell case and shimmed to achieve normal cell spacing. A 35% solution of potassium hydroxide was introduced into the cell case and the electrolyte level was adjusted to 1/16-1/8" above the top of the sample test plates. A length of cadmium wire, sheathed in non-woven nylon, was used as a reference electrode in these tests. The ten (10) test plate cells were charged and discharged in series using a constant current power supply. The plates were charged at 3.60 amperes for five (5) hours for a total input of 18 ampere hours. They were discharged at 3.2 amperes to 1.00 volt per plate. Current and test plate voltage were recorded as a function of time during charge and discharge. The results of sample test plate performance evaluation are given in Table I.

4.2 A 1.90cm length of red heat shrinkable plastic tubing was positioned in the tab of each outside or half electrode. A similar piece of tubing was positioned over both tabs of a full electrode which consisted of two (2) half electrodes.

5. Separator Bag Fabrication

The separator bag for the negative electrode assembly was fabricated by sealing the sides and one end of two pieces of inorganic separator. The Allbond Epoxy cement was applied to the edges of the asbestos side of two (2) pieces of the material and positioned on either side of a dummy electrode the same thickness as the negative electrode. The assembled and cemented bag was restrained and inverted to facilitate epoxy flow. (After curing

TABLE I

PERFORMANCE EVALUATION DATA FOR SAMPLES OF NICKEL POSITIVE PLATES

SUPPLIED AS GFM FOR USE IN 100AH & 300AH NICKEL-ZINC CELLS

Test Plate Ident.	Cycle 1		Cycle 2		Cycle 3	
	Charge Input (AH)	Discharge Output (AH)	Charge Input (AH)	Discharge Output (AH)	Charge Input (AH)	Discharge Output (AH)
1-016	18	14.6	18	14.4	-	-
1-045	18	13.8	18	14.5	-	-
1-078	18	15.9	18	15.1	-	-
1-165	18	13.1	18	14.7	-	-
1-181	18	12.7	18	14.0	-	-
1-109	18	11.0(1)	18	11.5(2)	18	14.8
1-115	18	11.0(1)	18	11.4(2)	18	14.4
1-121	18	12.1(1)	18	11.6(2)	18	14.8
1-134	18	9.6(1)	18	10.7(2)	18	14.0
1-143	18	10.9(1)	18	11.0(2)	18	14.2

Notes: (1) 17 Hour Charged Stand prior to Discharge
(2) Ten (10) Day Charged Stand prior to Discharge
(3) Balance of Test Discharges accomplished with only 1/4-1/2 hour Charged Stand prior to Discharge

at room temperature for 12 - 16 hours, the restraints were removed and the dummy electrode removed.) The resultant separator bag was completely sealed on the sides and bottom with the separator ceramic coating outboard. A negative electrode assembly was inserted in the separator bag and the resultant bagged negative electrode was forwarded to cell assembly.

6. Interseparator Preparation

6.1 Group 1

The .33mm thick non-woven polypropylene material, Pellon #2530, was cut into pieces 27.3cm x 16.8cm. Two (2) pieces of the material were heat sealed with a 0.3cm wide seal positioned 0.16cm from the sides and 0.63cm from one end. The positive electrode was positioned within the sealed bag with the bottom of the electrode against the bottom seal of the bag and the electrode sides equidistant from the sealed sides of the bag. This configuration of interseparator bag allowed for positive electrode growth and aided in centering the positive electrode on the negative electrode during cell assembly.

6.2 Group 2

The treated fuel cell grade asbestos paper was cut into pieces 16.8cm x 27.3cm. One (1) end of each cut piece was reinforced by immersing it 1/2"cm deep in PS-N-50-15 cement for ten (10) seconds and allowing the piece to air dry for 2-3 hours in a well ventilated space. The three unreinforced edges were coated on one (1) side with a 0.5cm wide application of PS-N-50-15 cement and allowed to dry for 15 minutes. Two (2) pieces were assembled to form a bag with coated edges together. Pressure was applied to assure a complete cement bond by placing the bag on a flat surface and rolling a 6.8kg., 6.3cm diameter cylindrical weight over the bag several times. The assembled bag was allowed to air dry for 12-16 hours. Heat was applied to the sealed edges of the bag using a heat sealer with a 0.3cm wide heater element.

6.3 Group 3

Heat sealed bags of .15mm thick Pellon #2506-K4 non-woven polyamide material were fabricated by the same methods and to the same dimensions as the bags for Group 1 cells. Positive electrodes were inserted and positioned in the bags. A 56.2cm length of fibrous tubing was cut from material with an inside width of 19cm. One folded edge of the tubing was cut and folded to make a wrap with an inside width of 16.8cm with an edge overlap of 0.6 cm. Bagged positive electrodes were positioned inside the wrap

with the tops of the heat sealed bags even with the ends of the wrap and the electrode tabs on the same side of the wrap. The wrap was then folded in the middle to form a "U" with the wrap overlap outside. For one (1) 100 ampere-hour cell, three (3) "U" wraps were required. One wrap contained one (1) half and one (1) full positive electrode. A second wrap contained two (2) full positive electrodes. The third wrap contained one (1) half positive electrode, leaving the remaining wrap cavity empty.

6.4 Group 4

A heat sealed bag of .30mm thick Pellon #2506 non-woven polyamide material was fabricated by the same methods and to the same dimensions as the bags for Group 1 cells. Positive electrodes were inserted and positioned in the bags.

7. Cell Fabrication

Each 100AH experimental nickel-zinc cell contained four (4) bagged negative electrodes, two (2) bagged half positive electrodes and three (3) bagged full positive electrodes. Positive electrodes nearest the cell case walls were half electrodes consisting of one (1) nickel plate. The positive electrodes between two (2) negative electrodes consisting of two (2) nickel plates. In the Group 3 cells, the empty cavity of fibrous tubing wrap was positioned against the cell case wall. The completed cell stacks were inserted in cell cases. Cell terminals were assembled to a cell cover and sealed with an acrylic cement. A bolt-through attachment of the electrode tabs to their respective terminals was effected and the cell case-to-cover was made with acrylic cement. The weight of the cell case, cover and terminal hardware was 1.1kg. The average weight of the completed 100AH nickel-zinc cell, prior to filling, was 3.2kg.

8. Cell Filling and Conditioning

Each 100 ampere-hour experimental nickel-zinc cell was vacuum filled with 425ml of a 34% solution of potassium hydroxide. A pressure relief valve was threaded loosely in the vent and the wide sides of the cells were restrained. The filled cells were allowed to soak at room temperature for 24 hours followed by an elevated temperature separator conditioning soak at 77-79°C. for 64-66 hours. An additional 25ml of electrolyte was introduced into each cell after the elevated temperature exposure.

A summary of the design of the experimental 100AH nickel-zinc cell is given in Appendix I.

TASK II - TEST AND EVALUATE TWELVE (12) 100AH EXPERIMENTAL NICKEL-ZINC CELLS

1. Objective of Task

The objective of the second contract task was to evaluate the relative performance of the four (4) groups of cells fabricated in Task I. To accomplish this evaluation it was necessary to design and fabricate test equipment.

2. Cell Formation

Each cell was given two (2) formation cycles in accordance with contract requirements. Each cell was charged at a 5.0 ampere rate to 1.91 - 1.92 volts or for 24 hours, whichever occurred first. The discharge was accomplished at 41.0 amperes (15 ma/sq. cm) to a voltage of 1.50 volts. Each cell was then drained at 13.5 amperes (5 ma/sq. cm) to 1.50 volts. Formation Cycle No. 2 was a repeat of the first cycle.

During the formation cycles some electrolyte spewed out of the cells through the vent trap. This electrolyte was collected and measured. The electrolyte level in each cell was then adjusted to a point level with the tops of the separator bags. The net quantity of electrolyte present in each cell after the completion of the formation cycles is given in Table II.

A summary of the charge input and discharge output capacities for each cell during the two (2) formation cycles is given in Tables III and IV.

A comparison of typical cell voltages for the four (4) different cell groups during the two (2) formation cycles discharges is given in Table V.

3. Performance Characterization Test

Following the second formation discharge and drain, each cell was charged at 5 amperes to 1.92 volts or for 24 hours, whichever occurred first. Each cell was then discharged at 110 amperes (40 ma/sq. cm) to 1.40 volts and drained at 13.5 amperes to 1.40 volts. The charge, discharge and drain cycle was repeated two additional times using discharge rates of 55 amperes (20 ma/sq. cm) and 27.5 amperes (10 ma/sq. cm). A summary of the charge input and the discharge and drain output capacities is given in Tables VI, VII and VIII. Cell voltage was recorded continuously as a function of time during each test cycle. A comparison of typical cell voltages taken during the three (3) test discharges of these cells is given in Table IX.

TABLE II

NET ELECTROLYTE QUANTITY

IN 100AH NICKEL-ZINC CELLS

AFTER TWO FORMATION CYCLES

CELL GROUP NO.	CELL NO.	ELECTROLYTE QUANTITY IN ML
1	1	380
	2	383
	3	378
2	1	425
	2	424
	3	444
3	1	450
	2	442
	3	444
4	1	435
	2	431
	3	446

TABLE III

SUMMARY OF CELL INPUT AND
OUTPUT CAPACITIES FOR 100AH
NICKEL-ZINC CELLS

FORMATION CYCLE NO. 1

Charge: 5.0A to 1.91-1.92 Volts or
for 24 Hours (120AH) Maximum,
whichever occurs first
Discharge: 41.0A to 1.50 Volts
Drain: 13.5A to 1.50 Volts

CELL		CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE	OUTPUT TO 1.50 V		
GROUP	NO.			DISCHARGE (AH)	DRAIN (AH)	TOTAL (AH)
1	1	120	1.877	60.8	15.2	76.0
	2	120	1.875	61.5	14.0	75.5
	3	120	1.877	60.8	15.1	75.9
2	1	120	1.876	60.8	13.3	74.1
	2	120	1.875	61.5	13.5	75.0
	3	120	1.878	60.8	14.4	75.2
3	1	120	1.874	47.2	23.4	70.6
	2	120	1.873	55.4	17.6	73.0
	3	120	1.874	52.6	18.0	70.6
4	1	120	1.869	64.8	10.8	74.6
	2	120	1.870	66.8	10.8	77.6
	3	120	1.869	66.8	8.3	75.1

TABLE IV

SUMMARY OF CELL INPUT AND
OUTPUT CAPACITIES FOR 100AH
NICKEL-ZINC CELLS

FORMATION CYCLE NO. 2

Charge: 5.0A to 1.91-1.92 Volts or
for 24 Hours (120AH) Maximum,
whichever occurs first
Discharge: 41.0A to 1.50 Volts
Drain: 13.5A to 1.50 Volts

CELL		CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE	OUTPUT TO 1.50 V		
GROUP	NO.			DISCHARGE (AH)	DRAIN (AH)	TOTAL (AH)
1	1	120	1.880	78.6	17.3	95.9
	2	120	1.879	80.7	17.1	97.8
	3	120	1.880	78.6	17.1	95.7
2	1	120	1.880	80.7	16.2	96.9
	2	120	1.879	81.3	15.1	96.4
	3	120	1.882	80.7	15.5	96.2
3	1	120	1.879	62.2	31.5	93.7
	2	120	1.877	62.2	33.8	96.0
	3	120	1.877	64.9	27.5	92.4
4	1	120	1.873	84.1	14.0	98.1
	2	120	1.873	84.7	15.8	100.5
	3	120	1.872	84.1	12.8	96.9

TABLE V

COMPARISON OF TYPICAL CELL VOLTAGES
100AH EXPERIMENTAL NICKEL-ZINC CELLS

FORMATION CYCLES DISCHARGE

Charge: 5.0A to 1.91-1.92 Volts or for 24 Hours (120AH) maximum whichever occurs first
Discharge: 41.0A to 1.50 Volts
Drain: 13.5A to 1.50 Volts

AMPERE HOUR OUTPUT	FORMATION NO. 1				FORMATION NO. 2			
	GROUP 1 (V)	GROUP 2 (V)	GROUP 3 (V)	GROUP 4 (V)	GROUP 1 (V)	GROUP 2 (V)	GROUP 3 (V)	GROUP 4 (V)
10	1.58	1.58	1.58	1.59	1.60	1.60	1.60	1.61
20	1.57	1.57	1.56	1.58	1.58	1.59	1.58	1.60
30	1.55	1.56	1.56	1.57	1.57	1.57	1.57	1.59
40	1.54	1.55	1.53	1.56	1.56	1.56	1.56	1.58
50	1.53	1.53	----	1.55	1.55	1.55	1.54	1.57
60	----	----	----	1.52	1.54	1.54	1.51	1.55
70	----	----	----	----	1.52	1.53	----	1.54
80	----	----	----	----	----	----	----	1.51
90	----	----	----	----	----	----	----	----
100	----	----	----	----	----	----	----	----
AHo to 1.50 V	61.03	61.03	51.70	66.15	79.30	80.90	63.10	84.30

TABLE VI

SUMMARY OF CELL INPUT AND OUTPUT
CAPACITIES FOR 100AH NICKEL-ZINC CELLS

PERFORMANCE CHARACTERIZATION
TEST CYCLE NO. 1

Charge: 5.0A to 1.92 Volts or for 24 Hours whichever occurs first
Discharge: 110.0A to 1.40 Volts
Drain: 13.5A to 1.40 Volts

CELL		CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE	OUTPUT TO 1.50V (AH)	OUTPUT TO 1.40 VOLTS		
GROUP	NO.				DISCHARGE (AH)	DRAIN (AH)	TOTAL (AH)
1	1	120	1.884	2.20	39.2	78.8	118.0
	2	120	1.883	2.38	35.9	79.9	115.8
	3	120	1.884	2.51	38.8	76.1	114.9
2	1	120	1.884	2.87	33.6	74.3	107.9
	2	120	1.884	4.64	43.6	72.0	115.6
	3	120	1.886	3.06	36.0	79.7	115.7
3	1	120	1.883	2.51	19.0	92.5	111.5
	2	120	1.882	3.51	21.3	90.7	112.0
	3	120	1.881	2.69	22.9	87.8	110.7
4	1	120	1.876	9.01	50.1	67.5	117.6
	2	120	1.877	4.28	43.9	72.0	115.9
	3	120	1.874	5.78	43.1	72.0	115.1

TABLE VII

SUMMARY OF CELL INPUT AND OUTPUT
CAPACITIES FOR 100AH NICKEL-ZINC CELLS

PERFORMANCE CHARACTERIZATION
TEST CYCLE NO. 2

Charge: 5.0A to 1.92 Volts or for 24 Hours whichever occurs first
Discharge: 55.0A to 1.40 Volts
Drain: 13.5A to 1.40 Volts

CELL		CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE	OUTPUT TO 1.50V (AH)	OUTPUT TO 1.40 VOLTS		
GROUP	NO.				DISCHARGE (AH)	DRAIN (AH)	TOTAL (AH)
1	1	120	1.894	57.8	77.9	37.1	115.0
	2	120	1.890	56.8	69.7	44.8	114.5
	3	120	1.891	57.8	74.3	41.4	115.7
2	1	120	1.891	60.5	74.3	40.7	115.0
	2	120	1.894	60.5	74.3	40.7	115.0
	3	120	1.896	57.8	74.3	40.9	115.2
3	1	120	1.893	34.8	42.2	68.6	110.8
	2	120	1.890	37.6	44.0	65.2	109.2
	3	120	1.891	44.9	51.3	59.2	110.5
4	1	120	1.884	71.5	84.3	31.1	115.4
	2	120	1.884	66.9	78.8	37.1	115.9
	3	120	1.887	49.5	72.4	36.9	109.3

TABLE VIII

SUMMARY OF CELL INPUT AND OUTPUT
CAPACITIES FOR 100AH NICKEL-ZINC CELLS

PERFORMANCE CHARACTERIZATION
TEST CYCLE NO. 3

Charge: 5.0A to 1.92 Volts or for 24 Hours whichever occurs first
Discharge: 27.5A to 1.40 Volts
Drain: 13.5A to 1.40 Volts

CELL		CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE	OUTPUT TO 1.50V (AH)	OUTPUT TO 1.40 VOLTS		
GROUP	NO.				DISCHARGE (AH)	DRAIN (AH)	TOTAL (AH)
1	1	120	1.880	100.4	105.0	7.5	112.5
	2	120	1.876	102.2	108.2	4.5	112.7
	3	120	1.877	102.2	108.6	3.6	112.2
2	1	120	1.880	102.2	108.6	3.8	112.4
	2	120	1.882	100.8	105.9	6.8	112.7
	3	120	1.881	101.3	105.9	5.8	111.7
3	1	120	1.882	72.4	74.7	30.2	104.9
	2	120	1.880	73.8	77.0	26.3	103.3
	3	120	1.879	81.6	83.9	25.0	108.9
4	1	120	1.873	106.8	109.5	3.4	112.9
	2	120	1.871	107.3	110.0	3.4	113.4
	3	120	1.874	107.7	111.8	3.4	115.2

TABLE IX

COMPARISON OF TYPICAL CELL VOLTAGES DURING DISCHARGE OF 100AH EXPERIMENTAL NiZn CELL GROUPS AT VARIOUS CURRENT RATES

AMP HRS OUTPUT	TEST NUMBER 1 DISCHARGE - 110A TO 1.40V				TEST NUMBER 2 DISCHARGE - 55A TO 1.40V				TEST NUMBER 3 DISCHARGE - 27.5A TO 1.40V			
	GR #1 (V)	GR #2 (V)	GR #3 (V)	GR #4 (V)	GR #1 (V)	GR #2 (V)	GR #3 (V)	GR #4 (V)	GR #1 (V)	GR #2 (V)	GR #3 (V)	GR #4 (V)
10	1.46	1.47	1.45	1.49	1.57	1.57	1.58	1.59	1.64	1.63	1.64	1.65
20	1.44	1.45	1.40	1.47	1.55	1.56	1.56	1.57	1.62	1.62	1.62	1.63
30	1.42	1.43	—	1.45	1.54	1.55	1.53	1.56	1.62	1.62	1.61	1.63
40	—	—	—	1.42	1.53	1.54	1.48	1.55	1.61	1.61	1.60	1.62
50	—	—	—	—	1.51	1.52	—	1.53	1.60	1.60	1.59	1.61
60	—	—	—	—	1.45	1.49	—	1.50	1.60	1.60	1.58	1.61
70	—	—	—	—	1.43	1.44	—	1.47	1.59	1.59	1.55	1.60
80	—	—	—	—	—	—	—	—	1.59	1.58	—	1.60
90	—	—	—	—	—	—	—	—	1.55	1.55	—	1.57
100	—	—	—	—	—	—	—	—	1.48	1.47	—	1.53
AHo To 1.40V	37.95	37.75	21.08	45.66	73.96	74.30	45.83	78.50	107.00	106.78	78.53	110.45

4. Cycle Life Testing

4.1 Test Equipment

An automatic cell and battery cycler was designed and fabricated for testing the 100AH cells in Task II and the 300AH cells in Task IV.

This equipment is capable of charging 18 cells connected in series at rates as high as 50 amperes. It will charge a series connected group of cells in either a constant current mode, constant potential mode or a modified constant potential mode using the voltage across the number of cells being charged as the cross-over potential and a preselected upper limit on charging current. The charge duration can be limited manually or automatically based on individual cell or cell group voltage, or on an elapsed time basis.

The equipment is capable of discharging cells or groups of cells in series through fixed resistors. The equipment is capable of automatically discharging cells or groups of series connected cells in a pre-programmed series of pulses of one (1) second minimum duration and maximum pulse current rates of 300 amperes. The duration of discharge can be limited manually or automatically based on individual cell or cell group voltage or on an elapsed time basis.

The equipment contains voltage monitoring capability for six (6) individual cells or six (6) groups of cells. The monitoring of charge current is done using a 50A/50MV shunt built into the equipment. Discharge current is monitored using a 300A/50MV shunt also built into the equipment. The voltage across the entire number of series connected cells can be monitored at a separate set of output jacks.

Data acquisition is accomplished using a Digitec Model 1267 Data Logger which provides excellent resolution and accuracy, rapid and controllable data acquisition rates, selective scanning capability and hard-copy printout of required data. With an input capacity of twenty (20) channels, the data logger can print cell or cell group voltage and charge or discharge current noting the time of reading and the number of the channel being read and recorded. The interval between readings can be selected at 1, 2, 10, 20 minutes and 1 hour. In addition, the data logger will act on command from the test equipment to print voltage and current data at the end of charge or discharge prior to automatically changing from one mode to the other.

4.2 Cell Testing

Following the completion of Performance-Characterization testing, each cell was charged at a 5 ampere rate for 24 hours (120AH). The four (4) groups of three (3) cells each were then connected to the Automatic Cycler and Data Logger and discharged until the last three (3) cell group reached 4.50 volts under load using repeated consecutive applications of the following six (6) step pulse profile:

	Pulse Profile Step	Current Rate (A)	Pulse Duration (SEC)
1.	Discharge	30	30
2.	Discharge	60	15
3.	Discharge	90	5
4.	Stand	0	65
5.	Discharge	30	60
6.	Stand	0	65

The results of the first cycle life test are summarized in Table X. Subsequent-cycle life test cycles were performed using a modified constant potential charge method. The charge current was limited to 15 amperes maximum and the voltage crossover potential was varied between 5.70 and 5.76 volts per 3-cell group. The discharge for each subsequent cycle was accomplished using the 6-step pulse profile described above. The charge method and discharge regime variations for each test cycle and the results of these tests are summarized in Table X.

The cells of Group 3 were removed from the test program after Cycle Life Test cycle number 6. Group 3 performance was below that of Groups 1, 2, and 4 and was adversely affecting the testing of the other groups. The relative performance of the four (4) groups of cells during the charge and discharge for test cycle number 5 is depicted in Figure 1. The performance of Groups 1, 2, and 4 during test cycle number 30 is depicted in Figure 2.

5. Failure Analysis

One (1) cell from each of the four (4) groups of 100AH experimental nickel-zinc cells was dissected to investigate potential failure modes and determine the general condition of the cell stack components. The conditions observed in the cell from Groups 1, 2, and 4 were generally similar. The Group 3 cell had been given only six (6) Cycle Life Test cycles and the electrode and separator degredation normally attributed to prolonged life cycle

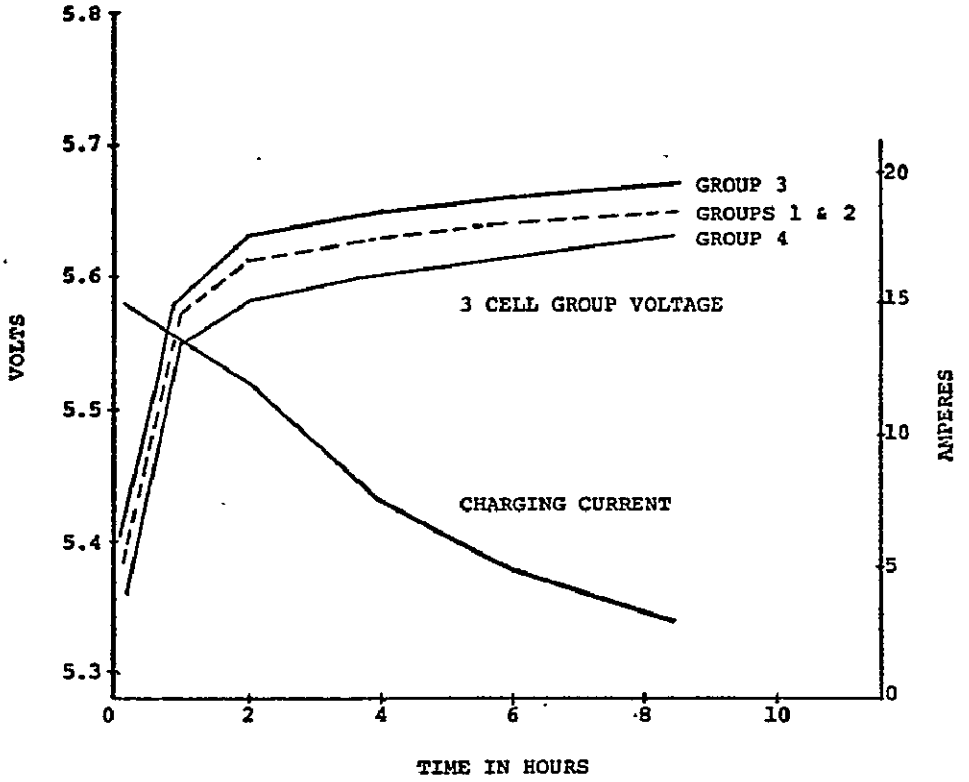
TABLE X

SUMMARY OF CYCLE LIFE TESTING 100AH NICKEL-ZINC CELL GROUPS

CYCLE NO.	CHARGE		DISCHARGE					OUTPUT TO ONE GROUP REACHING 4.20 VOLTS		REMARKS
	METHODS	AMP HRS. IN	PULSE PROFILE UNTIL	OUTPUT TO 4.50 VOLTS						
				GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP #	OUTPUT	
		(AH)		(AH)	(AH)	(AH)	(AH)		(AH)	
1	5A for 24 hours	120	Last cell group reached 4.50 volts	53	56	23	61			
2	Modified constant potential - 15A Max. 5.70 volts/group to approx. 110% of previous cycle output.	72	First cell group reached 4.20 volts	39	34	37	54	3	76	
3		82		47	40	40	64	3	67	
4		70		45	37	40	59	3	61	
5		67	Second cell group reached 4.20 volts.	47	32	27	61	2	76	
6		79		47	32	29	60	2	76	Note 1
7		101	First cell group reached 4.20 volts	N/A	N/A	-	N/A	2	75	Note 2
8		93		33	23	-	60	2	82	
9		79		35	16	-	52	2	71	
10		76		21	9	-	46	2	64	Note 3
11		71		18	7	-	42	2	62	Note 3
12		70		32	14	-	47	2	64	
13		67		29	14	-	45	2	62	
14		64		13	7	-	31	2	55	Note 4
15	Modified constant potential - 15A Max. 5.76 volts/group to approx. 110% of previous cycle output.	72	First cell group reached 4.20 volts	12	7	-	33	2	57	Note 3
16		71		11	7	-	34	2	58	Note 3
17		68		21	11	-	41	2	58	
18		70		19	10	-	41	2	60	
19		72		19	10	-	41	2	59	Note 5
20		63		10	7	-	32	2	58	Note 3
21	Modified constant potential - 15A Max. 5.73 volts/group to approx. 110% of previous cycle output	68	First cell group reached 4.20 volts	18	10	-	38	2	59	
22		67		19	10	-	38	2	60	
23		69		16	10	-	38	2	60	
24		72		7	7	-	22	2	58	Note 3
25		68		14	12	-	36	2	60	
26	Modified constant potential - 15A Max. 5.76 volts/group to approx. 110% of previous cycle output.	62	First cell group reached 4.20 volts	17	11	-	36	2	58	
30		57		7	6	-	17	2	51	
34		55	Each cell group reached 4.20 volts	9	7	-	13	1	49	
								2	46	Note 6
								4	51	

NOTES:

1. Group 3 removed from testing after this cycle.
2. Charged stand for 6 days prior to discharge.
3. Charged stand for 16 hours prior to discharge.
4. Charged stand for 38 hours prior to discharge.
5. Sponge zinc deposits on cell stack edges.
6. Testing terminated.



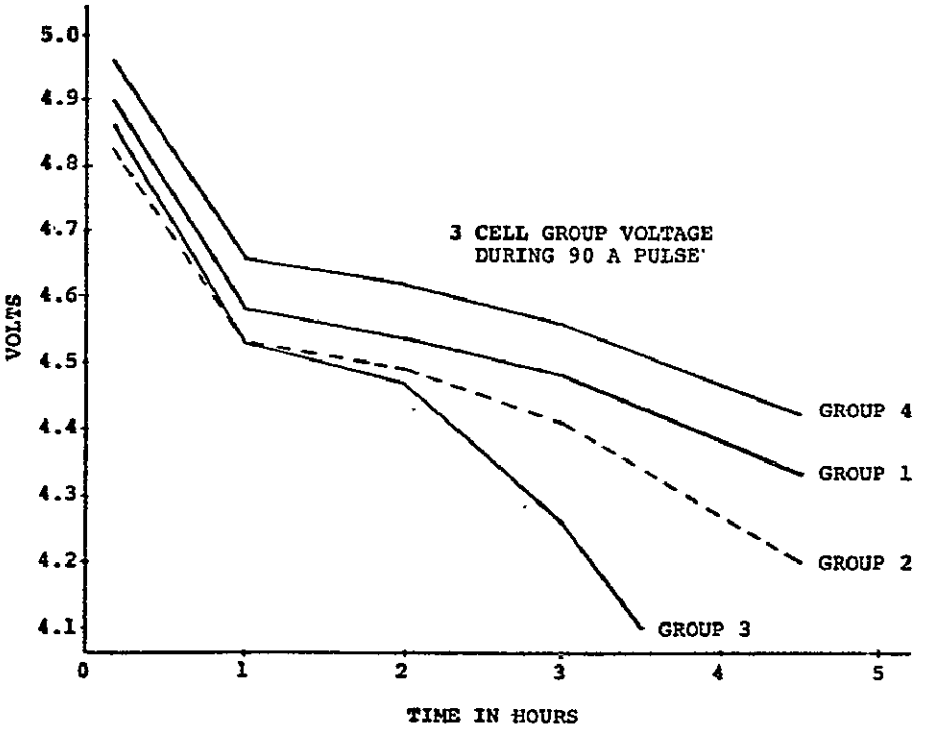
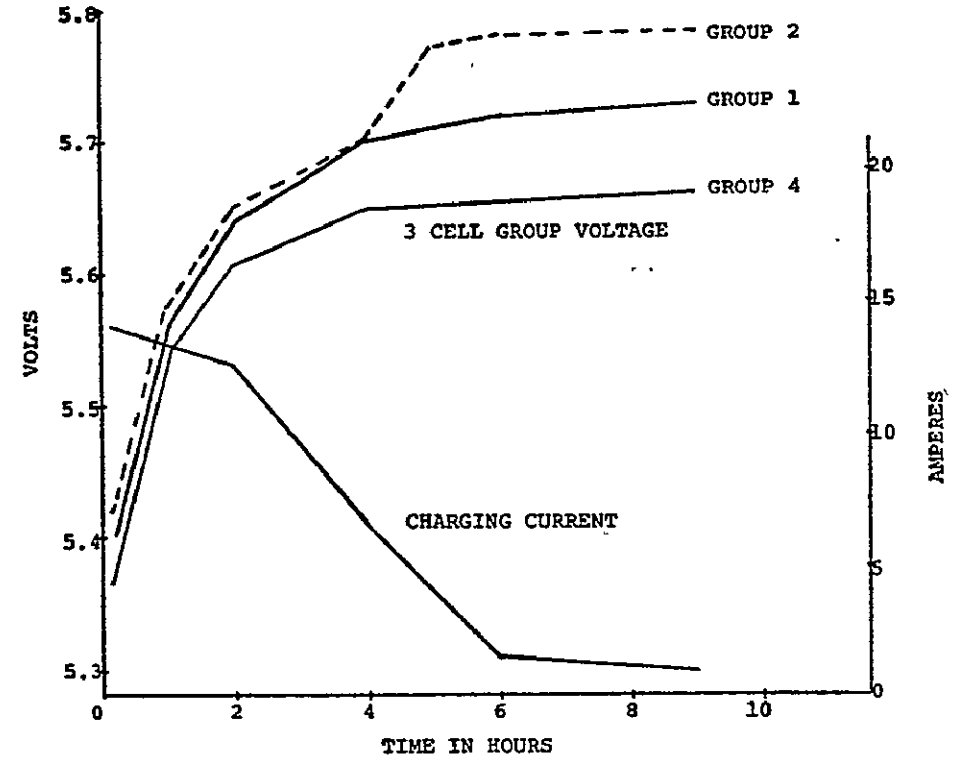


FIGURE 1 VOLTAGE CURVES OF 100AH NiZn CELL GROUPS DURING CYCLE LIFE TEST CYCLE 5.



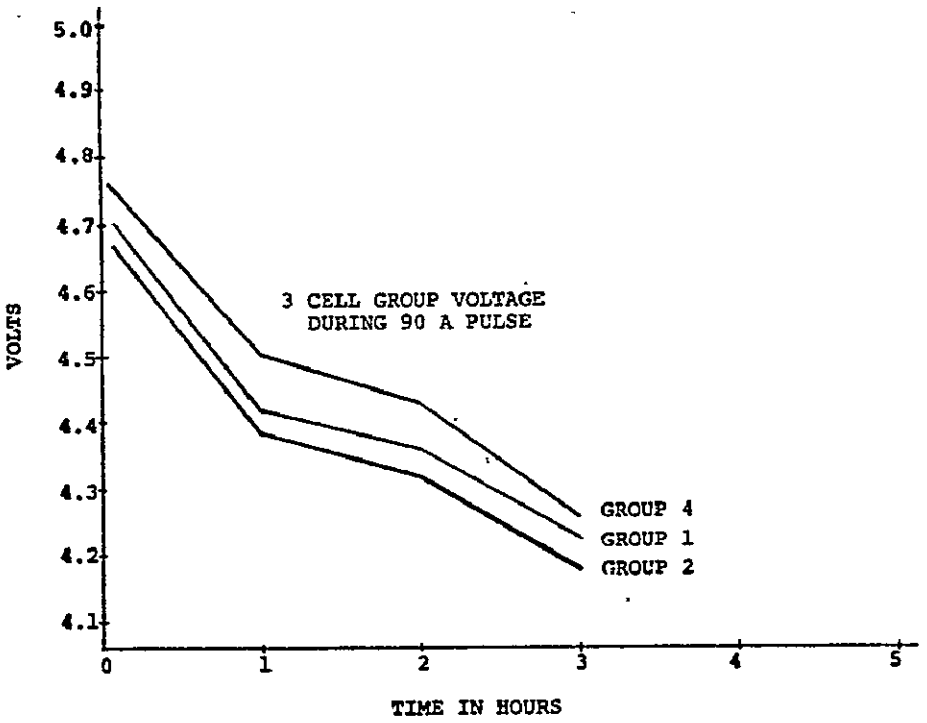


FIGURE 2 VOLTAGE CURVES OF 100AH NiZn CELL GROUPS DURING CYCLE LIFE TEST CYCLE 30.

testing was not as pronounced as in the other groups which had seen thirty-four (34) cycles. All of the cells had a 150 - 160 day wet life at the time of dissection.

5.1 External Inspection

The open circuit voltage of the cells was 1.70 to 1.75 volts prior to dissection. The Groups 1, 2, and 4 cells exhibited sponge zinc deposits on the cell stack edges particularly on the positive cell terminal side. Sponge zinc sludge was present at the bottom of the cell stack. The separator bags on the negative electrodes were slightly distorted at the bottom 2 - 4cm of the edge seal area. The Group 3 cell had small amounts of zinc oxide sludge present at the bottom of the cell stack and no distortion of the negative electrode separator bag visible from the outside.

5.2 Internal Inspection

The four (4) cells were opened and inverted for three hours to drain off and collect free electrolyte. The amount of free electrolyte taken from each cell was as follows:

Cell From	Free Electrolyte
Group 1	59ml
Group 2	18ml
Group 3	16ml
Group 4	12ml

With the exception of the Group 3 cell, the cell stacks were separated by sliding them out of the case cavity. To separate the cell stack for the Group 3 cell, it was necessary to cut through the narrow sides and the bottom of the case and remove the case, in two (2) sections, from the cell stack. The tab to terminal attachment on all cells was secure and in good condition. Each cell was disassembled and observations made on the condition of the interseparator, nickel positive electrodes, inorganic separator bags, and negative electrodes. Except where noted, the following general conditions existed in the four (4) cells dissected.

5.2.1 Interseparator - The heat seals on all non-woven materials and the treated asbestos material were intact. Fibrous tubing material was not damaged.

5.2.2 Nickel Positive Electrodes - The edges of the positive electrodes were curled toward the side of the electrode in which the grid was more prominent. The concavity in the electrode caused by the edge curling varied in depth from cell to cell

but was generally between 0.3 and 0.5 centimeters. In the half end electrodes and the electrodes in the cell from Group 3, this distortion was slightly less pronounced. The nickel positive electrodes had grown in length approximately 0.4 to 0.6cm and in width between 0.3 and 0.4cm.

5.2.3 Inorganic Separator Bags - These separator bags bore the impressions of the distortion in the adjacent positive electrodes. Where the separator bags were positioned between two (2) full positive electrodes, they were molded to the point that they had a concave and convex side. This created cracks in the ceramic coating of the separator material predominantly in the area of the bag epoxy seal. On the inside surface of the bags there was some evidence of shallow zinc penetration into the asbestos matrix material.

5.2.4 Negative Electrodes - The loss in effective electrode surface area due to shape change was estimated at between 9 percent (%) and 11 percent (%) for the Groups 1, 2, and 4 cells and 4 percent (%) to 6 percent (%) for the electrodes in the Group 3 cell. The errosion of negative active material was primarily across the top and along the side edges of the electrodes. The potassium titanate mat was present in place on both sides of the electrodes.

The eight (8) cells which were not subjected to Failure Analysis were shipped to NASA Lewis Research Center.

TASK III - CONSTRUCT SIX (6) EXPERIMENTAL 300AH VENTED NICKEL-ZINC CELLS

1. Objective of Task

The objective of this task was to further evaluate two (2) selected interseparator materials in nickel-zinc cells of 300 ampere-hour nominal capacity. Each interseparator material was to be used in the fabrication of one (1) group of three (3) cells.

2. Cell Materials

2.1 With the exception of the interseparator materials and the larger cell cases and covers, the cell materials used in the 300AH cells were the same as those used in the 100AH cells fabricated in Task I.

2.2 The cell case was fabricated from 0.63cm thick high temperature acrylic. The cell cavity measured 17.14cm wide, 6.51cm thick and 31.1cm deep. The cell cover was machined from 0.63cm thick high temperature acrylic.

2.3 The interseparator material selected for Group 1 cells was the .30mm thick non-woven nylon, Pellon #2506. The material selected for Group 2 cells was the .33mm thick non-woven polypropylene, Pellon #2530. It was found the latter material was no longer being manufactured and a .17mm thick non-woven polypropylene, Pellon #2533 was selected as the replacement. Since the Pellon #2533 is approximately half the thickness of the originally selected Pellon #2530, double layers of the replacement material were used to fabricate interseparator bags for Group 2 cells.

3. Cell Fabrication

3.1 The negative electrodes, separator bags, positive electrodes and interseparator bags were prepared using the same methods and procedures employed in Task I.

3.2 The cell stack for the 300AH cells consisted of eleven (11) full positive electrodes, two (2) half positive electrodes and twelve (12) negative electrodes. Each full and half positive electrode for Group 1 cells was inserted into a heat sealed bag of Pellon #2506 non-woven nylon. Each full and half positive electrode for Group 2 cells was inserted into a heat sealed bag of double layers of Pellon #2533 non-woven polypropylene.

3.3 Each negative electrode was inserted into an epoxy sealed bag of machine coated flexible inorganic separator.

3.4 Each cell stack was assembled, connected to a cell cover assembly and inserted into a cell case. The cell case to cover seal was made with an acrylic cement. Each cell was weighed, inspected, restrained and pressure tested. The average weight of the dry 300AH nickel-zinc cell was 7.6 Kg.

4. Cell Filling and Conditioning

Each 300AH nickel-zinc cell was vacuum filled with 1300 ml of a 34% solution of potassium hydroxide. After soaking at room temperature for 24 hours, each cell was given an elevated temperature separator conditioning soak at 77 - 79°C for 64 - 66 hours. Following this conditioning period, the cells were given cell testing in accordance with Task IV requirements.

A summary of the design of the experimental 300AH nickel-zinc cell is given in Appendix I.

TASK IV - TEST AND EVALUATE SIX (6) EXPERIMENTAL 300AH VENTED NICKEL-ZINC CELLS

1. Objective of Task

The objective of this task was to evaluate, through testing, the performance of two (2) groups of 300AH nickel-zinc cells and to determine the better interseparator material for use in the final cell configuration.

2. Cell Formation

The three (3) cells of each group were given two (2) formation cycles. Each formation cycle consisted of:

Charging each cell at 16 amperes to 1.91 - 1.92 volts or for 24 hours, whichever occurred first.

Discharging each cell at 135 amperes (15ma/cm^2) to 1.50 volts.

Draining each cell at 30 amperes to 1.50 volts.

Individual cell voltage was recorded as a function of time during the performance of the two (2) formation cycles. A summary of cell voltages taken during formation cycles discharge is given in Tables XI and XII. A summary of the charge input and the discharge and drain output capacities for each cell of both groups is given in Table XIII.

3. Performance Characterization Test

Following the completion of the second formation cycle, each cell was given a series of three (3) test cycles to characterize the performance of the cell during test discharges at various rates. Before each test discharge each cell was charged at 16 amperes to 1.91 - 1.92 volts or for 24 hours, whichever occurred first. After each test discharge each cell was drained at 30 amperes to 1.40 volts. The test discharge rates were as follows:

Test No. 1	360 amperes	(40ma/sq. cm) to 1.40 volts
Test No. 2	180 amperes	(20ma/sq. cm) to 1.40 volts
Test No. 3	90 amperes	(10ma/sq. cm) to 1.40 volts

Cell voltage was recorded during the charge,discharge, and drain of each test cycle. Figure 3 depicts the typical cell voltage curves generated during the test discharges for the cells of both groups. A summary of the charge input and the discharge and drain output capacities for each test in the series is given in Table XIV.

TABLE XI

TEST CELL VOLTAGE
300AH NiZn CELLS TASK III GROUP 1

FORMATION CYCLES DISCHARGE

DISCHG. OUTPUT (AH)	FORMATION NO. 1				FORMATION NO. 2		
	CELL 1 (V)	CELL 2 (V)	CELL 3 (V)		CELL 1 (V)	CELL 2 (V)	CELL 3 (V)
2	1.68	1.67	1.66		1.73	1.73	1.73
11	1.62	1.62	1.61		1.68	1.67	1.67
18	-	-	-		-	-	-
22	-	-	-		-	-	-
34	1.58	1.58	1.57		1.61	1.61	1.61
45	-	-	-		-	-	-
68	1.57	1.57	1.56		1.59	1.59	1.59
90	-	-	-		-	-	-
102	1.55	1.55	1.55		1.58	1.58	1.58
112	-	-	-		-	-	-
135	1.54	1.54	1.54		1.57	1.57	1.57
157	-	-	-		-	-	-
170	1.53	1.52	1.52		1.56	1.56	1.56
180	-	-	-		-	-	-
204	1.51	1.50	1.50		1.55	1.55	1.55
225	-	-	-		-	-	-
238	-	-	-		1.53	1.53	1.53
247	-	-	-		-	-	-
272	-	-	-		1.51	1.51	1.51
300	-	-	-		-	-	-
OUTPUT TO 1.50 V	209	204	202		290	287	286

TABLE XII

TEST CELL VOLTAGE
300AH NiZn CELLS TASK III GROUP 2

FORMATION CYCLES DISCHARGE

DISCHARG. OUTPUT (AH)	FORMATION NO. 1				FORMATION NO. 2		
	CELL 1 (V)	CELL 2 (V)	CELL 3 (V)		CELL 1 (V)	CELL 2 (V)	CELL 3 (V)
2	1.65	1.65	1.66		1.71	1.70	1.71
11	-	-	-		1.65	1.65	1.65
18	1.57	1.57	1.58		-	-	-
22	-	-	-		1.61	1.60	1.61
34	1.55	1.55	1.56		-	-	-
45	-	-	-		1.57	1.56	1.57
68	1.54	1.53	1.54		1.55	1.55	1.56
90	-	-	-		1.55	1.54	1.55
102	1.53	1.52	1.53		-	-	-
112	-	-	-		1.54	1.54	1.55
135	1.51	1.51	1.52		1.54	1.54	1.54
157	-	-	-		1.53	1.53	1.54
170	1.50	1.50	1.51		-	-	-
180	-	-	-		1.53	1.53	1.53
204	-	-	-		1.52	1.52	1.53
225	-	-	-		1.51	1.51	1.52
238	-	-	-		-	-	-
247	-	-	-		1.50	1.50	1.51
272	-	-	-		-	-	-
300	-	-	-		-	-	-
OUTPUT TO 1.50 V	173	168	182		262	261	264

TABLE XIII

SUMMARY OF CELL INPUT AND OUTPUT CAPACITIES
300AH NICKEL-ZINC CELLS GROUPS 1 AND 2

FORMATION CYCLES 1 AND 2

FORMATION CYCLE NO. 1		GROUP 1 CELLS				GROUP 2 CELLS		
		1	2	3		1	2	3
Charge Input at 16A	AH	384	384	384		384	384	384
Voltage at End of Charge	V	1.87	1.87	1.87		1.89	1.89	1.88
Discharge Output at 135A to 1.50 Volts	AH	209	204	202		173	168	182
Drain Output at 30A to 1.50 Volts	AH	61	56	53		82	80	75
Total Output to 1.50 Volts	AH	270	260	255		255	248	257

FORMATION CYCLE NO. 2		GROUP 1 CELLS				GROUP 2 CELLS		
		1	2	3		1	2	3
Charge Input at 16A	AH	384	384	384		384	384	384
Voltage at End of Charge	V	1.88	1.88	1.87		1.89	1.89	1.89
Discharge Output at 135A to 1.50 Volts	AH	290	287	286		262	261	264
Drain Output at 30A to 1.50 Volts	AH	51	48	44		80	81	76
Total Output to 1.50 Volts	AH	341	335	330		342	342	340

FIGURE 3

TYPICAL CELL VOLTAGE CURVES FOR
300AH NICKEL-ZINC CELLS DURING
DISCHARGES AT VARIOUS RATES

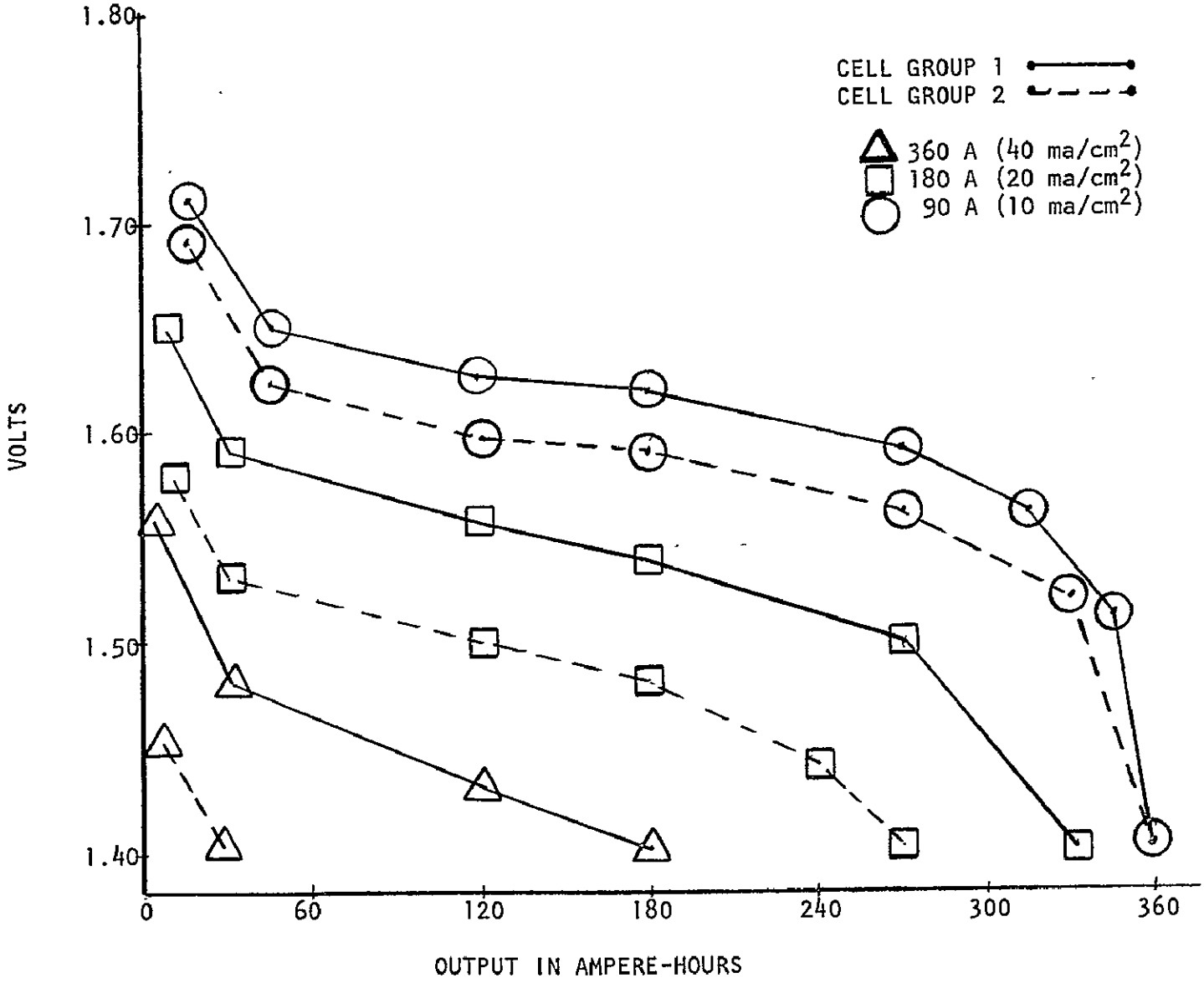


TABLE XIV

SUMMARY OF CELL INPUT
AND OUTPUT CAPACITIES
300AH NICKEL-ZINC CELLS
GROUPS 1 AND 2

PERFORMANCE CHARACTERIZATION TEST

TEST CYCLE NO. 1			GROUP 1 CELLS			GROUP 2 CELLS		
			1	2	3	1	2	3
Charge input at 16A		AH	384	384	384	384	384	384
Voltage at end of charge		V	1.88	1.88	1.88	1.89	1.89	1.89
Discharge output at 360A to:	1.50V	AH	23	20	21	1	-	2
	1.40V	AH	182	176	180	23	18	40
Drain output at 30A to:	1.50V	AH	165	168	159	313	318	297
	1.40V	AH	166	170	160	315	320	299
Total output to 1.40 Volts		AH	348	346	340	338	338	339

TEST CYCLE NO. 2			GROUP 1 CELLS			GROUP 2 CELLS		
			1	2	3	1	2	3
Charge input at 16A		AH	384	384	384	384	384	384
Voltage at end of charge		V	1.88	1.88	1.88	1.91	1.90	1.90
Discharge output at 180A to:	1.50V	AH	256	247	258	120	90	159
	1.40V	AH	331	328	336	272	264	291
Drain output at 30A to:	1.50V	AH	24	24	18	84	92	64
	1.40V	AH	26	26	20	87	94	67
Total output to 1.40 Volts		AH	357	354	356	359	358	358

TEST CYCLE NO. 3			GROUP 1 CELLS			GROUP 2 CELLS		
			1	2	3	1	2	3
Charge input at 16A		AH	384	384	384	384	384	384
Voltage at end of charge		V	1.88	1.88	1.89	1.91	1.91	1.90
Discharge output at 90A to:	1.50V	AH	350	349	346	343	343	348
	1.40V	AH	358	357	354	358	358	359
Drain output at 30A to:	1.50V	AH	5	6	6	9	8	8
	1.40V	AH	7	8	8	11	11	10
Total output to 1.40 Volts		AH	365	365	362	369	369	369

4. Cycle Life Test

4.1 Test Equipment

The automatic cycler which was designed, fabricated and used in testing the 100AH nickel-zinc cells in Task II was adjusted and programmed for use in testing the 300AH nickel-zinc cells in this task.

4.2 Cell Testing

The three (3) cells of Group 1 were charged at 20 amperes to an end voltage, per cell, of 1.91 - 1.92 volts. The Group 1 cells were then connected in series to the test equipment and discharged through the fixed resistance load combination which was programmed for the following pulse profile steps:

Pulse Profile Step No.	Description	Pulse Duration	Pulse Current
1	Discharge	1 Sec.	30 amperes
2	Discharge	4 Sec.	200 amperes
3	Stand	7 Sec.	0 amperes

This pulse profile was repeated continuously until the first cell reached 1.40 volts. This completed Cycle Life Test Cycle #1.

Test Cycles #2 through #8 were accomplished by charging the cells at 20 amperes to an input capacity of approximately 105 percent (105%) of the output capacity of the previous cycle discharge. The test discharge was the same as used in Cycle #1. After Cycle #8 the cells were removed from the test equipment. The three (3) cells of Group 2 were given the first Cycle Life Test cycle and test Cycles #2 through #5 in the manner described for Group 1 cells.

The test equipment was then adjusted to accommodate six (6) cells series connected. The pulse profile test discharge currents remained the same. The cell charging parameters were revised, by direction, to a fixed input of 300 ampere-hours at a 20 ampere rate. No limit was placed on the cell end of charge voltage. Group 1 and Group 2 cells were connected in series and connected to the test equipment. The cells were given 52 additional Cycle Life Test cycles using, except where noted, a fixed input of 300 ampere-hours and the pulse profile test discharge method. A tabulation of the Cycle Life Test results is given in Tables XV and XVI. Typical charge and discharge cell voltage curves for two (2) of the test cycles are given in Figures 4 and 5.

FIGURE 4

TYPICAL CELL VOLTAGE CURVES

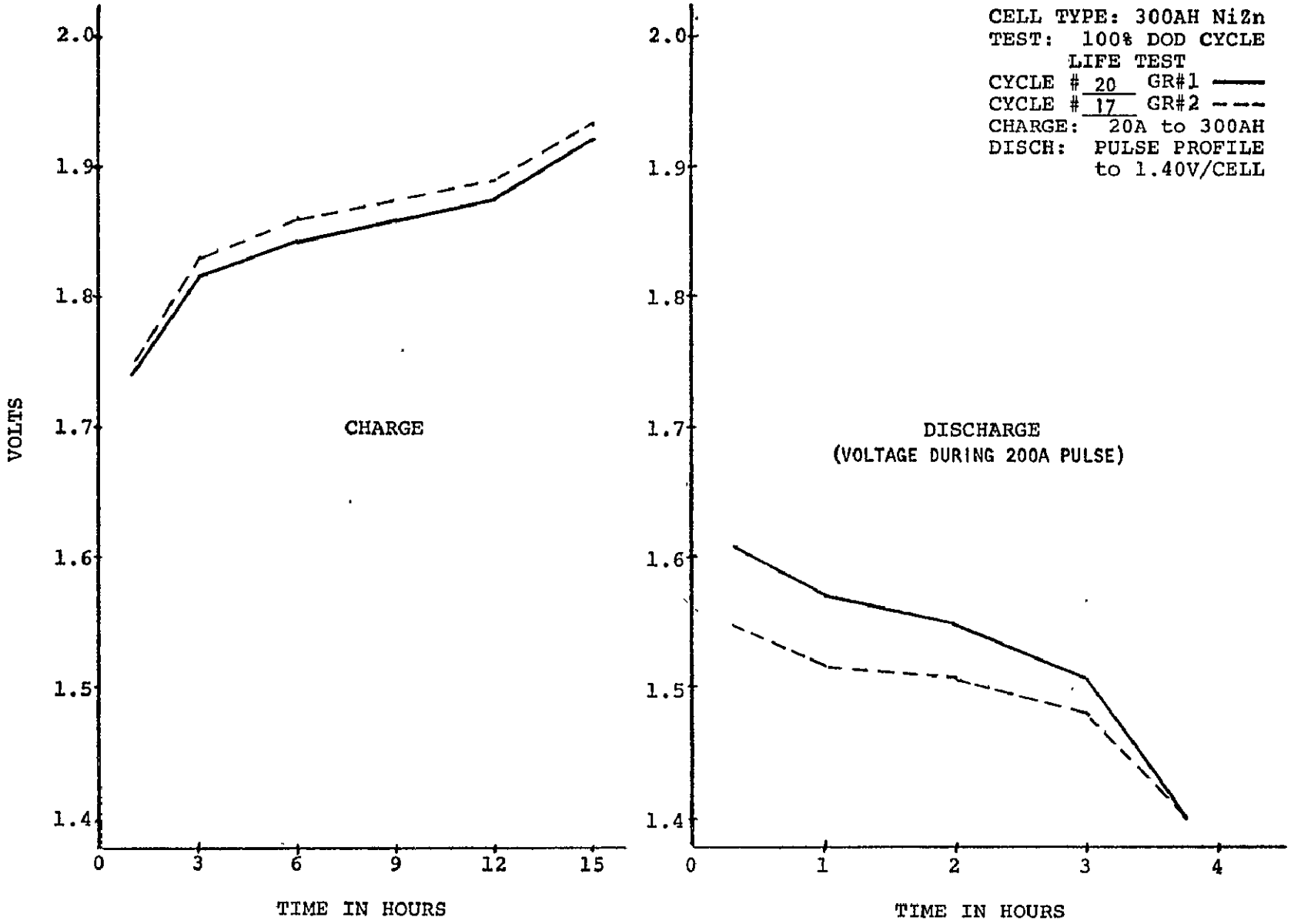


FIGURE 5

TYPICAL CELL VOLTAGE CURVES

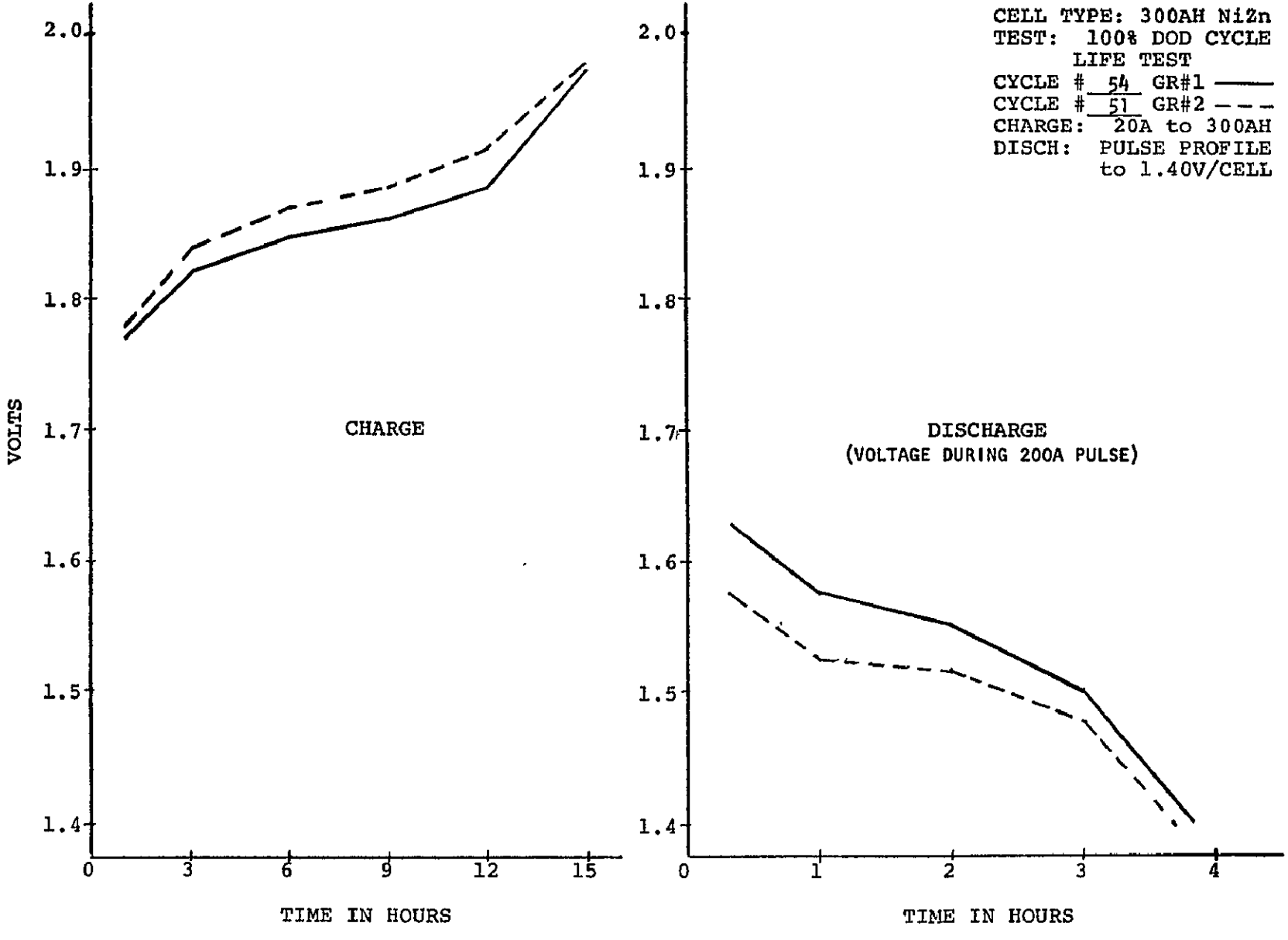


TABLE XV

SUMMARY OF CYCLE LIFE TESTING
300AH NiZn CELLS, TASK III GROUP 1

CYCLE NO.	CHARGE					DISCHARGE				DRAIN			TOTAL OUTPUT			NOTES
	METHOD	AMP HRS. IN (AH)	VOLTAGE AT END OF CHARGE			AMP HRS. OUT (AH)	VOLTAGE AT END OF DISCHARGE			AMP HRS. OUT						
			CELL 1 (V)	CELL 2 (V)	CELL 3 (V)		CELL 1 (V)	CELL 2 (V)	CELL 3 (V)	CELL 1 (AH)	CELL 2. (AH)	CELL 3 (AH)	CELL 1 (AH)	CELL 2 (AH)	CELL 3 (AH)	
1	20A to 1.91-1.92V	433	1.91	1.91	1.92	320	1.40	1.40	1.40	0	0	0	320	320	320	
2	20A to 105% of	360	1.90	1.90	1.90	323	1.40	1.40	1.40	0	0	0	323	323	323	
3	previous cycle	340	1.89	1.89	1.89	315	1.43	1.42	1.39	0	0	0	315	315	135	
4	output.	330	1.89	1.90	1.89	310	1.45	1.43	1.39	0	0	0	310	310	310	
5		325	1.89	1.89	1.89	301	1.44	1.43	1.39	0	0	0	301	301	301	
6		315	1.89	1.89	1.88	291	1.43	1.42	1.39	0	0	0	291	291	291	
7		305	1.89	1.89	1.89	284	1.45	1.43	1.39	0	0	0	284	284	284	
8		300	1.88	1.89	1.89	275	1.45	1.44	1.40	0	0	0	275	275	275	
9	20A to a 300 AH	300	1.89	1.89	1.88	271	1.45	1.44	1.40	0	0	0	271	271	271	
10	fixed input	300	1.89	1.89	1.88	273	1.45	1.44	1.40	0	0	0	273	273	273	
11		300	1.90	1.89	1.89	278	1.43	1.42	1.39	0	0	0	278	278	278	
12		300	1.90	1.90	1.89	276	1.47	1.44	1.39	0	0	0	276	276	276	
13		300	1.91	1.91	1.89	268	1.39	1.45	1.46	0	0	0	268	268	268	
14		300	1.91	1.91	1.89	275	1.45	1.43	1.39	0	0	0	275	275	275	
15		300	1.90	1.87	1.85	229	1.49	1.50	1.39	0	0	0	229	229	229	
16	20A to 1.91-1.92V	273	1.92	1.92	-	253	1.44	1.40	-	0	0	0	253	253	-	Note 1
17	20A to a 300 AH	300	1.93	1.92	-	261	1.45	1.40	-	0	0	0	261	261	-	
18	fixed input	300	1.93	1.93	-	273	1.44	1.40	-	0	0	0	273	273	-	
19		300	1.93	1.93	-	287	1.43	1.40	-	0	0	0	287	287	-	
20		300	1.92	1.91	-	280	1.44	1.41	-	0	0	0	280	280	-	
21		300	1.92	1.93	-	283	1.44	1.41	-	0	0	0	283	283	-	
22		300	1.92	1.91	-	285	1.43	1.38	-	0	0	0	285	285	-	
23		300	1.92	1.91	-	273	1.44	1.40	-	0	0	0	273	273	-	
24		300	1.93	1.92	-	275	1.44	1.40	-	0	0	0	275	275	-	
25		300	1.94	1.93	-	274	1.44	1.40	-	0	0	0	274	274	-	
26		300	1.94	1.94	-	279	1.44	1.42	-	0	0	0	279	279	-	
27		300	1.94	1.93	-	277	1.45	1.41	-	0	0	0	277	277	-	
28		300	1.94	1.94	-	274	1.45	1.42	-	0	0	0	274	274	-	
29		300	1.95	1.94	-	273	1.45	1.43	-	0	0	0	273	273	-	
30		300	1.96	1.94	-	273	1.46	1.44	-	0	0	0	273	273	-	
31		300	1.96	1.92	-	273	1.46	1.43	-	0	0	0	273	273	-	
32		300	1.96	1.93	-	279	1.44	1.42	-	0	0	0	279	279	-	
33		300	1.97	1.94	-	272	1.46	1.44	-	0	0	0	272	272	-	
34		300	1.97	1.94	-	275	1.46	1.44	-	0	0	0	275	275	-	
35		300	1.98	1.95	-	273	1.45	1.42	-	94	76	0	367	349	-	Note 2
36		300	1.88	1.88	-	248	1.43	1.41	-	0	0	0	248	248	-	
37		300	1.90	1.90	-	273	1.41	1.44	-	0	0	0	273	273	-	
38		300	1.92	1.92	-	276	1.44	1.40	-	0	0	0	276	276	-	
39		300	1.93	1.93	-	273	1.45	1.42	-	0	0	0	273	273	-	
40		300	1.95	1.89	-	262	1.48	1.39	-	29	0	0	281	262	-	
41		300	1.92	1.90	-	266	1.46	1.40	-	0	0	0	266	266	-	
42		300	1.96	1.91	-	265	1.47	1.40	-	12	0	0	277	265	-	
43		300	1.96	1.87	-	231	1.51	1.40	-	53	0	0	284	231	-	
44		300	1.96	1.88	-	251	1.49	1.40	-	30	0	0	281	251	-	
45		300	1.97	1.89	-	248	1.50	1.40	-	62	0	0	310	248	-	
46		300	1.90	1.88	-	240	1.48	1.40	-	41	0	0	281	240	-	

TABLE XV
(continued)

SUMMARY OF CYCLE LIFE TESTING
300AH NiZn CELLS, TASK III GROUP 1

CYCLE NO.	CHARGE					DISCHARGE				DRAIN			TOTAL OUTPUT			NOTES
	METHOD	AMP HRS. IN (AH)	VOLTAGE AT END OF CHARGE			AMP HRS. OUT (AH)	VOLTAGE AT END OF DISCHARGE			AMP HRS. OUT						
			CELL 1 (V)	CELL 2 (V)	CELL 3 (V)		CELL 1 (V)	CELL 2 (V)	CELL 3 (V)	CELL 1 (AH)	CELL 2 (AH)	CELL 3 (AH)	CELL 1 (AH)	CELL 2 (AH)	CELL 3 (AH)	
47	20A to 300 AH fixed input	300	1.90	-	-	272	1.42	-	-	0	0	0	272	-	-	Note 3
48		300	1.93	-	-	279	1.44	-	-	0	0	0	279	-	-	
49		300	1.96	-	-	270	1.44	-	-	0	0	0	270	-	-	
50		300	1.97	-	-	280	1.43	-	-	0	0	0	280	-	-	
51		300	1.96	-	-	272	1.43	-	-	0	0	0	272	-	-	
52		300	1.98	-	-	286	1.40	-	-	0	0	0	286	-	-	
53		300	1.96	-	-	279	1.40	-	-	0	0	0	279	-	-	
54		300	1.98	-	-	284	1.40	-	-	0	0	0	284	-	-	
55		300	1.90	-	-	273	1.40	-	-	0	0	0	273	-	-	
56		300	1.92	-	-	275	1.40	-	-	0	0	0	275	-	-	
57		300	1.94	-	-	272	1.40	-	-	0	0	0	272	-	-	
58		300	1.96	-	-	275	1.40	-	-	0	0	0	275	-	-	
59		300	1.95	-	-	275	1.40	-	-	0	0	0	275	-	-	
60		300	1.96	-	-	275	1.40	-	-	0	0	0	275	-	-	
61		-	-			-	-						-	-	-	Note 4

NOTES:

1. Cell No. 3 failure.
2. See Table XVII
3. Cell No. 2 failure.
4. Cell No. 1 failure.

TABLE XVI

SUMMARY OF CYCLE LIFE TESTING
300AH NiZn CELLS, TASK III GROUP 2

CYCLE NO.	CHARGE					DISCHARGE				DRAIN			TOTAL OUTPUT			NOTES
	METHOD	AMP HRS. IN (AH)	VOLTAGE AT END OF CHARGE			AMP HRS. OUT (AH)	VOLTAGE AT END OF DISCHARGE			AMP HRS. OUT						
			CELL 1 (V)	CELL 2 (V)	CELL 3 (V)		CELL 1 (V)	CELL 2 (V)	CELL 3 (V)	CELL 1 (AH)	CELL 2 (AH)	CELL 3 (AH)	CELL 1 (AH)	CELL 2 (AH)	CELL 3 (AH)	
1	20A to 1.91-1.92V	380	1.92	1.91	1.92	331	1.45	1.40	1.41	0	0	0	331	331	331	
2	20A to 105% of	345	1.91	1.91	1.91	310	1.41	1.40	1.42	0	0	0	310	310	310	
3	previous cycle	325	1.90	1.90	1.90	292	1.41	1.40	1.41	0	0	0	292	292	292	
4	output	310	1.89	1.89	1.89	258	1.39	1.39	1.41	0	0	0	258	258	258	
5	20A to 300 AH	300	1.91	1.91	1.91	275	1.41	1.40	1.41	0	0	0	275	275	275	
6	fixed input	300	1.92	1.91	1.91	280	1.41	1.39	1.41	0	0	0	280	280	280	
7		300	1.91	1.91	1.91	268	1.41	1.40	1.42	0	0	0	268	268	268	
8		300	1.92	1.92	1.91	276	1.39	1.40	1.42	0	0	0	276	276	276	
9		300	1.92	1.92	1.92	280	1.41	1.40	1.41	0	0	0	280	280	280	
10		300	1.93	1.92	1.92	276	1.41	1.40	1.42	0	0	0	276	276	276	
11		300	1.93	1.93	1.93	276	1.42	1.40	1.42	0	0	0	276	276	276	
12		300	1.92	1.91	1.92	276	1.41	1.40	1.40	0	0	0	276	276	276	
13	20A to 1.91-1.92V	286	1.92	1.92	1.92	255	1.41	1.40	1.41	0	0	0	255	255	255	
14	20A to 300 AH	300	1.93	1.93	1.93	261	1.41	1.40	1.40	0	0	0	261	261	261	
15	fixed input	300	1.94	1.94	1.94	273	1.39	1.41	1.41	0	0	0	273	273	273	
16		300	1.94	1.94	1.94	287	1.41	1.40	1.41	0	0	0	287	287	287	
17		300	1.94	1.94	1.93	280	1.41	1.39	1.41	0	0	0	280	280	280	
18		300	1.94	1.94	1.94	283	1.41	1.40	1.41	0	0	0	283	283	283	
19		300	1.94	1.94	1.93	285	1.39	1.37	1.39	0	0	0	285	285	285	
20		300	1.94	1.94	1.93	273	1.40	1.40	1.42	0	0	0	273	273	273	
21		300	1.94	1.94	1.93	275	1.42	1.39	1.42	0	0	0	275	275	275	
22		300	1.95	1.95	1.94	274	1.41	1.39	1.42	0	0	0	274	274	274	
23		300	1.95	1.95	1.95	279	1.41	1.40	1.42	0	0	0	279	279	279	
24		300	1.95	1.95	1.94	277	1.40	1.39	1.42	0	0	0	277	277	277	
25		300	1.95	1.95	1.94	274	1.41	1.40	1.42	0	0	0	274	274	274	
26		300	1.96	1.96	1.95	273	1.41	1.40	1.42	0	0	0	273	273	273	
27		300	1.96	1.96	1.95	273	1.41	1.40	1.42	0	0	0	273	273	273	
28		300	1.96	1.96	1.96	273	1.41	1.40	1.42	0	0	0	273	273	273	
29		300	1.96	1.96	1.95	279	1.39	1.38	1.41	0	0	0	279	279	279	
30		300	1.97	1.97	1.96	272	1.41	1.40	1.42	0	0	0	272	272	272	
31		300	1.97	1.97	1.96	275	1.40	1.39	1.41	0	0	0	275	275	275	
32		300	1.98	1.98	1.97	273	1.41	1.40	1.41	64	61	70	337	334	343	Note 1
33		300	1.91	1.91	1.90	248	1.41	1.39	1.40	0	0	0	248	248	248	
34		300	1.95	1.95	1.94	273	1.41	1.39	1.40	0	0	0	273	273	273	
35		300	1.96	1.96	1.95	276	1.41	1.39	1.40	0	0	0	276	276	276	
36		300	1.97	1.96	1.96	273	1.41	1.39	1.40	0	0	0	273	273	273	
37		300	1.96	1.96	1.96	262	1.45	1.44	1.44	0	0	0	262	262	262	
38		300	1.95	1.95	1.95	266	1.43	1.41	1.42	0	0	0	266	266	266	
39		300	1.97	1.96	1.97	265	1.44	1.42	1.42	12	12	12	277	277	277	
40		300	1.97	1.97	1.97	231	1.48	1.47	1.47	53	53	53	284	284	284	
41		300	1.97	1.96	1.96	251	1.49	1.40	1.44	30	30	30	281	281	281	
42		300	1.97	1.96	1.97	248	1.45	1.44	1.44	31	31	31	279	279	279	
43		300	1.97	1.96	1.97	240	1.46	1.45	1.45	41	41	41	281	281	281	
44		300	1.95	1.95	1.96	272	1.41	1.39	1.40	0	0	0	272	272	272	
45		300	1.97	1.96	1.97	279	1.41	1.40	1.40	0	0	0	279	279	279	
46		300	1.99	1.99	1.99	270	1.40	1.38	1.38	0	0	0	270	270	270	
47		300	1.98	1.98	1.98	280	1.39	1.38	1.38	0	0	0	280	280	280	

TABLE XVI
(continued)

SUMMARY OF CYCLE LIFE TESTING
300AH NiZn CELLS, TASK III GROUP 2

CYCLE NO.	CHARGE					DISCHARGE				DRAIN			TOTAL OUTPUT			NOTES
	METHOD	AMP HRS. IN (AH)	VOLTAGE AT END OF CHARGE			AMP HRS. OUT (AH)	VOLTAGE AT END OF DISCHARGE			AMP HRS. OUT						
			CELL 1 (V)	CELL 2 (V)	CELL 3 (V)		CELL 1 (V)	CELL 2 (V)	CELL 3 (V)	CELL 1 (AH)	CELL 2 (AH)	CELL 3 (AH)	CELL 1 (AH)	CELL 2 (AH)	CELL 3 (AH)	
48	20A to 300 AH fixed input	300	1.97	1.97	1.98	272	1.40	1.39	1.40	0	0	0	272	272	272	
49		300	1.98	1.98	1.99	286	1.35	1.34	1.35	0	0	0	286	286	286	
50		300	1.98	1.97	1.97	279	1.36	1.33	1.35	0	0	0	279	279	279	
51		300	1.98	1.98	1.98	284	1.34	1.31	1.33	0	0	0	284	284	284	
52		300	1.94	1.94	1.95	273	1.39	1.36	1.39	0	0	0	273	273	273	
53		300	1.96	1.96	1.98	272	1.41	1.37	1.38	0	0	0	272	272	272	
54		300	1.99	1.97	1.98	268	1.39	1.36	1.37	0	0	0	268	268	268	
55		300	1.99	1.97	1.98	268	1.39	1.36	1.37	0	0	0	268	268	268	
56		300	1.98	1.98	1.99	268	1.39	1.37	1.37	0	0	0	268	268	268	
57		300	1.99	1.99	2.00	268	1.39	1.39	1.38	20	20	20	288	288	288	

NOTES:

1. See Table XVII

The increase in cell temperature due to test discharge was monitored during several Cycle Life Test cycles. One cell of each group was wrapped in approximately 2.5cm thick soft packing material. A thermometer was positioned between the soft packing and the narrow side of the cell case. Temperature readings were recorded at regular intervals during test discharge. The rise in temperature for the Group 2 cell was approximately 15 percent (15%) greater than that of the Group 2 cell. Figure 6 depicts the typical increase in Group 1 and Group 2 cell temperatures during test discharge.

4.3 Testing Events and Observations

4.3.1 Group 1, Cell #3, Cycles #15 and #16

During the charge for Cycle #15, Group 1, Cell #3 voltage at the end of charge was 0.040 volts lower than in the previous cycle. The output capacity during discharge was 229AH compared to 275AH for the previous cycle. During the charge for Cycle #16, Cell #3 would not accept charge and it was removed from the test program. The gradual but steady decline in open circuit voltage indicated that the cell was shorted internally.

4.3.2 Group 1 Cycle #16, Group 2 Cycle #13

Each test cell was charged at 20 amperes to 1.92 volts to compare performance with Cycle #1 results for each group. The input and output capacities were not comparable with any previous cycle results. The charge criteria for subsequent cycles reverted to the 300AH fixed input previously adopted.

4.3.3 Group 1 Cycle #35, Group 2 Cycle #32

After the completion of the normal charge and discharge on the automatic cycler, the discharge was continued until the last cell reached 1.40 volts. This extended discharge was followed by a drain at a constant current of 30 amperes until each cell had reached 1.00 volts. The output capacities of each cell were calculated for the normal discharge, the extended discharge and the drain. These values are given in Table XVII.

4.3.4 Group 1 Cycle #40 through Cycle #47

Cell #2 of Group 1 showed a marked decrease in output capacity and charge end voltage in test cycles #40 through #46. Group 1 Cell #1 and the three (3) cells of Group 2 required additional capacity draining when the testing of Group 1 Cell #2 was complete in these cycles. The open circuit voltage of

FIGURE 6

TYPICAL CHANGE IN CELL
TEMPERATURE DURING
CYCLE LIFE TEST DISCHARGE
OF 300 AH NiZn CELLS

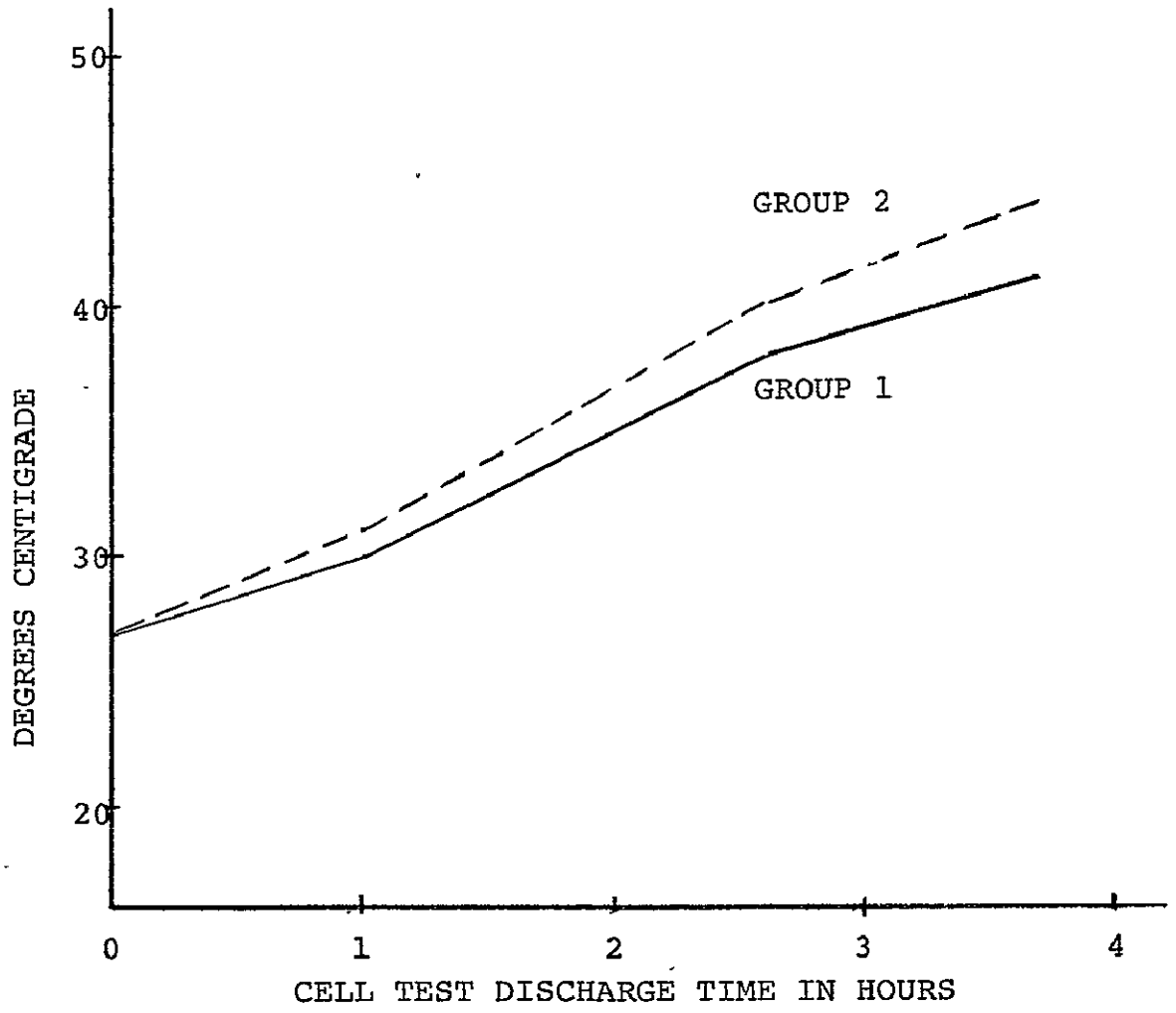


TABLE XVII

TEST DISCHARGE AND DRAIN OUTPUT
300AH NiZn CELLS TASK III GROUPS 1 AND 2

CYCLE LIFE TESTING

TEST/DRAIN SEQUENCE	GROUP	1	1	2	2	2
	CELL #	1	2	1	2	3
	CYCLE	35	35	32	32	32
CHARGE: 20A FOR 15 HOURS 300AH FIXED INPUT		300AH	300AH	300AH	300AH	300AH
NORMAL DISCHARGE: 30A/200A PULSE PROFILE TO FIRST CELL REACHING 1.400V		273AH TO 1.454V	273AH TO 1.426V	273AH TO 1.409V	273AH TO 1.396V	273AH TO 1.411V
EXTENDED DISCHARGE: 30A/200A PULSE PROFILE TO LAST CELL REACHING 1.400V		27.6AH TO 1.401V	27.6AH TO 1.362V	27.6AH TO 1.318V	27.6AH TO 1.295V	27.6AH TO 1.350V
DRAIN: 30A TO 1.00V PER CELL		66.8AH	48.5AH	37.2AH	33.8AH	42.5AH
TOTAL AMPERE-HOUR OUTPUT		367.4AH	349.1AH	337.8AH	334.4AH	343.1AH

Group 1 Cell #2 indicated a slow internal short was present in the cell and it was removed from the testing program during cycle #47.

4.3.5 Group 1 Cell #1 Cycle #60

After the completion of Cycle #60 test discharge the open circuit voltage of Cell #1 declined at a rate which indicated internal shorting of the cell. The cell was removed from the testing program.

5. Failure Analysis

The three (3) cells of Group 1 were dissected in the manner described under Task II of this report. In general, the conditions observed in the 100AH cells were present in the 300AH cells to a greater degree. This was probably caused by two (2) factors. First, the cell stacks for the 300AH cells did not fit as tightly in the cell cases as did the 100AH cell stacks leaving slightly more room for distortion of the nickel positive electrodes. Second, the cells were given more Cycle Life Test cycles.

5.1 External Inspection

Similar to the 100AH cells, these 300AH cells exhibited sponge zinc deposits on the cell stack edges and some zinc sludge at the bottom of the cell stack. The distortion of the negative electrode inorganic separator bags was more pronounced.

5.2 Internal Inspection

The three (3) cells were opened and the free electrolyte was drained off and collected. The average quantity of free electrolyte collected was 141 ml. The tab-to-terminal attachment on all cells was secure.

5.2.1 Cell 3 (After Cycle Life Test Cycle #16)

The distortion of the nickel electrodes caused a concavity of between 0.4 and 0.7 centimeters depth on the grid side of the electrodes. This condition was reflected in the adjacent negative electrode separator bags causing cracks in the ceramic coating of the inorganic separator material not only at the epoxy bag seal but on the surfaces between the electrodes. The point at which the failure occurred was along the bottom seal of one of the inorganic separator bags. Damage at that point was sufficient to allow zinc material to exit the bag, build up between the electrodes, work its way through the .30mm thick layer of non-woven nylon interseparator material and contact the nickel positive electrode. The heat seals on the interseparator bags

were intact and, other than the point of cell failure, the general condition of the bags was good. The loss in effective negative electrode surface area due to shape change was estimated at eight percent (8%).

5.2.2 Cell 2 (After Cycle Life Test Cycle #47) Cell 1 (After Cycle Life Test Cycle #60)

The distortion of the nickel electrodes taken from these cells created a concavity of between 0.6 and 0.8 centimeters depth on the grid side of the nickel electrode. Electrode growth was the same as in the 100AH cells. This edge curling distortion was sufficient to damage the interseparator material near the heat seal of the bottom of the interseparator bag. This condition existed in approximately twenty-five percent (25%) of the bags in these cells. The damage inflicted on the inorganic separator material was more severe than in Cell 3. The impression of the negative electrode grid material was clearly visible on the separator surface particularly in the areas of more extreme positive electrode curling. The location and mechanism of the shorting which caused the failure of both cells was the same as in Cell 3. Negative electrode shape change was estimated at between nine percent (9%) and twelve percent (12%).

TASK V - FABRICATION OF EXPERIMENTAL 300 AMPERE-HOUR VENTED NICKEL-ZINC CELLS

1. Objective of Task

The objective of this task was to fabricate seven (7) cells in the 300 ampere-hour configuration using the interseparator (electrolyte absorber) material selected by the NASA Project Manager based on the performance of cell constructed under Task III and tested under Task IV.

2. Cell Materials

The interseparator material selected by the NASA Project Manager for use in the 300 ampere-hour cells fabricated in this task was Pellon #2506, the .30mm thick non-woven nylon. All other cell materials were the same as used in Task III cell construction.

3. Positive Electrode Modification

Based on the failure analysis of 100 ampere-hour and 300 ampere-hour cells, it was determined that the nickel positive plate orientation should be altered to minimize damage to the separator caused by electrode growth and distortion. The screen-grid within the nickel positive plate was primarily on one surface of the plate. It was determined that full positive electrodes should be assembled using two (2) nickel positive plates oriented such that the grid surfaces faced each other. Half end positive electrodes would be oriented with the positive plate grid surface facing the cell case wall.

To accomplish this change it became necessary to alter the tab position on twelve (12) nickel positive plates per cell. This involved removing the tab from one corner of the electrode where it had been welded to a coined area and welding a tab in the opposite corner which had not been coined. Various methods of plate surface preparation and welding were tried. The best results were achieved by removing the sintered nickel material from the grid in a 2.86cm wide x 2.54cm long area and welding a tab directly to the plate grid. The nickel screen grid was cleaned prior to welding and the entire tab attachment area was insulated with applications of PPO in chloroform after the welding operation.

4. Cell Fabrication

The seven (7) 300 ampere-hour cells were fabricated using heat sealed bags of the Pellon #2506 material on the nickel positive electrodes. The full positive electrodes consisted of one

(1) altered and one (1) unaltered nickel positive plates with the grid surfaces face-to-face. The two (2) half end positive electrodes consisted of an altered plate on one end and an unaltered plate on the opposite end of the cell stack, both oriented with the plate grid surface facing the cell case wall. The seven (7) cell stacks were assembled and inserted in cell cases. The cell electrode tabs were cut to length, formed and attached to their respective terminals in the cell cover assembly. The case-to-cover seal was made with an acrylic cement. The cells were then pressure tested, weighed, marked, and inspected. Pressure relief valves and cell terminal top nuts were installed in place.

The weight of the individual cells ranged from 7.58 to 7.63 Kg.

5. Cell Filling Kit

Since the cells were to be shipped in the dry state, a filling kit was prepared which included:

- 34% KOH solution premeasured in 900ml and 400ml increments
- cell filling adapters
- cell restraining plates
- spare vent relief valves
- spare terminal top nuts
- instructions for filling and conditioning the cells

The seven (7) 300AH vented nickel-zinc cells and the cell filling kit were packaged and shipped to the NASA-Lewis Research Center.

TASK VII - CASE AND COVER DESIGN

1. Objective of Task

The objective of this task was to design a molded cell case and cell cover to accommodate the 300 ampere-hour nickel-zinc cell developed under the contract.

2. Design Features

In order to provide flexibility in cell fabrication methods and aid in cell activation, installation and maintenance, the following features were incorporated in the design of the cell case and cover:

- Provision for making the case-to-cover seal with ultrasonic welding methods or by using adhesives.
- Positioning of cell terminal openings in the cell cover to allow the use of one standard intercell connector when cells are positioned in standard battery configurations.
- Provisions for filling the cell with electrolyte by either gravity or vacuum methods.
- An extended internal vent trap to minimize electrolyte loss due to angular orientation.
- A vent sump on the cell case top to minimize electrolyte spewage and allow for the addition of optional filters or vent caps.
- Reinforcements in the cover to render the cover capable of withstanding pressures in excess of 20 psig.
- Cell cover cavities for the use of hexagonal base terminals, the design of which provides for a minimum of stress concentrations while allowing some flexibility of terminal design.
- Provision for alternative cell case heights.

3. Cell Case Design

Alternate cell case heights were incorporated in the design to enable cells made with these cases to be used in battery compartments designed around existing standard cell and battery heights. The maximum dimensions of the cell cases and

cells made using these cases are as follows:

	Basic Design	Alternate Design
Cell overall height to top of terminals	33.02cm	27.62cm
Cell case height	31.06cm	25.65cm
Cell case width	17.76cm	17.76cm
Cell case thickness	7.13cm	7.13cm

Both the basic and alternate cell case designs accept the same cell cover.

4. Cell Cover Design

The cell cover design incorporated an energy director for use in ultrasonic welding of the cover to the cell case. Vent openings in the cell cover were designed using standard threaded holes and provisions for sealing with standard size "O" rings.

5. Cell Case and Cover Material

The material approved by the NASA Project Manager for use in molding the cell case and cover was Type GFN-2, 20% glass filled virgin Noryl manufactured by General Electric Company. The color of this material was specified to be Gray #780.

The design of the cell case and the cell cover was delivered to the NASA Project Manager with a list of recommended mold fabricators.

APPENDIX I

CELL DESIGN SUMMARY
100AH AND 300AH EXPERIMENTAL
VENTED NICKEL-ZINC CELLS

		100 AH	300 AH
CELL CAPACITY (NOMINAL)			
CELL DIMENSIONS			
HEIGHT (OVERALL)		33.02 CM	34.16 CM
HEIGHT (TOP OF CASE)		31.43 CM	32.38 CM
WIDTH		18.38 CM	18.38 CM
THICKNESS		3.33 CM	7.87 CM
AVERAGE WEIGHT		3.2 Kg	7.6 Kg
ELECTRODES			
POSITIVE:			
QUANTITY	FULL (+)	3	11
	HALF (+)	2	2
SIZE - LENGTH X WIDTH		24.4 x 14.9 CM	24.4 x 14.9 CM
THICKNESS	FULL (+)	1.78 MM	1.78 MM
	HALF (+)	.89 MM	.89 MM
LEADS		Nickel Strip 2.54 CM x .20 MM	Nickel Strip 2.54 CM x .20 MM
CAPACITY (THEORETICAL)		123 AH	369 AH

APPENDIX I

CELL DESIGN SUMMARY
100AH AND 300AH EXPERIMENTAL
VENTED NICKEL-ZINC CELLS
(CONTINUED)

ELECTRODES (continued)

NEGATIVE:

QUANTITY	4	12
SIZE - LENGTH X WIDTH	25.1 x 15.5 CM	25.1 x 15.5 CM
THICKNESS	1.70 MM	1.70 MM
LEADS	Silver Strip 2.54 CM x .10 MM	Silver Strip 2.54 CM x .10 MM
COLLECTOR (DISTEX)	5Ag27-1/0	5Ag27-1/0
ABSORBER MAT	YED YIFL-II	YED YIFL-II
MIX	98% ZnO - 2% HgO	98% ZnO - 2% HgO
ZINC MASS	449 gm	1347 gm
ZINC VOLUME	210 cc	630 cc
ZINC DENSITY	2.14 gm/cc	2.14 gm/cc
Zn:Ni CAPACITY RATIO	2.99:1	2.99:1

SEPARATOR

NEGATIVE ELECTRODE	Sealed Bag Inorganic Separator	Sealed Bag Inorganic Separator
POSITIVE ELECTRODE	See Text	See Text

APPENDIX I

CELL DESIGN SUMMARY
100AH AND 300AH EXPERIMENTAL
VENTED NICKEL-ZINC CELLS
(CONTINUED)

ELECTROLYTE		
TYPE	34% KOH SOLUTION	34% KOH SOLUTION
QUANTITY	See Text	1300 ml

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Yardney Electric Division, Attn: Vice President of Engineering,
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