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FABRICATION AND TEST OF SEALED SILVER-ZINC CELLS

by C. Philip Donnel III

YARDNEY ELECTRIC DIVISION

YARDNEY ELECTRIC CORPORATION

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16. Abstract One hundred seventy-five (175) Type HS40-7 sealed silver-zinc cells were fabricated in lots of thirty-five (35) cells each. These cells were filled, given formation cycles and sent to NASA LeRC. Two (2) cells were retained to be used as a control group during the cell testing portion of the program performed at Yardney.

Six (6) groups of experimental 40AH sealed silver-zinc cells were fabricated. The four (4) cells of each group contained one variation from the standard configuration (HS40-7) cell. These variations included positive electrodes made by the Yardney continuous process rolling mill technique, separator fabrication process changes, and the substitution of Yardney KT Mat (YIFL-II) for the normally used negative absorber. These experimental cells were given formation cycles and, with the exception of ten (10) cells selected for the cell testing program, were shipped to NASA LeRC.

Two (2) cells from each of five (5) experimental cell groups plus two (2) cells of the standard configuration were given test cycles to characterize the voltage and capacity performance of the cells at various discharge rates. The test cells were then subjected to 100% DOD Cycle Life Testing at 22°C using automatic cell cycling equipment. The results of the testing performed indicate that material and/or process variations are available which will improve both performance and cycle life of the existing 40 ampere-hour sealed silver-zinc cell configuration. The average cycle life to 50% loss of nominal capacity in cells from two (2) of the experimental groups was 150 - 165 cycles.

A series of 12 ampere-hour cells was fabricated and tested as part of a developmental program to incorporate the 40AH sealed silver-zinc cell fabrication technology into a cell of smaller size. Base-line configuration cells and experimental variations were produced using the HS40-7 cell fabrication and processing methods adapted to the smaller cell size. One hundred twenty (120) cells were given formation cycles and, with the exception of twelve (12) cells selected for the cell testing program, were shipped to NASA Lewis Research Center.

Two (2) base-line configuration cells and two (2) cells from each of five (5) groups of experimental cells were given test cycles to determine their voltage and capacity characteristics at various discharge rates. The cells were then subjected to 100% DOD Cycle Life Testing at 22°C. The results of tests on these 12 ampere-hour cells indicate that sealed silver-zinc cells using inorganic separators with a nominal capacity of less than 40 ampere-hours could be designed and fabricated and would give performance comparable to the HS40-7 cell when operated at comparable current densities.

All of the fabrication and testing performed during this Phase II Program was accomplished in the Sealed Silver-Zinc Production Facility established at Yardney Electric Division, Pawcatuck, Connecticut under NASA Lewis Research Center Contract NAS3-16805 Phase I. NASA Contractors Report CR-134591, entitled "Development and Fabrication of Sealed Silver-Zinc Cells" describes the work accomplished in Phase I.

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SUMMARY

One hundred seventy-five (175) Type HS40-7 sealed silver-zinc cells were fabricated, in lots of thirty-five (35) cells each. These cells were filled, given formation cycles and sent to NASA LeRC. Two (2) cells were retained to be used as a control group during the cell testing portion of the program performed at Yardney.

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INTRODUCTION

Over the past several years NASA-Lewis Research Center has promoted the development of sealed silver-zinc battery cells by funding programs with private contractors in the battery and related industries.

Under one of these NASA funded programs, McDonnell-Douglas Corporation's Astropower Laboratory developed and fabricated a 40 ampere-hour sealed silver-zinc rechargeable cell which contained essentially inert separator materials and electrolyte absorbers. Their development of semi-flexible inorganic separator material 3420-25FMA, was a significant contribution to sealed silver-zinc battery cell technology.

In 1970, McDonnell-Douglas elected to discontinue operations at Astropower Laboratory in Newport Beach, California. In 1972, NASA-Lewis Research Center funded, under Contract NAS3-16805, Phase I, the establishment of a 300 square meter production facility at Yardney Electric, Yardney Electric Corporation in Pawcatuck, Connecticut. This facility was designed, constructed, equipped and operated for the continued utilization of the technology developed and documented by Astropower Laboratory. As part of the same program, a quantity of 40 ampere-hour sealed silver-zinc cells, Type HS40-7, was fabricated and tested in this facility under carefully controlled fabrication and processing conditions. The results of the testing performed on these cells indicated that the transfer of technology from Astropower Laboratory to Yardney Electric Division had been accomplished successfully under guidance and funding by NASA-Lewis Research Center.

NASA-Lewis Research Center continued to fund programs to support its on-going evaluation of cell components, especially inorganic separators, for sealed silver-zinc battery cells. One such program involved the fabrication and testing of standard and experimental 40 ampere-hour and experimental 12 ampere-hour sealed silver-zinc cells.

It is the purpose of this report to describe the fabrication and testing of standard and experimental sealed silver-zinc battery cell configurations in NASA's facility at Yardney Electric Division, Yardney Electric Corporation, Pawcatuck, Connecticut, under NASA funding on Phase II of Contract NAS3-16806.

TASK I - CELL MANUFACTURING (HS40-7 CELLS)

1. Objective of Task

To fabricate, form, finish and deliver one hundred seventy-five (175) forty ampere-hour (40AH) sealed silver-zinc cells using inorganic separator, cell Model HS40-7, in accordance with the drawings, specifications and procedures supplied by NASA Lewis Research Center. The one hundred seventy-five (175) cells to be fabricated in five (5) separate lots of thirty-five (35) cells each.

2. Cell Materials

2.1 The conductor material for the positive electrodes was Exmet product 3Ag10-3/0 in a roll width of 9.16cm $\pm$ 0.38mm. The long way of the diamonds (LWD) was parallel to the width of the coil. In fabricating the electrode grid, it was necessary to make only one (1) cut to obtain the grid width dimension of 7.01/7.09cm.

2.2 The conductor grid material for the negative electrodes was Exmet product 5Ag38-1/0 DISTEX in a roll width of 15.24cm $\pm$ 0.76mm.

2.3 The conductor tab material for both the positive and negative electrodes was fine silver strip, 0.64cm wide x 0.15mm thick. Each electrode used a tab strip length of 7.62cm.

2.4 The active positive electrode material was silver powder, Handy & Harman product "Silpowder 130", purchased in accordance with Drawing No. 1D12572 and Handy & Harman product specifications for "Silpowder 130".

2.5 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 22.7Kg. of powder.

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

2.7 The electrolyte used was a 45 percent (45%) solution of potassium hydroxide, "Baker Analyzed" reagent grade packaged in one (1) pint, sealed polyethylene bottles. One (1) pint of this electrolyte was sufficient to fill four (4) of the type HS40-7 cells.

2.8 The Allbond epoxy and the RB3-1 epoxy used to seal the cell terminal hardware to the cell cover and also to top pot the cell was purchased from Bacon Industries, Inc. in kit form, each kit containing 0.5 liter of resin and 0.5 liter of hardener.

2.9 The inert material used for the sling, to aid in positioning the cell stack inside the cell case, was Teflon film, 0.13mm thick x 8.25cm wide.

2.10 The three (3) sizes of Parker "O" rings were made of Compound E-540-8, which is ethylene-propylene, and the "O" rings were shipped without preservatives, which might have interfered with proper sealing when used in the terminal assembly CB502709.

2.11 The semi-tubular rivets, used to attach the electrode tabs to the underside of the cell terminals, were produced of CONSIL 901 (coin silver) wire, 0.30cm in diameter, on a standard rivet machine.

2.12 The terminal casting, from which the finished terminal was machined, was made by centrifugally casting molten coin silver. These parts were cast using Tool No. T12-0001 and conformed to Drawing No. CB502712. Prior to machining, all castings were 100 percent (100%) X-rayed, a precaution taken to avoid machining castings with voids and similar defects. The castings were machined to specifications and gold-plated per Specification MIL-G-45204B (27 March 1967), Type I, Grade A, Class 1.

2.13 The metal washer used in the terminal assembly was fabricated from 1.59cm diameter coin silver rod. It was machined to conform to Drawing No. CB502711 and was gold-plated per MIL-G-45204B (27 March 1967), Type I, Grade A, Class 1.

2.14 The jam nuts used to secure the terminal assembly were fabricated from 1.11cm hexagonal coin silver rod. These parts were machined to conform to Drawing No. 1D12512 and were then gold-plated per Specification MIL-G-45204B (27 March 1967), Type I, Grade A, Class 1.

2.15 The cell cases were furnished by NASA Lewis Research Center. Each cell case conformed to NASA Drawing 1D12556 and was injection molded of glass fortified grade 534-801 natural polyphenylene oxide, Liquid Nitrogen Processing Corporation product NF-1006, with 30 percent (30%) glass content.

2.16 Molded cell covers, per Drawing 1D12509, were supplied by NASA Lewis Research Center. These covers were injection molded of the same material used for the cell cases. Each cover was supplied with a plug per Drawing 1D12510 which was injection molded of the same material.

3. Negative Electrode Fabrication

3.1 Each Model HS40-7 cell contained five (5) negative electrode assemblies consisting of a pressed zinc oxide powder electrode contained inside a fuel cell grade asbestos bag coated with a ceramic separator composition.

3.2 The negative conductor grid consisted of expanded silver mesh, Exmet product DISTEX 5Ag38-1/0, cut to 7.06cm x 9.12cm and welded to a fine silver strip tab, 0.64cm width x 0.13mm thick. The expanded mesh pieces and the cut silver tabs were degreased in an ultrasonic cleaner using acetone as the cleaning agent. Following the ultrasonic cleaning, the excess acetone was shaken off and the parts were allowed to air dry. Using a locating fixture to properly position the tab in relation to the grid, the tab was welded to the DISTEX grid, using a 50 KVA resistance welder with tungstenite welding tips. Four (4) spot welds secured the tab to the conductor grid to form the negative conductor grid sub-assembly.

3.3 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, which was then placed in a Despatch oven and allowed to dry overnight at approximately 70°C. A sample of the negative mix was then 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.

3.4 Each negative electrode used two (2) absorber layers cut from potassium titanate paper furnished to the contractor by NASA Lewis Research Center. The particular material was coded product LPM174-67 and was manufactured by the Mead Corporation. Each absorber layer measured 7.06cm x 9.14cm.

3.5 In fabricating the negative electrode, 30.1 grams of negative mix was weighed out. Using the negative electrode mold, one (1) piece of potassium titanate paper was placed in the bottom of the mold. Fifty percent (50%) of the volume of negative mix was then poured into the mold on top of the potassium titanate paper. This mix was then spread evenly with a tamping tool. Next, a collector-grid assembly was positioned in the mold so that it would lie flat on the mix; then the remainder of the mix was poured on top of the collector-grid assembly and again spread evenly, using a tamping tool. A second piece of potassium titanate paper was placed on the top of the mix in the mold followed by positioning of the top punch into the mold. The filled mold was then positioned between the platens of a hydraulic press and pressed at 36,000 Kg. to compact the negative electrode mix around the collector-grid assembly.

3.6 Each electrode was measured to determine that the width was 7.11cm $\pm$ 0.38mm, that the length was 9.21cm $\pm$ 0.38mm, that the thickness was in the range of 0.22 - 0.23cm and the weight was in the range of 37.8 - 39.0 grams. All negative electrodes used in assembling HS40-7 cells conformed to the above requirements.

3.7 Following acceptance of each electrode on the basis of dimensions and weight, a plastic sleeve was positioned over the electrode tab and a numbered identification tab was attached to the end of the tab. Negative electrode sub-assemblies in this condition, together with appropriate traceability data, were stored in plastic boxes to await subsequent operations. The edges of acceptable electrodes were reinforced by a light application of a two percent (2%) solution of polyphenylene oxide (PPO) in chloroform.

4. Positive Electrode Fabrication

4.1 Each Type HS40-7 cell contained six (6) positive electrodes. Each positive electrode contained 23.0 $\pm$ 0.1 grams of silver powder (product "Silpowder 130") and the completed positive electrode sub-assembly weighed from 25.2 - 25.6 grams. Each electrode measured 9.21cm x 0.69 - 0.74mm thickness.

4.2 A positive electrode conductor-grid sub-assembly was fabricated by welding a fine silver strip, 7.62cm long and 0.64cm wide x 0.13mm thick, onto a rectangular silver mesh grid, Exmet product 3Ag10-3/0, cut to 7.05cm x 9.11cm dimensions and ultrasonically cleaned in acetone. A locating fixture positioned the silver tab accurately in respect to the conductor-grid prior to the application of three (3) spot welds to complete this sub-assembly.

4.3 The positive electrode assembly fabrication was accomplished by evenly distributing 23 grams of "Silpowder" around the conductor-grid sub-assembly in matched metal molds and pressing to the specification thickness in a 91,000 kilograms hydraulic press.

4.4 Following the pressing operation, each positive electrode sub-assembly was dried at 125°C for one (1) hour to remove any residual moisture prior to the sintering operation.

4.5 The dried positive electrode sub-assembly was then sintered at 650°C for a period of four (4) minutes. This sintering produced a strong mechanical bond due to physical coalescence of the particles of "Silpowder 130" to each other and, due to the cementing action of the sintering process, resulting in binding of the powder particles to the conductor-grid.

4.6 It should be pointed out that the molding of the positive electrode was done in a three (3) piece compression mold consisting of a base plate, a mold ring and a punch. During the pressing operation, the electrode components were pressed to a fixed dimension rather than using a pre-determined force. This was done to consistently control the thickness of the finished pressed electrode.

4.7 Following the sintering operation, positive electrode sub-assemblies were given 100 percent (100%) inspection to eliminate electrodes which might have mechanical defects, evidence of contamination or variance from dimensional and weight requirements. Those electrodes passing the 100 percent (100%) inspection had insulating sleeves applied to the tab and identifying serial numbers were attached to the tab at this point.

5. Separator Processing and Fabrication

5.1 The processing and fabrication of inorganic separators for the HS40-7 cells was carried out in accordance with proprietary procedures supplied by NASA Lewis Research Center.

The raw materials necessary to prepare and fabricate the separators were supplied by NASA Lewis Research Center.

6. Assembly of HS40-7 Cells

6.1 The complete positive and negative electrode assemblies were stacked in the proper sequence with five (5) negative electrodes and six (6) positive electrodes comprising a cell stack. Figure (3) shows a complete electrode stack inside a cell case using a Teflon film as a protective sling to facilitate the insertion of the electrode stack into a cell case.

6.2 The tabs of the electrode stack were formed utilizing a "comb" assembly aid. The formed tabs were cut to length and a 0.32cm diameter hole was punched in the center of the tab stack to provide a means of riveting the tab stack to the underside of the cell terminals.

6.3 With the electrode stack still only partially inserted into the cell case, the electrode tabs were secured to the appropriate terminal tabs using a coin silver rivet which was turned over using a special rivet setter. The area of the connections between the electrode tabs and the cell terminals was given a protective coating of Allbond epoxy. After this epoxy had set, the electrode stack was pushed completely down into the cell case and the cell cover was then secured to the corresponding ledge inside the cell case.

6.4 The cover was ultrasonically welded to the cell case, using a Branson Model 220C ultrasonic welder and a nesting fixture for properly positioning the cell directly beneath the horn of the ultrasonic welder during sealing. Prior to this operation, the cell was placed in an oven that had been stabilized at 100°C and allowed to remain in this oven for five (5) minutes. It was then transferred immediately from the oven to the ultrasonic welding fixture and welded, using settings, hold times and weld times previously determined to be appropriate for this piece of equipment.

6.5 Following the ultrasonic welding operation, each cell was placed between restraining plates inside a cylindrical metal bomb and pressurized through a special fitting to 3.5KG/cm^3. In order for a cell to be acceptable, there could be no evidence of leakage during a ten (10) minute period at the 3.5Kg/cm^3 level.

6.6 After completion of the pressure test, the area between the inside seal of the cell case and the periphery of the cell cover was pre-sealed with a thin bead of RB3-1 Allbond epoxy which was then allowed to cure at room temperature for 16 - 24 hours.

7. Filling and Formation of Cells

7.1 The cells to be filled were first weighed to the nearest 0.1 gram in the dry state. The cells, the 45% solution of potassium hydroxide and all the equipment necessary to vacuum fill the cells were placed in a glove box which was flooded with dry nitrogen. One hundred and ten milliliters (110 ml) of electrolyte were carefully premeasured and introduced into the cell. The vented cell was then placed in a vacuum chamber inside the glove box and a vacuum of 710 $\pm$ 25mm of mercury was achieved in the chamber. This vacuum was maintained for thirty (30) seconds. The chamber was then allowed to return slowly to ambient pressure. The filled and vacuumed cell was weighed again and the weight gain due to filling was calculated to verify that the correct amount of electrolyte was present in the cell. The cell was restrained between two (2) steel plates 15.2cm x 11.4cm x 6.4mm thick and secured using four (4) round head bolts, 5.7cm long, and wing nuts. The filled and restrained cells remained in the nitrogen atmosphere during a soaking period of at least twenty-four (24) hours. Before removing the cell from the nitrogen atmosphere, the molded vent plug was positioned loosely in the vent hole in the cell cover.

7.2 Each cell was charged for the first formation cycle at a constant current rate of 1.5A to a voltage, while charging, of 1.98 - 2.00 volts or until an input of 45 ampere-hours was achieved, whichever occurred first. The cell was charged using a constant current power supply. Charging current was monitored using an ammeter with $\pm$1.0% accuracy. Cell voltage was monitored using a 3-1/2 digit digital voltmeter with an accuracy of $\pm$0.1%. The cell voltage was recorded as a function of time during charging. The cell charging input capacity was calculated and recorded.

7.3 Each charged cell was connected to formation discharge equipment capable of discharging and monitoring ten (10) cells simultaneously at rates between 0.5 and 10.0 amperes. Individual cell voltages were monitored using a cell selector switch and a digital panel voltmeter with $\pm$0.1% accuracy. Discharge current was adjusted using a variable resistor. Currents were read on a panel ammeter with an accuracy of $\pm$1.0%. Individual cells reaching discharge end voltage were deleted from the circuit by means of manually actuated switches.

7.4 Each cell was discharged at a constant current rate of 6.0A to a voltage, while discharging, of 1.00 volt. The cell discharge voltage was recorded as a function of time. The cell discharge output capacity was calculated and recorded.

7.5 Each cell was then low rate drained at a constant current of 2.0A to a voltage, while discharging, of 1.00 volt. The cell drain voltage was recorded as a function of time. The cell drain output capacity was calculated and recorded.

7.6 The first formation cycle input capacity, discharge capacity and low rate drain capacity for each cell is given in Tables I through V.

TABLE I

FORMATION CYCLES DATA
CELL TYPE HS40-7
TASK I, LOT 1

CELL TYPE HS40-7			FORMATION CYCLE NO. 1				FORMATION CYCLE NO. 2					
TASK NO.	LOT or GRP. NO.	CELL NO.	CHARGE INPUT (AH)	DISCHARGE OUTPUT TO 1.00V (AH)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)	CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE (V)	DISCHARGE OUTPUT TO 1.00V (AH)	DISCHARGE PLATEAU VOLTAGE (V)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)
I	1	001	40.50	34.55	1.26	35.81	45.00	1.976	41.40	1.484	0.90	42.30
		002	40.50	34.44	1.43	35.87	45.00	1.975	41.45	1.484	0.66	42.11
		003	40.50	33.71	1.51	35.22	45.00	1.976	41.62	1.484	0.64	42.26
		004	40.50	33.68	1.51	35.19	45.00	1.979	41.69	1.485	0.70	42.39
		005	40.50	34.06	1.05	35.11	45.00	1.980	41.44	1.483	0.79	42.23
		006	41.25	34.35	1.31	35.66	45.00	1.981	41.52	1.477	0.63	42.15
		007	41.25	33.83	0.81	34.64	45.00	1.975	41.32	1.478	0.72	42.04
		008	41.25	35.00	0.95	35.96	45.00	1.974	41.65	1.479	0.55	42.20
		009	41.25	35.06	1.09	36.15	45.00	1.977	41.77	1.481	0.44	42.21
		010	41.25	34.96	0.82	35.78	45.00	1.974	41.45	1.474	0.66	42.11
		011	43.50	38.15	0.89	39.04	45.00	1.972	41.89	1.481	0.31	42.20
		012	43.50	38.25	1.06	39.31	45.00	1.981	41.87	1.485	0.23	42.10
		013	43.50	37.82	1.22	39.04	45.00	1.979	41.85	1.483	0.31	42.16
		014	43.50	38.18	1.03	39.21	45.00	1.978	41.92	1.484	0.26	42.18
		015	43.50	38.36	0.90	39.26	45.00	1.975	41.89	1.478	0.32	42.21
		016	45.00	39.62	0.77	40.39	45.00	1.982	42.09	1.481	0.43	42.52
		017	45.00	39.33	0.85	40.18	45.00	1.987	41.90	1.478	0.53	42.43
		018	45.00	39.39	0.76	40.15	45.00	1.981	42.28	1.479	0.41	42.69
		019	45.00	39.07	1.10	40.17	45.00	1.982	41.82	1.481	0.55	42.37
		020	45.00	39.29	0.64	39.93	45.00	1.980	41.63	1.481	0.70	42.33
		021	42.00	34.95	2.32	37.27	45.00	1.971	41.61	1.482	0.51	42.12
		022	42.00	35.52	1.75	37.27	45.00	1.974	41.56	1.482	0.50	42.06
		023	42.00	36.27	1.20	37.47	45.00	1.978	41.64	1.484	0.28	41.92
		024	42.00	36.50	1.03	37.53	45.00	1.978	41.88	1.482	0.27	42.15
		025	42.00	36.39	1.06	37.45	45.00	1.976	41.73	1.482	0.36	42.09
		026	41.25	34.42	1.38	35.80	45.00	1.985	41.93	1.481	0.52	42.45
		027	41.25	34.59	1.06	35.65	45.00	1.986	41.63	1.483	0.78	42.41
		028	41.25	33.57	1.98	35.55	45.00	1.986	42.17	1.483	0.51	42.74
		029	41.25	34.33	1.45	35.78	45.00	1.987	42.25	1.483	0.40	42.65
		030	41.25	34.07	1.58	35.65	45.00	1.991	42.23	1.481	0.42	42.65
		031	44.25	38.42	0.98	39.40	45.00	1.980	42.75	1.484	0.51	43.26
		032	44.25	37.84	1.51	39.25	45.00	1.978	42.58	1.483	0.53	43.11
		033	44.25	38.58	0.80	39.38	45.00	1.997	42.39	1.481	0.63	43.02
		034	44.25	38.44	0.91	39.35	45.00	1.996	42.54	1.480	0.68	43.22
I	1	035	44.25	38.67	1.00	39.67	45.00	1.986	42.64	1.476	0.51	43.13

TABLE II

FORMATION CYCLES DATA
CELL TYPE HS40-7
TASK I, LOT 2

CELL TYPE	HS40-7		FORMATION CYCLE NO. 1				FORMATION CYCLE NO. 2					
TASK NO.	LOT or GRP. NO.	CELL NO.	CHARGE INPUT (AH)	DISCHARGE OUTPUT TO 1.00V (AH)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)	CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE (V)	DISCHARGE OUTPUT TO 1.00V (AH)	DISCHARGE PLATEAU VOLTAGE (V)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)
I	2	036	41.25	35.93	1.12	37.05	45.00	1.980	42.01	1.482	0.43	42.44
		037	41.25	35.63	1.37	37.00	45.00	1.980	42.06	1.486	0.39	42.45
		038	41.25	35.62	1.55	37.17	45.00	1.984	41.49	1.485	0.53	42.02
		039	41.25	35.12	1.74	36.86	45.00	1.986	41.93	1.485	0.51	42.44
		040	41.25	35.78	1.26	37.04	45.00	1.985	41.79	1.476	0.53	42.32
		041	42.75	37.91	1.01	38.92	45.00	1.977	41.16	1.482	0.43	41.59
		042	42.75	37.87	0.98	38.85	45.00	1.973	40.90	1.483	0.63	41.53
		043	42.75	37.80	1.11	38.91	45.00	1.973	40.81	1.483	0.58	41.39
		044	42.75	37.34	1.56	38.90	45.00	1.973	40.88	1.483	0.80	41.68
		045	36.00	30.51	1.23	31.74	45.00	1.972	41.80	1.480	0.50	42.30
		046	39.75	34.72	1.21	35.93	45.00	1.973	40.69	1.485	0.34	41.03
		047	39.75	34.61	1.22	35.83	45.00	1.974	40.71	1.481	0.39	41.08
		048	39.75	35.50	0.90	35.90	45.00	1.978	40.60	1.486	0.52	41.12
		049	39.75	34.92	1.03	35.95	46.00	1.978	41.06	1.483	0.37	41.43
		050	41.17	35.29	0.70	35.99	45.00	1.987	41.70	1.473	0.13	41.83
		051	39.75	34.32	1.20	35.52	45.00	1.981	42.22	1.487	0.34	42.56
		052	39.75	34.59	1.03	35.62	45.00	1.977	41.95	1.484	0.37	42.32
		053	39.75	34.46	1.13	35.59	45.00	1.979	42.07	1.490	0.46	42.53
		054	39.75	34.96	1.25	35.21	45.00	1.984	42.32	1.487	0.44	42.76
		055	39.75	34.29	1.15	35.44	45.00	1.979	41.96	1.478	0.50	42.46
		056	40.13	35.42	1.29	36.71	45.00	1.982	41.73	1.475	0.40	42.13
		057	40.13	35.80	1.08	36.88	45.00	1.980	41.40	1.484	0.44	41.84
		058	36.00	30.99	0.98	31.97	45.00	1.976	41.65	1.480	0.35	42.00
		059	40.13	35.74	1.11	36.85	45.00	1.989	41.46	1.483	0.56	42.02
		060	40.13	35.83	1.01	36.84	45.00	1.986	41.75	1.481	0.49	42.24
		061	40.50	34.97	1.00	35.97	45.00	1.987	41.45	1.479	0.64	42.09
		062	40.50	34.50	1.49	35.99	45.00	1.978	41.75	1.489	0.39	42.14
		063	40.50	34.11	1.79	35.90	45.00	1.983	41.89	1.466	0.30	42.19
		064	40.50	35.20	0.91	36.11	45.00	1.980	42.09	1.492	0.33	42.42
		065	40.50	35.20	1.05	36.25	45.00	1.982	42.06	1.492	0.31	42.37
		066	39.75	33.85	1.27	35.12	45.00	1.988	42.88	1.483	0.45	43.33
		067	39.75	33.63	1.47	35.10	45.00	1.989	42.94	1.488	0.52	43.46
		068	39.75	32.03	2.73	34.76	45.00	1.990	42.80	1.486	0.56	43.36
		069	39.75	33.24	2.35	34.59	45.00	1.992	42.91	1.487	0.44	43.35
I	2	070	39.75	32.32	2.30	34.62	45.00	1.989	42.68	1.488	0.71	43.39

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TABLE III

FORMATION CYCLES DATA
CELL TYPE HS40-7
TASK I, LOT 3

CELL TYPE HS40-7			FORMATION CYCLE NO. 1				FORMATION CYCLE NO. 2					
TASK NO.	LOT or GRP. NO.	CELL NO.	CHARGE INPUT (AH)	DISCHARGE OUTPUT TO 1.00V (AH)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)	CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE (V)	DISCHARGE OUTPUT TO 1.00V (AH)	DISCHARGE PLATEAU VOLTAGE (V)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)
I	3	071	36.00	31.16	0.83	31.99	45.00	1.971	41.35	1.484	0.35	41.70
		072	36.00	30.74	1.19	31.93	45.00	1.979	41.32	1.473	0.34	41.66
		073	36.00	30.68	1.53	32.21	45.00	1.987	42.34	1.483	0.38	42.74
		074	36.00	31.14	1.03	32.17	45.00	1.985	42.20	1.481	0.34	42.54
		075	36.00	31.05	1.06	32.11	45.00	1.988	42.15	1.481	0.40	42.55
		076	36.45	32.[illegible]	1.26	33.30	45.00	1.981	40.79	1.478	0.47	41.26
		077	36.00	31.21	1.13	32.34	45.00	1.990	42.36	1.482	0.33	42.69
		078	36.00	31.45	0.93	32.38	45.00	1.993	42.46	1.483	0.33	42.79
		079	38.05	32.81	1.20	34.01	45.00	1.978	41.70	1.481	0.34	42.04
		080	36.45	32.70	0.76	33.46	45.00	1.988	40.95	1.478	0.38	41.33
		081	38.05	32.71	1.15	33.86	45.00	1.973	41.49	1.481	0.34	41.83
		082	38.05	32.63	1.20	33.83	45.00	1.974	41.49	1.482	0.33	41.82
		083	38.05	32.78	0.99	33.77	45.00	1.977	41.49	1.480	0.51	42.00
		084	38.05	32.57	1.23	33.80	45.00	1.978	41.59	1.476	0.34	41.93
		085	36.00	30.82	1.25	32.07	45.00	1.984	42.19	1.480	0.33	42.52
		086	36.00	30.56	1.26	31.82	45.00	1.985	42.09	1.482	0.46	42.55
		087	36.00	31.03	1.08	32.11	45.00	1.980	42.30	1.482	0.45	42.75
		088	36.00	31.01	1.13	32.14	45.00	1.981	42.30	1.482	0.43	42.73
		089	36.00	30.49	1.39	31.88	45.00	1.987	42.19	1.484	0.38	42.57
		090	36.45	31.80	1.30	33.10	45.00	1.972	41.80	1.479	0.42	42.22
		091	36.45	31.92	1.24	33.16	45.00	1.973	41.62	1.478	0.53	42.15
		092	36.45	31.83	1.33	33.16	45.00	1.960	41.79	1.490	0.27	42.06
		093	36.45	31.94	1.06	33.01	45.00	1.965	41.82	1.486	0.31	42.13
		094	36.45	31.69	1.40	33.09	45.00	1.967	41.71	1.482	0.31	42.02
		095	36.00	31.73	0.88	32.61	45.00	1.968	41.97	1.485	0.33	42.30
		096	36.00	31.72	0.88	32.60	45.00	1.976	42.07	1.484	0.26	42.33
		097	36.00	31.56	0.95	32.51	45.00	1.977	42.09	1.489	0.29	42.38
		098	34.50	30.06	0.97	31.03	45.00	1.980	41.90	1.484	0.37	42.27
		099	36.00	31.44	1.03	32.47	45.00	1.973	42.02	1.489	0.26	42.28
		100	36.22	32.29	1.00	33.29	45.00	1.980	40.99	1.481	0.30	41.29
		101	36.22	32.45	0.83	33.28	45.00	1.981	41.19	1.474	0.36	41.55
		102	36.22	32.45	0.85	33.30	45.00	1.982	41.29	1.490	0.36	41.65
		103	36.22	32.33	0.99	33.32	45.00	1.981	40.89	1.480	0.30	41.19
		104	36.22	32.21	0.92	33.13	45.00	1.984	41.10	1.471	0.33	41.43
I	3	105	36.45	31.89	1.23	33.12	45.00	1.988	41.07	1.476	0.43	41.50

TABLE IV

FORMATION CYCLES DATA
CELL TYPE HS40-7
TASK I, LOT 4

CELL TYPE HS40-7			FORMATION CYCLE NO. 1				FORMATION CYCLE NO. 2					
TASK NO.	LOT or GRP. NO.	CELL NO.	CHARGE INPUT (AH)	DISCHARGE ~~OUTPUT~~ TO 1.00V (AH)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)	CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE (V)	DISCHARGE OUTPUT TO 1.00V (AH)	DISCHARGE PLATEAU VOLTAGE (V)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)
I	4	106	41.17	35.49	0.56	36.05	45.00	1.987	41.79	1.473	0.19	41.99
		107	28.50	24.12	1.02	25.14	45.00	1.982	42.33	1.480	0.31	42.64
		108	28.50	24.09	1.05	25.14	45.00	1.973	42.33	1.472	0.20	42.53
		109	28.50	24.37	0.83	25.20	45.00	1.986	42.42	1.480	0.17	42.59
		110	41.17	35.49	0.53	36.02	45.00	1.989	41.79	1.481	0.23	42.02
		111	33.00	26.06	1.85	27.91	45.00	1.998	41.56	1.479	0.31	41.87
		112	33.00	26.92	1.30	28.22	45.00	1.975	42.98	1.467	0.30	43.29
		113	33.00	26.64	1.19	27.83	45.00	1.997	43.40	1.474	0.29	43.69
		114	41.17	35.49	0.86	36.35	45.00	1.988	41.49	1.482	0.23	41.72
		115	33.00	25.15	2.28	27.43	45.00	2.009	43.16	1.471	0.35	43.51
		116	33.00	27.80	1.24	29.04	45.00	1.963	40.59	1.479	0.33	40.92
		117	33.00	28.09	0.99	29.08	45.00	1.961	40.50	1.476	0.26	40.76
		118	33.00	28.20	0.99	29.19	45.00	1.964	40.39	1.488	0.26	40.65
		119	33.00	28.30	0.91	29.21	45.00	1.965	40.50	1.488	0.30	40.80
		120	33.00	28.20	1.04	29.24	45.00	1.964	40.80	1.481	0.30	41.10
		121	33.00	28.30	1.11	29.41	45.00	1.966	40.80	1.489	0.30	41.10
		122	33.00	28.40	0.96	29.36	45.00	1.975	40.99	1.487	0.33	41.32
		123	33.00	28.50	1.04	29.54	45.00	1.983	41.49	1.490	0.43	41.92
		124	33.00	28.42	1.14	29.56	45.00	1.978	41.59	1.492	0.40	41.99
		125	33.00	28.09	1.44	29.53	45.00	1.979	41.59	1.489	0.40	41.99
		126	34.50	29.19	1.17	30.36	45.00	1.985	42.19	1.470	0.57	42.76
		127	34.50	29.07	1.39	30.46	45.00	1.983	42.29	1.470	0.42	42.71
		128	41.17	35.19	0.73	35.92	45.00	1.987	41.79	1.480	0.23	42.02
		129	34.50	28.50	1.83	30.33	45.00	1.979	42.28	1.476	0.45	42.73
		130	34.50	28.69	1.50	30.19	45.00	1.979	42.28	1.476	0.46	42.74
		131	34.50	28.69	1.10	29.79	45.00	1.988	42.74	1.473	0.44	43.18
		132	34.50	28.76	1.46	30.22	45.00	1.984	42.58	1.478	0.38	42.96
		133	34.50	28.96	1.43	30.39	45.00	1.986	42.82	1.480	0.31	43.13
		134	34.50	29.08	1.40	30.48	45.00	1.984	42.57	1.480	0.49	43.06
		135	34.50	29.01	1.36	30.37	45.00	1.986	42.74	1.470	0.42	43.16
		136	37.50	31.79	1.77	33.56	45.00	1.986	42.97	1.481	0.38	43.35
		137	37.50	32.27	1.20	33.47	45.00	1.985	47.96	1.480	0.32	43.28
		139	37.50	32.24	1.29	33.53	45.00	1.977	43.01	1.479	0.08	43.09
I	4	140	37.50	31.88	1.65	33.53	45.00	1.982	43.00	1.478	0.19	43.19

TABLE V

FORMATION CYCLES DATA
CELL TYPE HS40-7
TASK I, LOT 5

CELL TYPE	HS40-7		FORMATION CYCLE NO. 1				FORMATION CYCLE NO. 2					
TASK NO.	LOT or GRP. NO.	CELL NO.	CHARGE INPUT (AH)	DISCHARGE OUTPUT TO 1.00V (AH)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)	CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE (V)	DISCHARGE OUTPUT TO 1.00V (AH)	DISCHARGE PLATEAU VOLTAGE (V)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)
I	5	141	31.50	27.28	0.93	28.81	45.00	1.989	39.99	1.486	0.33	40.32
		142	31.50	27.58	0.75	28.33	45.00	1.991	39.79	1.485	0.40	40.19
		143	31.50	27.44	0.69	28.13	45.00	1.999	39.90	1.486	0.33	40.23
		144	31.50	27.54	0.67	28.21	45.00	1.999	39.79	1.487	0.43	40.22
		145	31.50	27.48	0.70	28.18	45.00	1.999	39.79	1.480	0.36	40.15
		146	36.00	30.06	1.34	31.40	45.00	1.987	40.99	1.480	0.36	40.35
		147	36.00	29.89	1.64	30.53	45.00	1.983	41.10	1.480	0.26	41.46
		148	36.00	29.99	1.02	31.01	45.00	1.992	41.19	1.477	0.40	41.59
		149	36.00	30.18	1.10	31.28	44.07	1.999	40.39	1.479	0.40	40.79
		150	36.00	30.15	0.60	30.75	42.75	1.999	39.30	1.480	0.07	39.37
		151	37.50	32.19	0.60	32.79	43.65	1.996	39.09	1.476	0.36	39.45
		152	37.50	31.82	1.03	32.85	43.65	1.994	39.09	1.476	0.30	39.39
		153	37.50	32.09	0.73	32.82	43.65	1.990	39.19	1.479	0.33	39.52
		154	37.50	31.19	1.03	32.22	43.65	1.999	39.09	1.478	0.43	39.52
		155	37.50	32.09	0.47	32.56	43.65	2.000	39.09	1.473	0.26	39.35
		156	41.25	35.59	0.76	36.35	44.16	2.003	40.99	1.480	0.66	41.65
		157	41.25	35.70	0.73	36.43	44.16	2.001	40.89	1.469	0.40	41.29
		158	40.50	33.19	0.83	34.02	45.00	1.989	41.89	1.468	0.70	42.59
		159	41.25	35.19	0.83	36.02	44.16	2.001	41.49	1.476	0.20	41.69
		160	41.25	35.49	0.86	36.35	44.16	2.000	40.99	1.480	0.36	41.35
		161	40.50	34.80	0.58	35.38	45.00	1.995	40.39	1.461	0.40	40.79
		162	40.50	35.10	0.83	35.93	45.00	1.986	40.99	1.464	0.30	41.29
		163	40.50	34.99	0.90	35.89	45.00	1.993	40.89	1.459	0.40	41.29
		164	40.50	35.10	0.60	35.70	45.00	2.003	40.59	1.460	0.40	40.99
		165	40.50	34.99	0.80	35.79	45.00	2.003	40.80	1.456	0.36	41.26
		166	39.00	33.00	0.56	33.56	44.25	2.000	40.69	1.470	0.33	41.02
		167	39.00	32.89	0.63	33.52	44.25	1.999	40.39	1.471	0.53	40.92
		168	31.71	25.99	1.16	27.15	43.50	2.000	39.30	1.470	0.53	39.83
		169	39.00	32.79	0.66	33.45	43.99	2.000	40.29	1.475	0.40	40.69
		170	39.00	32.70	0.56	33.26	43.87	2.000	39.79	1.467	0.60	40.39
		171	40.50	34.39	1.00	35.39	45.00	2.000	40.80	1.474	0.60	41.40
		172	40.50	34.59	0.96	35.55	45.00	1.984	40.89	1.471	0.56	41.45
		173	40.50	34.69	0.73	35.42	45.00	1.989	40.80	1.470	0.53	41.33
		174	40.50	35.10	0.60	35.70	45.00	1.999	40.99	1.468	0.50	41.49
I	5	175	40.50	34.99	0.73	35.72	45.00	1.992	40.99	1.470	0.53	41.52

7.7 Following the completion of Formation Cycle No. 1, each vented cell was heat treated for twenty-four (24) hours at a temperature of 100°C while sealed in a cylindrical steel bomb. To minimize the presence of carbon dioxide, the bomb enclosure was purged with dry nitrogen prior to sealing. The pressure within the bomb and the temperature in the oven were recorded as a function of time during the heat treatment. At the end of the twenty-four (24) hour period, the oven was turned off and allowed to return to room temperature.

7.8 During the manufacture of Lot 1 and Lot 2 cells, an experiment was conducted to determine the approximate loss of water from the cell electrolyte during heat treatment for normal and extended periods of time. Five (5) cells from Lot 1 (S/N's 031 through 035) were exposed to 100°C temperature, while enclosed in pressure vessels, for 196 hours. The loss in cell weight due to this elevated temperature exposure was between 1.9 and 2.3 grams with an average loss of 2.08 grams. The cells were brought back to their original weight by the addition of distilled water to each cell. Five (5) cells from Lot 2 (S/N's 036 through 040) were checked for weight loss during the normal 24 hours of heat treatment. The loss in cell weight for the cells of this group was between 0.8 and 1.4 grams with an average loss of 1.10 grams.

7.9 Each cell was removed from the bomb and the cell vent was thoroughly cleaned of any electrolyte residue. A molded vent plug was cemented into place in the threaded vent hole using Allbond Epoxy.

7.10 The entire cell top cavity and the cell terminal hardware were thoroughly cleaned and dried. The cell top was then completely filled with Allbond Epoxy. The epoxy encapsulated the cell terminal washer, the vertical surfaces of the terminal nut and the top surface of the cell case. The epoxy was allowed to cure at room temperature for 16 - 24 hours.

7.11 The sealed cell was given a second formation cycle using the same equipment and procedures used in Formation Cycle No. 1. Cells delivering 40 ampere-hours output at the 6.0A discharge rate with a plateau voltage of 1.42 volts or higher were considered acceptable for shipment to NASA Lewis Research Center. Of the one hundred seventy-five (175) cells given Formation Cycle No. 2, thirteen (13) cells failed to deliver the required 40 ampere-hours discharge capacity output. All thirteen (13) cells were from Lot 5 which exhibited generally a lower discharge capacity output. The thirteen (13) cells were given an elevated temperature soak for 48 hours at 40°C after which a third formation cycle was performed. Eight (8) of the cells delivered the required discharge capacity output during the third formation cycle discharge. The remaining five (5) cells were given an additional elevated temperature soak for 48 hours at 40°C followed by a fourth formation cycle. All five (5) cells gave the required discharge capacity output during the fourth formation cycle discharge. The results of the two (2) additional formation cycles are given in Table VI. A thorough review and analysis of cell material traceability, fabrication, processing and inspection data indicate that the cause of the lower capacity in Lot 5 cells was an increase in the average thickness of ceramic coating on separator bags. Coating thickness on cell Lot 1 through Lot 4 separator bags had averaged 0.256mm and the average coating thickness for cell Lot 5 separator bags was 0.267mm.

7.12 The Formation Cycle No. 2 charge input capacity, cell voltage at the end of charge, discharge output capacity, cell plateau voltage, and low rate drain capacity for each cell are given in Tables I through V.

8. Cell Finishing and Shipment

8.1 Following the second formation cycle, each cell was removed from its restraining fixture, weighed to the nearest gram, cleaned, inspected dimensionally and returned to its restraining fixture. Permanent polarity indication was marked on the top of the cell adjacent to the positive terminal. The cell case on the positive side was permanently marked with the cell assembly code date, the cell serial number, the cell type, the letters "NASA" and inspection status marking. The negative side of the cell case was permanently marked with the cell filling date code and the words "YARDNEY ELECTRIC CORPORATION". The final inspection of each cell was then completed and each individual cell was packaged in a separate unit cell container designed to accomodate a single cell restrained between two (2) steel plates. Several such unit cell packages were then packed in wooden crates for shipment.

8.2 With the exception of two (2) cells (Lot 2, S/N 069 and 070) all of the cells manufactured during the performance of this task were shipped to NASA Lewis Research Center. The two (2) cells noted above were used as a control group during the cell test program described in Task IV of this report.

TABLE VI

ADDITIONAL
FORMATION CYCLES DATA
CELL TYPE HS40-7
TASK I, LOT 5

CELL TYPE HS40-7			FORMATION CYCLE NO. 3				FORMATION CYCLE NO. 4					
TASK NO.	LOT or GRP. NO.	CELL NO.	CHARGE INPUT	DISCHARGE OUTPUT TO 1.00V	DRAIN OUTPUT TO 1.00V	TOTAL OUTPUT	CHARGE INPUT	VOLTAGE AT END OF CHARGE	DISCHARGE OUTPUT TO 1.00V	DISCHARGE PLATEAU VOLTAGE	DRAIN OUTPUT TO 1.00V	TOTAL OUTPUT
			(AH)	(AH)	(AH)	(AH)	(AH)	(V)	(AH)	(V)	(AH)	(AH)
I	5	141	45.00	41.59	0.76	42.35						
		142	45.00	41.40	0.96	43.36						
		143	45.00	41.29	0.93	42.22						
		144	45.00	41.59	0.80	42.39						
		145	45.00	41.59	0.80	42.39						
		150	43.50	41.49	0.63	42.12						
		151	42.75	40.01	0.93	40.94						
		152	40.95	38.90	0.80	39.70	43.80		41.53	1.479	1.21	42.74
		153	42.45	40.30	0.56	40.86						
		154	42.00	39.30	0.73	40.03	43.80		41.90	1.479	1.11	43.01
		155	41.07	39.00	0.76	39.76	43.80		41.90	1.481	1.20	43.10
		168	41.07	38.80	0.66	39.46	43.80		42.00	1.478	1.03	43.03
I	5	170	42.15	39.23	0.96	40.19	43.80		41.64	1.479	1.30	42.94

TASK II - CONSTRUCT TWENTY-FOUR (24) 40AH EXPERIMENTAL CELLS

1. Objective of Task

The objective of this task was to construct six (6) groups of 40AH cells, each four (4) cell group containing one (1) variation in cell materials or one (1) change in processing technique.

2. Cell Materials

With the exception of the substitutions described under Cell Fabrication, the cell materials used in the groups of cells constructed for this task were the same as those used in Task I cells.

3. Cell Fabrication

The fabrication and processing techniques used during the construction of the twenty-four (24) cells in this task were, wherever possible, the same as those used during the manufacture of the cells in Task I. The following discussion of the individual groups of cells points out those deviations necessitated by the incorporation of the various experimental modifications specified.

3.1 Group 1 - The cells of this group used silver electrodes which were produced on the Yardney continuous process rolling mill. The silver powder used was Yardney Type HS which conformed to Yardney Specification YEC-207. The dimensions and the weight of the active material of these electrodes was the same as the mold pressed electrodes produced in accordance with Drawing No. 1D12571. Two (2) pieces of 0.64cm wide x 0.10mm thick fine silver strip were welded onto the electrode, one (1) on either side, to effect conductor tab attachment. A single piece of the heat shrink tubing was used to insulate the dual tabs on the electrode.

3.2 Group 2 - The experimental modification initially specified for this group was the use of Handy and Harman "Silpowder 130" in manufacturing positive electrodes by the Yardney continuous process rolling mill techniques. It was found, after some experimentation, that Silpowder 130 was not compatable with the rolling mill process. By technical direction from the NASA Project Manager, the modification was changed to the use of Yardney Type HC silver powder. Other than the difference in silver powder type, the electrode fabrication was identical to that of Group 1.

3.3 Group 3 - An alternate method of impregnating sheets of

0.25mm thick fuel cell grade asbestos was introduced into the processing of separators for Group 3 cells. The sheet of asbestos was formed into a tube and slowly immersed, open end first, in the impregnating solution contained in a glass cylinder with approximately 6.5cm larger inside diameter than the diameter of the asbestos tube. The sheet was slowly withdrawn from the solution and allowed to dry for a short period in moving air at room temperature while still formed into a tube. The tubes were then opened and the balance of the drying was done with the sheets hanging by one corner in moving air at room temperature. The impregnated (treated) sheets were processed by normal methods during the remaining separator fabrication. A control group of asbestos sheets was impregnated by normal methods at the same time using impregnating solution and asbestos sheets from the same batches. A comparison of the materials produced by the two methods showed almost no difference in percentage of weight gain in the asbestos material due to impregnation. It was noted, however, that the asbestos impregnated by the normal method was considerably more hygroscopic than the "cylinder dip" impregnated material.

3.4 Group 4 - The impregnating solution and ceramic filled slurry used to process and fabricate the separators for Group 4 cells used trichloroethylene as the solvent. Trichloroethylene was substituted for chloroform on an equal volume basis. No significant difference was noted in any processing step leading up to the application of slurry to the asbestos bag. Difficulties were encountered during the slurry application process in that the cast coating on the bag had a tendency to crack. The cracking occurred in the area between the heat seal of the asbestos bag and the radii in the bag material where the bag was formed for electrode insertion. Attempts to eliminate the cracking by varying the slurry viscosity, and the concentration of solvent in the atmosphere in which the dipped bag was dried were to no avail. By technical direction from the NASA Project Manager the definition of the modification for the experimental cell group was changed.

The revised definition of the process variation to be incorporated in Group 4 cells called for the bagged positive and negative electrodes to be given only one (1) dipping in the normal ceramic filled slurry to achieve a coating thickness of 0.05 to 0.07mm per side. The 0.55 to 0.83mm decrease in cell stack thickness was compensated for by using two (2) additional 0.13mm thick Teflon film assembly strips on the outside of the cell stack.

3.5 Group 5 - The fuel cell grade asbestos used to fabricate the separator bags for this group of cells was impregnated by the vendor. With this process already completed, the material was cut to separator bag size and processed in the normal manner.

3.6 Group 6 - The negative electrodes fabricated for the cells of this group utilized an absorber mat manufactured by Yardney in place of the standard mat. The Yardney material used was Type YIFL-II made in accordance with Yardney specification YP-614. Pieces of this material were pressed onto both surfaces of each negative electrode.

4. Cell Filling and Formation

Each of the twenty-four (24) cells was filled and given formation cycles as described under Task I. The results of the two (2) formation cycles is given in Table VII. Upon completion of formation cycles, the cells were either shipped to NASA Lewis Research Center or transferred to the experimental cell evaluation program conducted under Task IV. Disposition of the twenty-four (24) cells was as follows:

Group No.	No.'s Shipped to NASA	No.'s Retained for Testing
1	003 and 004	001 and 002
2	002 and 004	001 and 003
3	001 and 002	003 and 004
4	001 through 004	None
5	001 and 004	002 and 003
6	002 and 003	001 and 002

TABLE VII

FORMATION CYCLES DATA
EXPERIMENTAL 40AH SEALED
SILVER-ZINC CELLS, TASK II
GROUPS 1 THROUGH 6

CELL TYPE	EXPERIMENTAL 40 AH CELLS		FORMATION CYCLE NO. 1				FORMATION CYCLE NO. 2					
TASK NO.	LOT or GRP. NO.	CELL NO.	CHARGE INPUT (AH)	DISCHARGE OUTPUT TO 1.00V (AH)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)	CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE (V)	DISCHARGE OUTPUT TO 1.00V (AH)	DISCHARGE PLATEAU VOLTAGE (V)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)
II	1	001	45.00	37.58	0.77	38.35	39.75	1.999	37.33	1.488	0.37	37.70
		002	45.00	38.03	0.44	38.47	39.75	1.990	37.57	1.486	0.35	37.92
		003	45.00	37.74	0.55	38.29	39.75	2.002	37.42	1.486	0.47	37.89
		004	45.00	37.80	0.56	38.36	39.75	2.002	37.26	1.487	0.35	37.61
II	2	001	35.25	31.80	0.27	32.07	38.25	1.997	34.09	1.491	0.27	34.36
		002	35.25	31.77	0.32	32.09	38.25	2.000	33.92	1.490	0.37	34.29
		003	35.25	31.75	0.38	32.13	36.00	1.998	31.93	1.490	0.42	32.35
		004	35.25	31.83	0.34	32.17	37.13	1.999	33.32	1.488	0.19	33.51
II	3	001	37.50	31.84	1.21	33.05	45.00	1.996	42.99	1.481	0.44	43.43
		002	37.50	31.65	1.43	33.08	45.00	1.997	42.98	1.472	0.44	43.42
		003	37.50	31.23	1.73	32.96	45.00	1.996	43.02	1.481	0.50	43.52
		004	37.50	31.24	1.51	32.75	45.00	1.996	43.18	1.481	0.54	43.72
II	4	001	31.50	28.05	0.65	28.70	45.00	1.995	42.09	1.481	0.70	42.79
		002	31.50	28.06	0.77	28.83	45.00	1.987	42.21	1.465	0.61	42.82
		003	31.50	27.16	1.23	28.39	44.25	1.999	41.43	1.485	0.78	42.21
		004	31.50	27.69	0.91	28.60	45.00	1.996	42.23	1.485	0.69	42.92
II	5	001	40.50	35.16	1.18	36.34	45.00	2.000	42.34	1.483	0.30	42.64
		002	40.50	34.88	1.51	36.40	45.00	1.983	42.30	1.483	0.33	42.63
		003	40.50	35.30	0.93	36.23	45.00	2.002	42.09	1.482	0.45	42.57
		004	40.50	35.27	1.02	36.29	44.25	2.004	41.35	1.484	0.48	41.83
II	6	001	45.00	37.99	0.64	38.63	43.86	2.002	40.17	1.473	0.43	40.60
		002	45.00	37.97	0.80	28.77	45.00	2.002	41.40	1.465	0.40	41.80
		003	45.00	38.19	0.66	38.85	45.00	1.995	41.20	1.475	0.34	41.54
		004	45.00	38.12	0.63	38.75	45.00	2.002	41.12	1.476	0.48	41.60

TASK III - 12 AMPERE-HOUR EXPERIMENTAL CELL FABRICATION

1. Objective of Task

The objective of this task was to fabricate one hundred forty (140) 12 ampere-hour sealed silver-zinc cells in groups of the size and experimental configuration specified or approved by the NASA Project Manager.

2. Cell Materials

Except as noted in the discussion of experimental cell configurations, the materials used to fabricate the 12 ampere-hour experimental cells were the following:

2.1 The conductor grid material for the positive electrodes was Exmet product 3Ag10-3/0.

2.2 The conductor grid material for the negative electrodes was Exmet product 5Ag52-1 DISTEX.

2.3 The conductor lead material for both the positive and negative electrode conductor grid assemblies was fine silver wire, 0.40mm diameter. Four (4) strands of this material were attached to each conductor grid.

2.4 The positive electrode active material was silver powder, Handy and Harman product "Silpowder 130", purchased in accordance with Drawing No. 1D12572 and Handy and Harman specifications for Silpowder 130.

2.5 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 22.7Kg of powder.

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

2.7 The electrolyte used was a 45 percent (45%) solution of potassium hydroxide, "Baker Analyzed" reagent grade packaged in one (1) pint, sealed polyethylene bottles. One (1) pint of this electrolyte was sufficient to fill twelve (12) of the 12 ampere-hour cells.

2.8 The Allbond epoxy used to seal the cell terminal hardware to the cell cover was purchased from Bacon Industries, Inc.

in kit form, each kit containing 0.5 liter of resin and 0.5 liter of hardener.

2.9 The inert material used for the sling, to aid in positioning the cell stack inside the cell case, was Teflon film, 0.13mm thick.

2.10 The cell case was molded to conform to Yardney Drawing No. 2569R-2. This part and the cell cover were molded using 30% glass fortified polyphenylene oxide.

2.11 The cell cover was molded to conform to Yardney Drawing No. 2570R-2. The molded cover was modified by machining the sides to create a 0.76mm wide x 0.38cm deep area around the cover for sealing compound. The cover vent hole was threaded to accept a sealing screw with a #8-32 thread.

2.12 The terminal assembly consisted of three parts:

- Yardney Part No. 2709-3, 1/4-28 screw terminal with No. 34 hole;
- Yardney Part No. 2710-3, nut, hex 1/4-28;
- Yardney Part No. 2711-3, washer for 1/4" terminal.

These parts are machined or punched from brass stock and gold-plated per MIL-G-14548A, Type II, Class 1, over silver-plating per QQ-S-365, Type III.

2.13 The epoxy used to encapsulate the area where the electrode leads enter the terminal hole was Type RB3-1, manufactured by Bacon Industries.

2.14 The threaded sealing plug was machined from 0.95cm diameter Noryl rod stock.

2.15 The compound used to effect a seal between the cell case and cell cover assembly was Yardney Type E-600 per Yardney Specification YEC1603.

3. Cell Fabrication

Except as noted in the discussion of Experimental Cell Configurations, the 12 ampere-hour cells were fabricated by the methods and to the dimensions described in this report section.

3.1 Negative Electrode Fabrication

3.1.1 Each 12 ampere-hour cell contained two (2) negative electrodes consisting of negative mix, a conductor grid assembly and negative absorber mats.

3.1.2 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, which was then placed in a Despatch oven and allowed to dry overnight at approximately 70°C. A sample of the negative mix was then 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.

3.1.3 The negative electrode conductor grid assembly consisted of DISTEX 5Ag52-1 cut to 7.54cm x 4.12cm and welded to four (4) strands of 0.40mm diameter fine silver wire. The expanded metal mesh pieces were cut to size and cleaned in an ultrasonic bath using acetone as the cleaning agent. Using a locating fixture to properly orient the grid in relation to the four (4) wires, the wires were welded to the grid using a 50KVA resistance welder with tungstenite tips.

3.1.4 Each negative electrode used two (2) absorber layers cut from potassium titanate paper furnished to the contractor by NASA Lewis Research Center. The particular material was coded product LPM174-67 and was manufactured by the Mead Corporation.

3.1.5 In fabricating the negative electrode, 21 grams of negative mix were weighed out. Using the negative electrode mold, one (1) piece of potassium titanate paper was placed in the bottom of the mold. Fifty percent (50%) of the volume of negative mix was then poured into the mold on top of the potassium titanate paper. This mix was then spread evenly with a tamping tool. Next, a collector-grid assembly was positioned in the mold so that it would lie flat on the mix; then the remainder of the mix was poured on top of the collector-grid assembly and again spread evenly, using a tamping tool. A second piece of potassium titanate paper was placed on the top of the mix in the mold followed by positioning of the top punch into the mold. The filled mold was then positioned between the platens of a hydraulic press and pressed at 36,000 kg. to compact the negative electrode mix around the collector-grid assembly.

3.1.6 Each electrode was measured to determine that the width was 4.18 - 4.23cm, that the length was 7.59 - 7.64cm, that the thickness was in the range of 0.284 - 0.294cm, and that the weight was in the range of 24.8 - 26.8 grams.

3.1.7 Following acceptance of each electrode on the basis of dimensions and weight, a plastic sleeve was positioned over the electrode tab and a numbered identification tab was attached to the end of the tab. The edges of acceptable electrodes were reinforced by a light application of a two percent (2%) solution of PPO in chloroform.

3.1.8 Negative electrode sub-assemblies in this condition, together with appropriate traceability data, were stored in plastic boxes to await subsequent operations.

3.2 Positive Electrode Fabrication

3.2.1 Each 12 ampere-hour cell contained three (3) positive electrodes consisting of silver powder and a conductor grid assembly.

3.2.2 A positive electrode conductor grid assembly was fabricated by welding four (4) strands of 0.40mm diameter fine silver wire to a 7.54 x 4.12cm piece of Exmet 3Ag10-3/0 expanded metal mesh. Proper lead-to-grid alignment and positioning was achieved with locating fixtures. The conductor grid was ultrasonically cleaned with acetone before and after the lead welding operation.

3.2.3 The positive electrode assembly fabrication was accomplished by evenly distributing 13.4 grams of "Silpowder 130" around the conductor grid assembly in matched metal molds and pressing to the specification thickness in a 91,000 kilograms hydraulic press. Electrode thickness was 0.86 - 0.91mm.

3.2.4 Following the pressing operation, each positive electrode sub-assembly was dried at 125°C for one (1) hour to remove any residual moisture prior to the sintering operation.

3.2.5 The dried positive electrode sub-assembly was then sintered at 650°C for a period of four (4) minutes. This sintering produced a strong mechanical bond due to physical coalescence of the particles of "Silpowder 130" to each other and due to the cementing action of the sintering process, resulting in binding of the powder particles to the conductor grid.

3.2.6 The molding of the positive electrode was done in a three (3) piece compression mold consisting of a base plate, a mold ring and a punch. During the pressing operation, the electrode components were pressed to a fixed dimension rather than using a pre-determined force. This was done to consistently control the thickness of the finished pressed electrode.

3.2.7 Following the sintering operation, positive electrode sub-assemblies were given 100 percent inspection to eliminate electrodes which might have mechanical defects, evidence of contamination or variance from dimensional and weight requirements. Those electrodes passing the 100 percent inspection had insulating sleeves applied to the leads and identifying serial numbers were attached to the leads at this point.

3.3 Separator Processing and Fabrication

3.3.1 The processing and fabrication of inorganic separators for the 12 ampere-hour cells was carried out in accordance with proprietary procedures supplied by NASA Lewis Research Center.

3.4 Assembly of 12 Ampere-Hour Cells

Each 12 ampere-hour cell consisted of three (3) bagged positive electrodes, two (2) bagged negative electrodes, a cell case, a cell cover assembly, a vent sealing screw and case-to-cover sealing compound.

3.4.1 The cell cover assembly was fabricated by sealing the junction area between the cell terminals and the cavities in the cell cover with Allbond epoxy and securing the terminal to the cover with the terminal nut. The epoxy was allowed to cure for 16 - 24 hours at room temperature.

3.4.2 The cell pack was assembled by alternately stacking bagged positive and negative electrodes with the three (3) sets of positive leads aligned on one side and the two (2) sets of negative leads on the opposite side of the pack. The bagged electrodes were aligned and inserted into a cell case with the aid of a protective sling of Teflon film. The electrode leads were formed to relieve any pressure on the electrodes or separators and threaded up through their respective terminals in a cell cover assembly. The cell stack was completely inserted in the cell case and the cell cover was positioned in the cell case cavity. Excess lead length was cut off flush with the top of the cell terminals and the electrode leads were soldered into their respective terminals. The underside of the cell terminals where the electrode leads enter the terminal was filled and encapsulated with RB3-1 epoxy to protect the lead-solder-terminal junction from corrosion by electrolyte. Having marked the positive electrode terminal and trimmed off excess protective sling material, the cell pack and cover assembly was again positioned in the cell case. The sealing area between the cell case and cover was completely filled with epoxy sealing compound. When this compound was cured, the wide sides of the cell case were restrained. Each cell was pressure tested with dry nitrogen gas to a gage pressure of 0.7kg/sq.cm. for ten (10) minutes. To be acceptable, the cell could manifest no sign of leakage during the test period.

3.5 Filling and Formation of Cells

3.5.1 The cells to be filled were first weighed to the nearest 0.1 gram in the dry state. The cells, the 45% solution of potassium hydroxide and all the equipment necessary to vacuum fill the cells were placed in a glove box which was flooded with dry nitrogen gas. The quantity of 30 - 31 milliliters of electrolyte were carefully premeasured and introduced into the cell. The vented cell was then placed in a vacuum chamber inside the glove box and a vacuum of 710 $\pm$ 25mm of mercury was achieved in the chamber. This vacuum was maintained for thirty (30) seconds. The chamber was then allowed to return slowly to ambient pressure. The filled cell was weighed again and the weight gain due to filling was calculated to verify that the correct amount of electrolyte was present in the cell. The cell was restrained between two (2) 3.2mm thick steel plates and left in the nitrogen atmosphere in the glove box for a soaking period of twenty-four (24) hours. Before removing the cell from the glove box, the vent plug was threaded loosely in the vent hole in the cell cover.

3.5.2 Each cell was charged for the first formation cycle at a constant current rate of 0.30A (2.3ma/sq.cm.) to a voltage, while charging, of 1.98 - 2.00 volts or until an input of 13.5 ampere-hours was achieved, whichever occurred first. The cells were discharged at 1.8 amperes (13.8ma/sq.cm.) to a voltage, while discharging, of 1.00 volt. The discharged cell was then low rate drained at a constant current rate of 0.6A (4.6ma/sq.cm.) to a voltage, while draining, of 1.00 volt. The cell voltage was monitored and recorded as a function of time during the charge, discharge and drain portions of the formation cycle. The cell input and output capacities were calculated and recorded. A summary of the data generated during the performance of the first formation cycle on 12 ampere-hour cells is given in Tables VIII through XI.

3.5.3 Following the completion of Formation Cycle No. 1, each vented cell was heat treated for twenty-four (24) hours at a temperature of 100°C while sealed in a cylindrical steel bomb. To minimize the presence of carbon dioxide, the bomb enclosure was purged with dry nitrogen prior to sealing. The pressure within the bomb and the temperature in the oven were recorded as a

TABLE VIII

FORMATION CYCLES DATA
EXPERIMENTAL 12AH SEALED
SILVER-ZINC CELLS, TASK III
GROUPS 5 THROUGH 9

CELL TYPE EXPERIMENTAL 12 AH CELLS			FORMATION CYCLE NO. 1				FORMATION CYCLE NO. 2					
TASK NO.	LOT or GRP. NO.	CELL NO.	CHARGE INPUT (AH)	DISCHARGE OUTPUT TO 1.00V (AH)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)	CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE (V)	DISCHARGE OUTPUT TO 1.00V (AH)	DISCHARGE PLATEAU VOLTAGE (V)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)
III	5	001	9.00	7.16	0.68	7.84	13.50	1.992	12.58	1.423	0.22	12.80
		002	8.40	6.58	0.59	7.17	13.50	1.994	12.45	1.419	0.28	12.73
		003	9.00	6.92	0.91	7.83	13.50	1.988	12.55	1.428	0.23	12.78
		004	9.75	8.03	0.48	8.51	13.50	1.985	12.52	1.429	0.20	12.72
III	6	001	13.20	10.41	0.40	10.81	12.00	2.002	11.63	1.411	0.11	11.74
		002	13.50	10.58	0.52	11.10	12.00	2.003	11.20	1.430	0.15	11.35
		003	13.50	10.93	0.19	11.12	12.00	2.001	11.68	1.428	0.09	11.77
		004	13.50	10.68	0.61	11.29	12.00	2.002	11.66	1.433	0.12	11.78
III	7	001	9.30	8.32	0.55	8.87	11.70	2.001	10.61	1.403	0.56	11.17
		002	9.30	8.31	0.44	8.75	12.39	2.002	11.52	1.415	0.47	11.99
		003	9.30	8.29	0.65	8.94	13.35	1.999	12.12	1.434	0.50	12.62
		004	9.30	8.38	0.56	8.94	13.35	1.999	11.69	1.417	1.04	12.73
III	8	001	9.75	8.54	0.55	9.09	11.10	1.999	10.55	1.433	0.31	10.86
		002	9.45	8.22	0.37	8.59	11.10	1.999	10.61	1.415	0.27	10.88
		003	9.45	8.11	0.38	8.49	12.90	2.001	12.32	1.398	0.25	12.57
		004	9.00	7.77	0.40	8.17	10.80	2.001	10.20	1.419	0.34	10.54
III	9	001	8.10	6.40	0.45	6.85	10.80	2.001	9.90	1.414	0.27	10.17
		002	8.10	6.51	0.44	6.95	11.10	1.999	10.40	1.414	0.25	10.65
		003	8.10	6.36	0.47	6.83	10.80	2.000	10.04	1.402	0.30	10.34
		004	8.10	6.35	0.34	6.69	11.40	2.002	10.69	1.406	0.25	10.94

TABLE IX

FORMATION CYCLES DATA
EXPERIMENTAL 12AH SEALED
SILVER-ZINC CELLS, TASK III
GROUP 10

Sheet 1 of 2

CELL TYPE	12 AH CELLS		FORMATION CYCLE NO. 1				FORMATION CYCLE NO. 2					
TASK NO.	LOT or GRP. NO.	CELL NO.	CHARGE INPUT (AH)	DISCHARGE OUTPUT TO 1.00V (AH)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)	CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE (V)	DISCHARGE OUTPUT TO 1.00V (AH)	DISCHARGE PLATEAU VOLTAGE (V)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)
III	10	001	9.60	7.92	0.47	8.39	13.50	2.002	12.37	1.416	0.24	12.61
		002	8.40	6.58	0.60	7.18	11.10	2.002	10.45	1.401	0.30	10.75
		003	9.60	8.16	0.35	8.51	13.50	1.992	12.33	1.423	0.25	12.58
		004	9.60	8.44	0.42	8.86	13.50	1.998	12.26	1.409	0.32	12.58
		005	9.60	8.16	0.38	8.54	13.50	1.994	12.34	1.412	0.33	12.67
		006	9.60	8.22	0.29	8.51	13.50	1.999	12.17	1.409	0.41	12.58
		007	9.90	8.35	0.43	8.78	13.50	1.994	12.29	1.417	0.28	12.57
		008	9.90	8.07	0.71	8.78	13.50	1.998	12.20	1.415	0.31	12.51
		009	9.90	8.11	0.62	8.73	13.50	2.001	11.91	1.421	0.65	12.56
		010	9.90	8.28	0.40	8.68	13.20	1.999	11.96	1.414	0.21	12.17
		011	9.90	8.31	0.37	8.68	13.50	1.999	12.21	1.416	0.27	12.48
		012	8.70	6.91	0.66	7.57	13.20	2.002	12.40	1.410	0.40	12.80
		013	9.00	7.63	0.28	7.91	12.90	2.001	12.32	1.412	0.28	12.60
		014	9.00	7.60	0.33	7.93	12.90	1.999	11.88	1.400	0.39	12.27
		015	9.00	7.65	0.25	7.90	12.90	2.002	12.37	1.429	0.21	12.58
		016	9.00	7.62	0.37	7.99	13.50	2.002	12.73	1.415	0.40	13.13
		017	7.50	6.20	0.45	6.65	13.50	1.997	12.67	1.410	0.32	12.99
		018	8.70	7.37	0.22	7.59	12.90	2.002	12.18	1.401	0.32	12.50
		019	9.00	7.55	0.33	7.88	12.60	2.000	11.98	1.402	0.26	12.24
		020	9.00	7.38	0.39	7.77	12.60	1.999	11.84	1.409	0.39	12.23
		021	9.00	7.48	0.32	7.80	13.20	2.002	12.52	1.411	0.25	12.77
		022	8.10	6.56	0.45	7.01	13.50	2.001	12.76	1.411	0.29	13.05
		023	7.80	6.30	0.39	6.69	12.90	2.000	11.86	1.403	0.52	12.38
		024	8.10	6.79	0.29	7.08	13.50	2.000	12.72	1.410	0.27	12.99
		025	8.10	6.63	0.36	6.99	12.90	1.999	12.17	1.410	0.25	12.42
		026	7.80	6.17	0.53	6.70	13.50	2.001	12.66	1.405	0.36	13.02
		027	7.80	6.53	0.23	6.76	13.50	1.999	12.44	1.396	0.31	12.75
		028	7.80	6.09	0.45	6.54	12.60	1.999	11.55	1.392	0.39	11.94
		029	7.80	5.95	0.66	6.61	13.20	2.002	12.04	1.387	0.40	12.44
		030	7.80	6.47	0.37	6.84	13.20	1.999	11.79	1.418	0.29	12.08
		031	7.80	6.56	0.26	6.82	13.50	1.997	12.27	1.395	0.43	12.70
		032	7.80	5.92	0.54	6.46	10.80	1.998	10.13	1.387	0.48	10.61
		033	7.80	6.34	0.39	6.73	10.80	2.003	10.22	1.381	0.34	10.56
		034	7.80	6.29	0.40	6.69	10.80	2.003	10.16	1.388	0.33	10.49
III	10	035	7.80	6.14	0.57	6.71	10.80	2.001	10.31	1.407	0.23	10.54

TABLE IX

FORMATION CYCLES DATA
EXPERIMENTAL 12AH SEALED
SILVER-ZINC CELLS, TASK III
GROUP 10

Sheet 2 of 2

CELL TYPE	12 AH CELLS		FORMATION CYCLE NO. 1				FORMATION CYCLE NO. 2					
TASK NO.	LOT or GRP. NO.	CELL NO.	CHARGE INPUT (AH)	DISCHARGE OUTPUT TO 1.00V (AH)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)	CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE (V)	DISCHARGE OUTPUT TO 1.00V (AH)	DISCHARGE PLATEAU VOLTAGE (V)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)
III	10	036	7.80	6.25	0.44	6.69	10.80	2.002	10.23	1.412	0.28	10.51
		037	7.80	6.30	0.37	6.67	10.80	2.003	10.27	1.402	0.28	10.55
		038	7.80	6.33	0.42	6.75	10.80	2.000	10.30	1.408	0.26	10.56
		039	7.80	6.37	0.32	6.69	10.80	2.003	10.31	1.416	0.24	10.55
		040	7.80	6.18	0.46	6.64	10.80	2.002	10.05	1.394	0.40	10.45
		041	8.40	6.63	0.42	7.05	13.20	2.002	12.11	1.411	0.47	12.58
		042	8.40	6.46	0.57	7.03	13.20	2.002	12.23	1.402	0.37	12.60
		043	9.00	6.40	0.47	6.87	13.20	2.003	12.17	1.406	0.45	12.62
		044	8.40	6.76	0.40	7.16	13.20	2.001	12.26	1.413	0.28	12.54
		045	9.00	6.49	0.46	6.95	13.20	2.002	12.36	1.416	0.33	12.69
		046	8.25	6.74	0.44	7.18	13.50	1.994	12.60	1.417	0.34	12.94
		047	8.25	6.58	0.52	7.10	13.50	1.992	12.58	1.425	0.31	12.89
		048	8.25	7.29	0.58	7.87	13.50	1.990	12.64	1.429	0.24	12.88
		049	8.40	6.74	0.55	7.29	13.50	1.990	12.64	1.389	0.28	12.92
		050	8.40	7.14	0.53	7.67	13.20	2.003	12.34	1.385	0.32	12.66
		051	9.15	7.39	0.53	7.92	12.60	2.002	12.01	1.402	0.26	12.27
		052	7.87	5.89	0.81	6.70	12.30	1.999	11.71	1.404	0.24	11.95
		053	7.87	6.06	0.72	6.78	12.75	1.999	12.13	1.412	0.21	12.33
		054	9.15	7.27	1.02	8.29	13.20	2.003	12.57	1.405	0.31	12.88
		055	7.87	6.51	0.24	6.75	13.20	2.003	12.51	1.414	0.22	12.73
		056	8.70	7.22	0.44	7.66	13.20	2.003	12.58	1.417	0.23	12.81
		057	7.87	6.16	0.68	6.84	13.20	2.002	12.47	1.411	0.28	12.75
		058	7.80	6.06	0.51	6.57	12.90	1.999	12.17	1.413	0.24	12.41
		059	7.80	6.12	0.50	6.62	13.50	1.998	12.79	1.416	0.25	13.04
		060	7.87	6.45	0.43	6.88	13.20	2.000	12.54	1.423	0.21	12.75
III	10	061	8.10	6.46	0.51	6.97	13.50	2.003	12.82	1.424	0.25	13.07

TABLE X

FORMATION CYCLES DATA
EXPERIMENTAL 12AH SEALED
SILVER-ZINC CELLS, TASK III
GROUPS 10A THROUGH 10D

CELL EXPERIMENTAL TYPE 12 AH CELLS			FORMATION CYCLE NO. 1				FORMATION CYCLE NO. 2					
TASK NO.	LOT or GRP. NO.	CELL NO.	CHARGE INPUT (AH)	DISCHARGE OUTPUT TO 1.00V (AH)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)	CHARGE INPUT (AH)	VOLTAGE AT END OF CHARGE (V)	DISCHARGE OUTPUT TO 1.00V (AH)	DISCHARGE PLATEAU VOLTAGE (V)	DRAIN OUTPUT TO 1.00V (AH)	TOTAL OUTPUT (AH)
		062	9.00	7.11	0.66	7.77	13.50	1.990	12.71	1.427	0.38	13.09
		063	9.00	7.25	0.45	7.70	13.50	2.006	12.79	1.425	0.22	13.01
III	10A	064	9.00	7.27	0.44	7.71	13.50	1.991	12.86	1.427	0.23	13.09
		065	9.00	7.23	0.49	7.72	13.50	1.994	12.75	1.422	0.22	12.97
		066	9.00	7.08	0.51	7.59	13.50	2.008	12.89	1.424	0.24	13.13
		067	8.10	6.55	0.45	7.00	13.50	1.992	12.25	1.438	0.54	12.79
		068	8.10	6.58	0.47	7.05	12.90	2.000	11.65	1.435	0.44	12.09
III	10B	069	8.10	6.31	0.58	6.89	12.90	1.998	11.68	1.433	0.40	12.08
		070	8.10	6.46	0.50	6.96	13.50	1.998	12.30	1.433	0.37	12.67
		071	8.10	6.52	0.56	7.08	13.50	1.995	12.29	1.411	0.43	12.72
		072	7.80	6.20	0.47	6.67	13.50	1.999	12.77	1.416	0.30	13.07
		073	7.80	5.98	0.68	6.66	13.50	2.003	12.72	1.418	0.37	13.09
III	10C	074	7.80	5.87	0.68	6.55	13.50	2.004	12.80	1.417	0.29	13.09
		075	7.80	5.93	0.56	6.49	13.50	2.008	12.83	1.412	0.20	13.03
		076	7.80	5.73	0.86	6.59	13.50	2.007	12.66	1.411	0.32	12.98
		077	8.10	5.86	1.03	6.89	13.50	1.992	12.22	1.436	0.42	12.64
III	10D	078	8.10	6.31	0.63	6.94	13.50	1.995	12.30	1.430	0.40	12.70
		079	8.10	6.11	0.68	6.79	12.90	2.001	11.52	1.429	0.51	12.03
		080	8.10	6.09	0.70	6.79	13.50	1.994	12.32	1.434	0.43	12.75

TABLE XI

FORMATION CYCLES DATA
EXPERIMENTAL 12AH SEALED
SILVER-ZINC CELLS, TASK III
GROUPS 11 THROUGH 14

CELL TYPE 12 AH CELLS			FORMATION CYCLE NO. 1				FORMATION CYCLE NO. 2					
TASK NO.	LOT OR GRP. NO.	CELL NO.	CHARGE INPUT	DISCHARGE OUTPUT TO 1.00V	DRAIN OUTPUT TO 1.00V	TOTAL OUTPUT	CHARGE INPUT	VOLTAGE AT END OF CHARGE	DISCHARGE OUTPUT TO 1.00V	DISCHARGE PLATEAU VOLTAGE	DRAIN OUTPUT TO 1.00V	TOTAL OUTPUT
			(AH)	(AH)	(AH)	(AH)	(AH)	(V)	(AH)	(V)	(AH)	(AH)
III	11	001	7.65	5.97	0.54	6.51	12.67	1.999	11.87	1.413	0.33	12.20
		002	9.60	6.19	0.39	6.58	13.50	2.000	12.78	1.424	0.32	13.10
		003	7.65	6.01	0.50	6.51	12.30	2.000	11.45	1.414	0.35	11.80
		004	9.60	5.46	0.99	6.45	13.20	1.999	12.61	1.429	0.31	12.92
		005	7.65	6.21	0.44	6.65	12.60	2.000	11.70	1.420	0.41	12.11
III	12	001	9.60	6.15	0.41	6.56	13.20	2.000	12.67	1.430	0.23	12.90
		002	9.60	5.68	0.47	6.15	13.20	2.002	12.54	1.422	0.41	12.95
		003	9.60	5.85	0.67	6.52	13.50	2.001	12.85	1.431	0.47	13.32
		004	7.65	5.97	0.49	6.46	11.17	2.000	10.38	1.395	0.62	11.00
		005	7.65	6.13	0.40	6.53	11.10	2.000	10.57	1.420	0.30	10.87
III	13	001	8.32	6.00	0.90	6.90	13.35	2.001	12.54	1.422	0.35	12.89
		002	8.32	6.03	0.84	6.87	13.35	2.000	12.43	1.413	0.45	12.88
		003	8.32	6.52	0.66	7.18	13.50	1.994	12.63	1.424	0.24	12.87
		004	8.32	6.60	0.59	7.19	13.50	1.991	12.70	1.422	0.27	12.97
		005	8.32	6.63	0.46	7.09	13.35	2.000	12.56	1.420	0.29	12.85
III	14	001	9.60	5.55	1.03	6.58	13.50	1.996	12.78	1.436	0.21	12.99
		002	9.60	6.19	0.40	6.59	13.50	2.001	12.76	1.425	0.24	13.00
		003	9.60	6.29	0.35	6.64	13.50	1.998	12.78	1.422	0.22	13.00
		004	9.60	6.47	0.25	6.72	13.50	1.994	12.70	1.445	0.18	12.88
		005	9.60	5.66	0.93	6.59	13.35	2.002	12.60	1.429	0.21	12.81

function of time during the heat treatment. At the end of the twenty-four (24) hour period, the oven was turned off and allowed to return to room temperature. Each cell was removed from the bomb and the cell vent was thoroughly cleaned of any electrolyte residue. A molded vent plug was cemented into place in the threaded vent hole.

3.5.4 The sealed cell was given a second formation cycle similar to the first. A summary of the data collected during the performance of this second formation cycle is given in Tables VIII through XI.

4. Experimental Cell Configurations

4.1 Groups 1 through 4 - 20 Cells

These four (4) groups of five (5) cells each were fabricated using cell cases and covers molded in polysulfone. The compound used to seal the terminal assemblies into the cell covers as well as effecting the case-to-cover seal was E-600. It was noted that after heat treatment in the pressure vessel, the cell cases showed signs of crazing. Further work on this cell group was terminated and the cell cases and covers used for the balance of the cells manufactured in this task were molded in 30% glass fortified polyphenylene oxide.

4.2 Group 5 (4 Cells)

The specification for the construction variation to be incorporated in the four (4) cells of Group 5 initially called for the use of trichloroethylene as the solvent in the preparation of the asbestos sheet impregnation solution and in the formulation of the ceramic filled slurry. After the difficulties experienced with this same variation in the 40AH cells of Task II, Group 4, the experiment was redefined. The incorporation of potassium titanate in powdered form in a negative absorber mat was investigated but, because the KT powder did not lend itself to continuous process mat fabrication by present methods, this variation was discontinued. Technical direction was given to manufacture Group 5 cells using the negative electrode absorber mat, YIFL-II, manufactured by Yardney, in place of the standard mat. This variation was similar to that specified for Task II, Group 6, 40 ampere-hour cells and was accomplished without incident.

4.3 Group 6 (4 Cells)

The positive electrodes for the cells in Group 6 were fabricated using the Yardney continuous process rolling mill and Yardney Type HS Silver Powder. The selection of Type HS powder was made by the NASA Project Manager based on the test results on Task II, Groups 1 and 2 cells. Electrode leads, four (4) strands of 0.40mm fine silver wire, were welded directly to the electrode, two (2) each on either side of the electrode in the same attachment area.

4.4 Group 7 (4 Cells)

This group of cells utilized positive electrodes in sealed separator bags which were NOT dip-coated with ceramic filled slurry.

4.5 Group 8 (4 Cells)

The cells of Group 8 were similar to the cells of Group 7 except that a 0.063mm thick layer of cast film made from the ceramic filled slurry was interposed between each bagged positive and negative electrode.

4.6 Group 9 (4 Cells)

The cells of this group contained standard electrodes in dip-coated separator bags plus a 0.063mm thick layer of cast film made from ceramic filled slurry interposed between each bagged positive and negative electrode.

4.7 Group 10 (80 Cells)

The first sixty-one (61) cells of this group were produced using the cell materials and cell fabrication methods described in detail under Task III, Sections 2 and 3 of this report. These cells and the cells of Groups 11 through 14 were considered the baseline configuration for the 12 ampere-hour experimental cells manufactured under Task III of the contract. The last nineteen (19) cells of this group were divided into four (4) sub-groups in order to incorporate additional experimental design changes.

One construction variation included in the 19 cells which made up Groups 10A through 10D was a different method of sealing the cell terminals to the cell cover. The incidence of leakage at the cell terminals was approximately 10% in the cells constructed, filled and formed by normal methods. The analysis of the leakage problem pointed to an inability of the terminal-to-cover seal using Allbond epoxy to withstand the 24 hour heat treatment at 100°C in the pressure vessel. A new terminal seal was designed and used which required two (2) "O" rings made of ethylene propylene compound. The 19 cells using the new terminal seal did not exhibit any leakage prior to being shipped to NASA

Lewis Research Center.

Initial 12 ampere-hour cell testing results from Task IV activity indicated that the cell performance was being adversely affected by the snug fit of the cell stack to the cell case and its influence on electrode and separator wetting. The construction and processing variations used in these four (4) sub-groups were the following:

4.7.1 Group 10A (5 Cells)

These cells were fabricated to the baseline configuration and were the control group for this series of experimental cells.

4.7.2 Group 10B (5 Cells)

This group of cells was fabricated to the baseline configuration except that the heat treatment in the pressure vessel (bomb) was for a 72 hour period instead of the normal 24 hours.

4.7.3 Group 10C (5 Cells)

The negative electrodes used in the cells of this group were 2.77mm thick instead of the normal 2.89mm thick. The amount of negative mix was adjusted to achieve the same density in the thinner electrode as in the standard thickness negative electrode.

4.7.4 Group 10D (4 Cells)

This group of cells was constructed to the Group 10C configuration. During the filling of the cell with electrolyte, the vacuum was held for five (5) minutes instead of the normal 30 seconds. The heat treatment in the pressure vessel was for a 72 hour period.

4.8 Group 11 through 14 (20 Cells)

The construction and processing of the cells of these groups was similar to the first 61 cells of Group 10, the baseline or standard configuration.

TASK IV - EXPERIMENTAL CELL EVALUATIONS

1. Objective of Task

The objective of this task was to evaluate, through testing, the relative performance of twelve (12) 40 ampere-hour experimental cells and twelve (12) 12 ampere-hour experimental cells at a temperature of 22°C.

2. 40 Ampere-Hour Cell Testing

The 40 ampere-hour cells selected by the NASA Project Manager for evaluation in this task are tabulated below:

TASK I, Lot 2, S/N's 069 and 070
TASK II, Group 1, S/N's 001 and 002
TASK II, Group 2, S/N's 001 and 003
TASK II, Group 3, S/N's 003 and 004
TASK II, Group 5, S/N's 002 and 003
TASK II, Group 6, S/N's 001 and 004

2.1 Performance Characterization Test

Each cell was given four (4) test discharges to determine cell voltage characteristics at different discharge rates. In preparation for each test discharge, each cell was charged at a constant current of 1.5 amperes to a voltage, while charging, of 1.98 - 2.00 volts or until an input capacity of 45.0 ampere-hours had been achieved. The charged cell was then discharged at the applicable test cycle discharge rate to an end voltage of 1.00 volt. Following each test discharge, each cell was further discharged (drained) at a current of 2.0 amperes to an end voltage of 1.00 volt. The test cycle discharge rates were:

Test Cycle No.	Test Discharge Rate
1	120A (186 ma/sq. cm.)
2	80A (124 ma/sq. cm.)
3	40A (62 ma/sq. cm.)
4	20A (31 ma/sq. cm.)

Cell voltage was monitored and recorded as a function of time during the charge, discharge and drain portions of each test cycle. The charge input capacity and the discharge and drain output capacities were calculated for each test cycle. Tables XII through XV present a summary of the performance of the twelve (12) test cells during each of the test cycles.

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TABLE XII

SUMMARY OF CELL TEST DATA
PERFORMANCE CHARACTERIZATION TEST
40AH SEALED SILVER-ZINC CELLS
TEST CYCLE NO. 1 (120A TO 1.00V)

TASK NO.	LOT OR GRP. NO.	CELL NO.	CHARGE INPUT	CELL VOLTAGE AT INTERVALS DURING TEST DISCHARGE									OUTPUT		
				START	5AH	10AH	15AH	20AH	25AH	30AH	35AH	40AH	TEST DIS-CHARGE	POST TEST DRAIN	TOTAL
			AH	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(AH)	(AH)	(AH)
I	2	069	45.00	0.887	1.007	1.080	1.124	1.148	1.161	1.156	----	----	33.73	8.20	41.93
		070	45.00	0.894	1.012	1.084	1.126	1.149	1.160	1.145	----	----	32.87	9.25	42.12
II	1	001	45.00	0.953	1.035	1.100	1.126	1.140	1.141	----	----	----	29.60	12.67	42.27
		002	45.00	0.957	1.035	1.103	1.130	1.143	1.147	1.092	----	----	30.50	12.37	42.87
II	2	001	36.75	0.926	1.009	1.075	1.104	1.120	1.120	----	----	----	28.00	8.57	36.57
		003	33.00	0.902	0.992	1.064	1.096	1.103	----	----	----	----	24.03	6.92	30.95
II	3	003	45.00	0.876	1.010	1.093	1.128	1.150	1.165	1.162	1.003	----	35.10	9.56	44.66
		004	45.00	0.901	1.007	1.090	1.128	1.153	1.169	1.168	1.098	----	35.60	10.49	46.09
II	5	002	45.00	0.921	1.012	1.080	1.111	1.130	1.144	1.145	----	----	34.00	8.93	42.93
		003	45.00	0.928	1.018	1.080	1.114	1.135	1.150	1.150	----	----	34.20	8.33	42.53
II	6	001	42.75	0.787	0.973	1.059	1.097	1.120	1.129	1.088	----	----	30.80	9.60	40.40
		004	43.50	0.809	0.987	1.070	1.110	1.132	1.140	1.110	----	----	31.70	9.77	41.47

TABLE XIII

SUMMARY OF CELL TEST DATA
PERFORMANCE CHARACTERIZATION TEXT
40AH SEALED SILVER-ZINC CELLS
TEST CYCLE NO. 2 (80A TO 1.00V)

TASK NO.	LOT OR GRP. NO.	CELL NO.	CHARGE INPUT AH	CELL VOLTAGE AT INTERVALS DURING TEST DISCHARGE START (V)	5AH (V)	10AH	15AH (V)	20AH (V)	25AH (V)	30AH (V)	35AH (V)	40AH (V)	OUTPUT TEST / DIS-CHARGE (AH)	POST TEST DRAIN (AH)	TOTAL (AH)
I	2	069	45.00	1.087	1.141	1.190	1.212	1.230	1.236	1.228	1.177	----	36.67	7.60	44.27
		070	45.00	1.104	1.146	1.196	1.221	1.235	1.239	1.232	1.177	----	36.33	8.08	44.41
II	1	001	43.50	1.325	1.187	1.196	1.220	1.226	1.226	1.217	----	----	33.73	8.52	42.25
		002	43.50	1.321	1.163	1.201	1.224	1.232	1.233	1.227	----	----	34.33	7.58	41.91
II	2	001	43.90	1.345	1.226	1.195	1.217	1.227	1.233	1.230	1.151	----	35.47	7.57	43.04
		003	43.50	1.317	1.234	1.166	1.192	1.204	1.212	1.212	----	----	33.40	8.91	42.31
II	3	003	45.00	1.227	1.165	1.203	1.234	1.249	1.251	1.241	1.203	----	37.07	8.90	45.97
		004	45.00	1.251	1.173	1.206	1.230	1.254	1.258	1.252	1.221	----	37.60	8.35	45.95
II	5	002	45.00	1.078	1.157	1.195	1.218	1.231	1.234	1.216	1.115	----	36.86	7.52	44.38
		003	45.00	1.056	1.145	1.188	1.211	1.225	1.227	1.206	1.101	----	36.13	8.19	44.32
II	6	001	41.63	1.036	1.124	1.167	1.191	1.202	1.195	1.159	----	----	33.33	7.62	40.95
		004	43.50	1.087	1.142	1.180	1.206	1.219	1.218	1.195	1.095	----	35.46	7.06	42.52

TABLE XIV

SUMMARY OF CELL TEST DATA
PERFORMANCE CHARACTERIZATION TEST
40AH SEALED SILVER-ZINC CELLS
TEST CYCLE NO. 3 (40A TO 1.00V)

TASK NO.	LOT OR GRP. NO.	CELL NO.	CHARGE INPUT	CELL VOLTAGE AT INTERVALS DURING TEST DISCHARGE									OUTPUT		
				START	5AH	10AH	15AH	20AH	25AH	30AH	35AH	40AH	TEST DIS-CHARGE	POST TEST DRAIN	TOTAL
			AH	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(AH)	(AH)	(AH)
I	2	069	45.00	1.345	1.279	1.300	1.324	1.340	1.347	1.342	1.312	1.149	40.60	4.59	45.19
		070	45.00	1.358	1.278	1.301	1.326	1.341	1.348	1.342	1.312	1.160	40.53	4.82	45.35
II	1	001	41.63	1.536	1.445	1.315	1.321	1.328	1.324	1.320	1.254	----	36.53	5.50	42.03
		002	41.63	1.562	1.445	1.314	1.321	1.329	1.327	1.324	1.269	----	36.07	4.67	40.74
II	2	001	40.37	1.496	1.353	1.291	1.314	1.322	1.320	1.315	1.236	----	35.80	3.83	39.63
		003	37.87	1.488	1.316	1.289	1.305	1.310	1.310	1.296	----	----	33.87	3.60	37.47
II	3	003	45.00	1.554	1.379	1.304	1.330	1.340	1.342	1.336	1.310	----	39.07	5.36	44.43
		004	45.00	1.554	1.383	1.306	1.331	1.342	1.345	1.339	1.318	----	39.23	5.10	44.33
II	5	002	45.00	1.446	1.287	1.311	1.328	1.338	1.340	1.331	1.307	1.102	40.16	4.00	44.16
		003	45.00	1.306	1.266	1.300	1.320	1.330	1.329	1.323	1.297	----	39.50	4.50	44.00
II	6	001	45.00	1.241	1.246	1.276	1.293	1.311	1.314	1.307	1.280	----	39.36	3.93	43.29
		004	45.00	1.295	1.262	1.287	1.306	1.317	1.32[illegible]	1.315	1.288	----	39.36	4.01	43.37

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TABLE XV

SUMMARY OF CELL TEST DATA
PERFORMANCE CHARACTERIZATION TEST
40AH SEALED SILVER-ZINC CELLS
TEST CYCLE NO. 4 (20A TO 1.00V)

TASK NO.	LOT OR GRP. NO.	CELL NO.	CHARGE INPUT	CELL VOLTAGE AT INTERVALS DURING TEST DISCHARGE									TEST DIS-CHARGE	POST TEST DRAIN	TOTAL
				START	5AH	10AH	15AH	20AH	25AH	30AH	35AH	40AH			
			AH	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(AH)	(AH)	(AH)
I	2	069	45.00	1.591	1.393	1.391	1.410	1.420	1.421	1.410	1.369	1.021	40.07	3.43	43.50
		070	45.00	1.594	1.392	1.389	1.410	1.421	1.421	1.412	1.382	1.091	40.47	2.83	43.30
II	1	001	43.50	1.700	1.604	1.454	1.402	1.409	1.407	1.402	1.381	----	38.33	3.84	42.17
		002	43.50	1.703	1.603	1.455	1.401	1.409	1.408	1.402	1.380	----	38.33	3.77	42.10
II	2	001	43.50	1.691	1.600	1.387	1.405	1.412	1.409	1.402	1.381	----	38.97	2.97	41.94
		003	43.50	1.666	1.572	1.367	1.386	1.389	1.389	1.384	1.356	----	38.42	3.50	41.92
II	3	003	45.00	1.635	1.411	1.386	1.402	1.408	1.406	1.397	1.372	1.115	40.20	5.57	45.77
		004	45.00	1.636	1.410	1.385	1.399	1.404	1.402	1.395	1.370	----	39.75	4.90	44.65
II	5	002	45.00	1.530	1.367	1.376	1.392	1.401	1.403	1.393	1.343	----	39.50	4.26	43.76
		003	45.00	1.478	1.357	1.366	1.385	1.396	1.399	1.389	1.330	----	38.66	4.99	43.65
II	6	001	45.00	1.560	1.355	1.361	1.379	1.388	1.390	1.380	1.354	1.223	41.03	1.68	42.71
		004	45.00	1.618	1.404	1.375	1.391	1.399	1.406	1.391	1.368	1.240	41.06	1.57	42.63

2.2 Cycle Life Testing (100% DOD)

Each cell, upon completion of performance-characterization testing, was then cycled continuously on a 100% depth of discharge regime. This testing was done on the Automatic Cell Cycler designed, fabricated and used in Phase I of the contract. The test regime specified by the NASA Project Manager and used to test these twelve (12) 40 ampere-hour cells was the following:

Charge - Constant current of 2.5 amperes for 18 hours or to 1.98 - 1.99 volts, whichever occurred first.

Discharge - Constant current of 20 amperes for 2 hours or to 1.20 volts, whichever occurred first.

A comparison of the average output capacities for each 2 cell group during Cycle Life Testing is given in Figure 1. A comparison of the typical cell voltage curves for each group during the discharge of Cycle Life Test Cycle 120 is given in Figure 2.

The Cycle Life Testing of 40 ampere-hour cells was terminated in order to conduct Cycle Life Testing on 12 ampere-hour cells fabricated in Task III. At that point none of the cells showed any signs of leakage or other physical degradation. The only cell electrical failure was experienced when the Task II, Group 2 cell, S/N 003, failed to accept charge in Cycle 137. The status of the individual cells at the completion of testing is summarized in Table XVI.

3. 12 Ampere-Hour Cell Testing

The 12 ampere-hour cells selected by the NASA Project Manager for evaluation in this task are tabulated below:

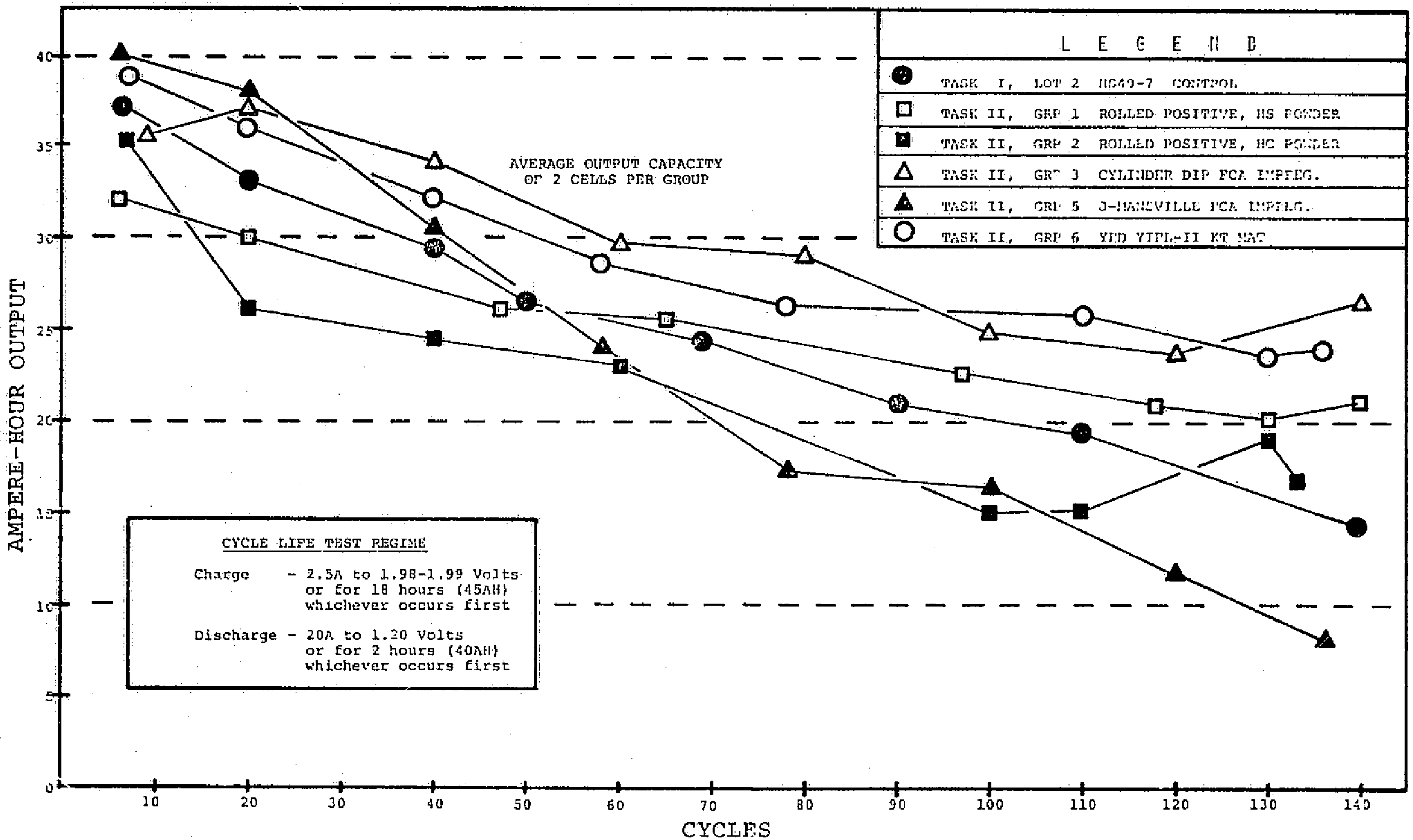
TASK III, Group 11, S/N 002
Group 12, S/N 003
Group 5, S/N's 001 and 004
Group 6, S/N's 001 and 002
Group 7, S/N's 002 and 003
Group 8, S/N's 001 and 003
Group 9, S/N's 002 and 004

3.1 Performance Characterization Test

Each cell was given four (4) test discharges to determine cell voltage characteristics at different discharge rates. In preparation for each test discharge, each cell was charged at

FIGURE 1

PERFORMANCE SUMMARY
100% DOD CYCLE LIFE TESTING
40 AH SEALED SILVER-ZINC CELLS



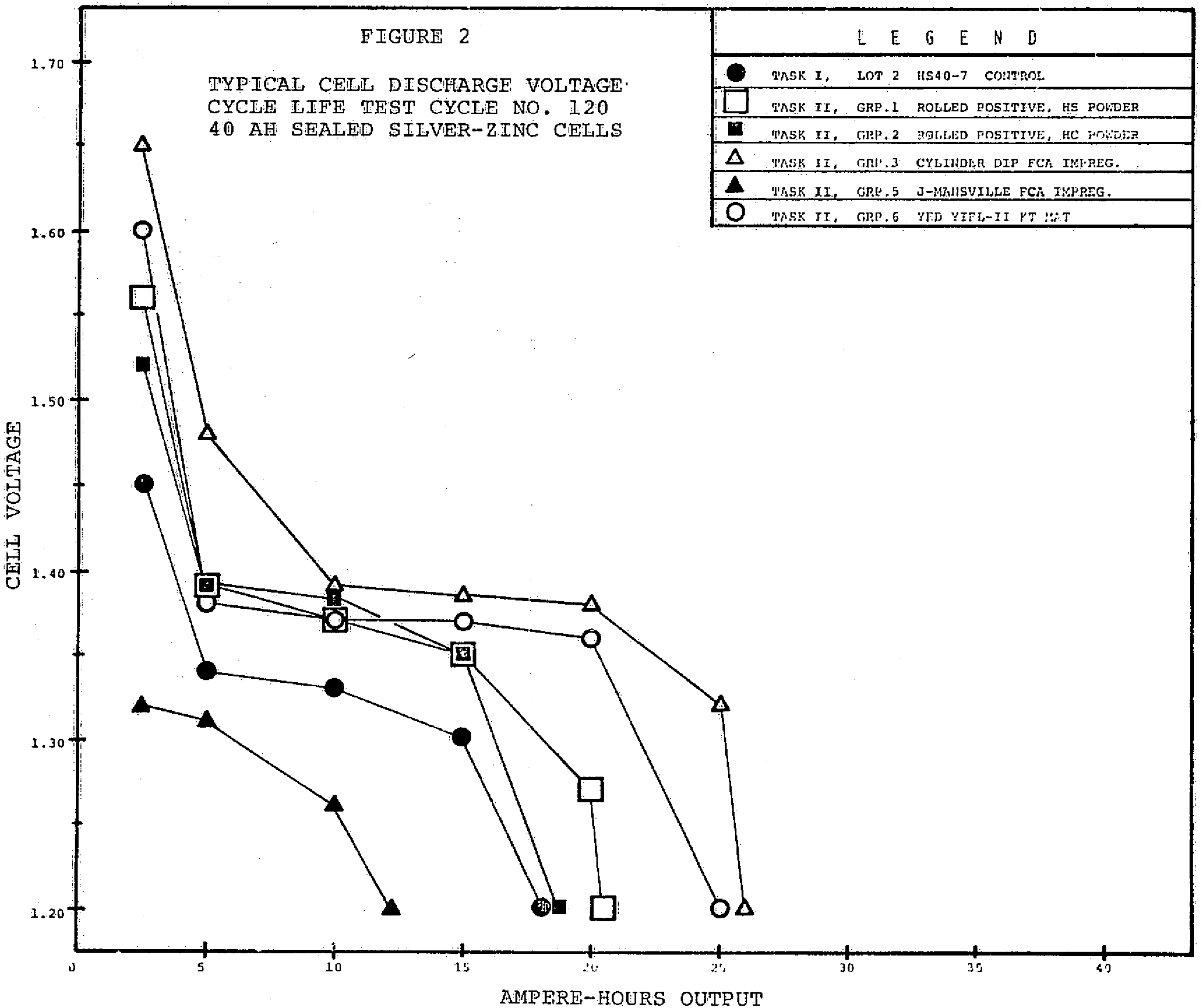


FIGURE 2

TYPICAL CELL DISCHARGE VOLTAGE
CYCLE LIFE TEST CYCLE NO. 120
40 AH SEALED SILVER-ZINC CELLS

TABLE XVI

SUMMARY OF TEST CELL STATUS ON COMPLETION OF CYCLE LIFE TESTING 40AH SEALED SILVER-ZINC CELLS

TASK	LOT or GROUP NO.	CELL CONSTRUCTION VARIATION	CELL NO.	CYCLES TO 50% OF NOMINAL CAPACITY	LAST TEST CYCLE			REMARKS
					CYCLE NO.	OUTPUT CAPACITY (AH)	OUTPUT/INPUT EFFICIENCY	
I	2	STANDARD CONSTRUCTION CELL TYPE HS40-7 CONTROL	069	100	182	10.75	97%	
			070	105	182	11.00	96%	
II	1	POSITIVE ELECTRODE YARDNEY ROLLING MILL PROCESS WITH YARDNEY TYPE HS POWDER. DUAL TAB ARRANGEMENT.	001	155	183	19.00	98%	
			002	150	183	19.25	96%	
II	2	POSITIVE ELECTRODE YARDNEY ROLLING MILL PROCESS WITH YARDNEY TYPE HC POWDER. DUAL TAB ATTACHMENT.	001	80	138	17.00	97%	
			003	65	136	20.66	52%	NO CHARGE ACCEPTANCE CYCLE 137
II	3	SEPARATOR FCA SUBSTRATE "CYLINDER DIP" IMPREGNATION	003	NOT APPLICABLE	165	23.12	97%	
			004	NOT APPLICABLE	163	22.37	97%	
II	5	SEPARATOR FCA SUBSTRATE IMPREGNATION BY JOHNS-MANVILLE	002	75	136	8.25	94%	
			003	70	136	8.25	96%	
II	6	NEGATIVE ELECTRODE YARDNEY KT MAT YIFL-II USED AS NEGATIVE ABSORBER	001	NOT APPLICABLE	136	24.25	97%	
			004	NOT APPLICABLE	136	24.12	97%	

a constant current of 0.30 amperes for 45 hours or to a voltage of 1.98 - 2.00 volts, whichever occurred first. The charged cell was then discharged at the applicable test cycle discharge rate to a voltage of 1.00 volt. Following each test discharge, each cell was further discharged (drained) at a current of 0.60 amperes to an end voltage of 1.00 volt. The test cycle discharge rates were:

Test Cycle No.	Test Discharge Rate
1	18A (140 ma/sq.cm.)
2	12A (93 ma/sq.cm.)
3	6A (46 ma/sq.cm.)
4	3A (23 ma/sq.cm.)

Cell voltage was monitored and recorded as a function of time during the charge, discharge and drain portions of each test cycle. The charge input capacity and the discharge and drain output capacities were calculated for each test cycle. Tables XVII through XX present a summary of the voltage and capacity characteristics of the twelve (12) test cells during each of the test cycles. As noted on Table XVII, the discharge current rate for Test Cycle No. 1 on Group II cell S/N 002 was 16A (124 ma/sq.cm.). Also noted is the test discharge cutoff voltage for Group 9 cell S/N 004 which was 0.90 volts.

3.2 Cycle Life Testing (100% DOD)

Upon completion of Performance Characterization Tests, each cell was cycled continuously on a 100% depth of discharge regime. This testing was done on the Automatic Cell Cycler equipment used to test the 40 ampere-hour cells. The test regime selected by the NASA Project Manager to test the 12 ampere-hour cells was the following:

<u>Charge</u> - Constant current of 1.05 amperes for 11.5 hours or to 2.01 - 2.02 volts, whichever occurred first.

<u>Discharge</u> - Constant current of 6.0 amperes for 2.0 hours or to 1.00 volt, whichever occurred first.

To accomplish this lower rate testing, new panel ammeters were calibrated and installed in the Automatic Cell Cycler and the charge and discharge currents were established by adjusting the program input to the power supply in the test equipment. Some time during these adjustments, the discharge current meter was unknowingly damaged. As a result, the indicated discharge current of 6.0 amperes was actually 12 amperes. This condition was

TABLE XVII

SUMMARY OF CELL TEST DATA
PERFORMANCE CHARACTERIZATION TEST
EXPERIMENTAL 12AH SEALED SILVER-ZINC CELLS
TEST CYCLE NO. 1 (18A TO 1.00V)

TASK NO.	LOT OR GRP. NO.	CELL NO.	CHARGE INPUT	CELL VOLTAGE AT INTERVALS DURING TEST DISCHARGE													OUTPUT		
				START	1AH	2AH	3AH	4AH	5AH	6AH	7AH	8AH	9AH	10AH	11AH	12AH	TEST DIS-CHARGE	POST TEST DRAIN	TOTAL
			(AH)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(AH)	(AH)	(AH)
III	5	001	12.30	0.88	0.97	1.03	1.06	1.06	----	----	----	----	----	----	----	----	4.87	7.16	12.03
		004	12.90	0.90	0.98	1.04	1.06	1.06	----	----	----	----	----	----	----	----	4.84	7.56	12.30
III	6	001	11.10	1.16	1.05	1.05	1.05	1.00	----	----	----	----	----	----	----	----	4.00	6.34	10.34
		002	11.10	1.16	1.06	1.05	1.04	1.00	----	----	----	----	----	----	----	----	4.00	6.39	10.39
III	7	002	11.40	0.89	1.00	1.03	1.05	1.05	1.01	----	----	----	----	----	----	----	5.58	5.49	11.70
		003	11.40	0.92	0.96	1.01	1.04	1.07	1.07	1.07	----	----	----	----	----	----	7.60	3.36	10.96
III	8	001	12.00	0.85	0.98	1.03	1.05	1.06	1.05	1.02	----	----	----	----	----	----	6.55	5.04	11.59
		003	12.00	0.78	0.94	0.98	1.01	1.02	----	----	----	----	----	----	----	----	4.80	6.68	11.46
III	9	002	12.00	0.79	0.90	0.98	1.00	----	----	----	----	----	----	----	----	----	3.85	7.14	10.99
		004	12.00	0.75	0.89	0.95	0.98	0.93	(NOTE	1)--	----	----	----	----	----	----	4.30	7.00	11.30
III	11	002	13.50	0.96	1.00	1.04	1.08	1.10	1.09	1.05	1.01	(NOTE	2)--	----	----	----	7.44	5.66	13.10
	12	003	13.50	0.90	0.97	1.02	1.06	1.07	1.06	1.04	1.04	1.02	----	----	----	----	8.46	4.73	13.19

NOTES:

(1) Discharge Cutoff Voltage -- 0.90 Volts

(2) Test Discharge Rate -- 16 Amperes

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TABLE XVIII

SUMMARY OF CELL TEST DATA
PERFORMANCE CHARACTERIZATION TEST
EXPERIMENTAL 12AH SEALED SILVER-ZINC CELLS
TEST CYCLE NO. 2 (12A TO 1.00V)

TASK NO.	LOT OR GRP. NO.	CELL NO.	CHARGE INPUT	CELL VOLTAGE AT INTERVALS DURING TEST DISCHARGE													OUTPUT		
				START	1AH	2AH	3AH	4AH	5AH	6AH	7AH	8AH	9AH	10AH	11AH	12AH	TEST DIS-CHARGE	POST TEST DRAIN	TOTAL
			(AH)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(AH)	(AH)	(AH)
III	5	001	13.50	1.20	1.15	1.14	1.17	1.19	1.19	1.17	1.16	1.12	1.11	----	----	----	9.93	2.87	12.80
		004	13.50	1.21	1.15	1.14	1.17	1.19	1.19	1.15	1.14	1.10	1.09	----	----	----	9.73	3.47	13.20
III	6	001	11.70	1.37	1.19	1.15	1.16	1.15	1.14	1.12	1.10	----	----	----	----	----	7.55	3.24	10.79
		002	11.70	1.35	1.19	1.14	1.14	1.14	1.12	1.10	1.03	----	----	----	----	----	7.20	3.60	10.80
III	7	002	13.50	1.14	1.10	1.12	1.14	1.16	1.17	1.17	1.17	1.17	1.16	1.09	----	----	10.55	2.63	13.18
		003	13.50	1.12	1.09	1.13	1.16	1.18	1.20	1.21	1.21	1.20	1.19	1.15	----	----	10.80	2.31	13.11
III	8	001	13.20	1.13	1.10	1.12	1.15	1.16	1.17	1.16	1.16	1.13	1.06	----	----	----	9.42	3.42	12.84
		003	12.15	1.04	1.07	1.09	1.11	1.13	1.14	1.13	1.07	----	----	----	----	----	7.77	3.39	11.16
III	9	002	13.20	1.12	1.06	1.09	1.12	1.13	1.10	1.09	1.03	1.02	----	----	----	----	8.25	4.65	12.90
		004	12.90	1.07	1.06	1.06	1.10	1.12	1.13	1.10	1.05	----	----	----	----	----	7.51	4.86	12.37
III	11	002	13.50	1.14	1.10	1.09	1.12	1.15	1.15	1.14	1.12	1.10	1.06	----	----	----	9.42	3.84	13.26
	12	003	13.50	1.10	1.07	1.09	1.12	1.14	1.15	1.15	1.14	1.13	1.10	1.00	----	----	10.00	3.30	13.30

TABLE XIX

SUMMARY OF CELL TEST DATA
PERFORMANCE CHARACTERIZATION TEST
EXPERIMENTAL 12AH SEALED SILVER-ZINC CELLS
TEST CYCLE NO. 3 (6A TO 1.00V)

TASK NO.	LOT OR GRP. NO.	CELL NO.	CHARGE INPUT	CELL VOLTAGE AT INTERVALS DURING TEST DISCHARGE													OUTPUT		
				START	1AH	2AH	3AH	4AH	5AH	6AH	7AH	8AH	9AH	10AH	11AH	12AH	TEST DIS-CHARGE	POST TEST DRAIN	TOTAL
			(AH)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(AH)	(AH)	(AH)
III	5	001	13.35	1.45	1.29	1.27	1.29	1.30	1.31	1.31	1.30	1.28	1.23	1.11	----	----	10.46	2.68	13.14
		004	13.35	1.48	1.33	1.28	1.29	1.30	1.31	1.31	1.29	1.26	1.20	----	----	----	9.83	3.29	13.12
III	6	001	11.70	1.59	1.50	1.42	1.27	1.27	1.27	1.25	1.21	1.16	----	----	----	----	8.42	2.63	11.05
		002	11.40	1.58	1.49	1.42	1.29	1.28	1.27	1.26	1.24	1.21	----	----	----	----	8.91	2.43	11.34
III	7	002	13.35	1.43	1.28	1.26	1.27	1.28	1.28	1.27	1.27	1.25	1.20	1.06	----	----	10.38	2.85	13.23
		003	12.60	1.41	1.26	1.26	1.27	1.29	1.29	1.29	1.29	1.27	1.22	1.06	----	----	10.74	1.64	12.38
III	8	001	12.90	1.42	1.26	1.25	1.27	1.28	1.28	1.28	1.27	1.24	1.16	1.02	----	----	10.14	2.45	12.59
		003	12.60	1.37	1.24	1.24	1.26	1.27	1.27	1.27	1.27	1.25	1.21	1.03	----	----	10.70	1.68	12.38
III	9	002	13.50	1.44	1.29	1.23	1.24	1.25	1.26	1.25	1.24	1.22	1.19	1.02	----	----	10.27	3.00	13.27
		004	13.50	1.42	1.28	1.22	1.22	1.23	1.23	1.21	1.19	1.16	1.09	----	----	----	9.35	3.86	13.21
III	11	002	13.35	1.45	1.29	1.25	1.27	1.28	1.29	1.29	1.29	1.27	1.25	1.18	----	----	10.67	2.57	13.24
	12	003	13.35	1.41	1.27	1.26	1.28	1.30	1.31	1.31	1.31	1.30	1.28	1.22	1.02	----	11.18	2.06	13.24

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TABLE XX

SUMMARY OF CELL TEST DATA
PERFORMANCE CHARACTERIZATION TEST
EXPERIMENTAL 12AH SEALED SILVER-ZINC CELLS
TEST CYCLE NO. 4 (3A TO 1.00V)

TASK NO.	LOT OR GRP. NO.	CELL NO.	CHARGE INPUT	CELL VOLTAGE AT INTERVALS DURING TEST DISCHARGE													OUTPUT		
				START	1AH	2AH	3AH	4AH	5AH	6AH	7AH	8AH	9AH	10AH	11AH	12AH	TEST DIS-CHARGE	POST TEST DRAIN	TOTAL
			(AH)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(AH)	(AH)	(AH)
III	5	001	12.60	1.62	1.40	1.36	1.37	1.38	1.38	1.38	1.38	1.36	1.32	1.23	1.11	----	11.22	1.05	12.27
		004	13.20	1.65	1.47	1.38	1.36	1.38	1.38	1.38	1.38	1.37	1.33	1.24	1.17	----	11.95	0.96	12.91
III	6	001	12.15	1.71	1.63	1.50	1.46	1.38	1.38	1.37	1.36	1.34	1.31	1.15	1.07	----	11.22	0.63	11.85
		002	11.85	1.71	1.64	1.59	1.41	1.38	1.38	1.37	1.35	1.33	1.20	----	----	----	9.41	2.14	11.50
III	7	002	12.90	1.61	1.41	1.35	1.37	1.38	1.38	1.38	1.38	1.36	1.31	1.24	1.17	----	11.52	1.07	12.59
		003	12.60	1.59	1.38	1.37	1.37	1.37	1.38	1.38	1.37	1.33	1.26	1.21	1.11	----	11.17	0.80	11.97
III	8	001	12.60	1.57	1.36	1.35	1.36	1.37	1.37	1.37	1.36	1.34	1.28	1.17	----	----	10.79	1.19	11.98
		003	11.55	1.53	1.35	1.35	1.36	1.36	1.37	1.37	1.34	1.29	1.21	1.10	----	----	10.17	0.83	11.00
III	9	002	12.90	1.59	1.37	1.33	1.33	1.34	1.35	1.35	1.34	1.32	1.27	1.13	----	----	10.21	2.17	12.38
		004	12.90	1.58	1.37	1.32	1.32	1.33	1.33	1.33	1.32	1.30	1.22	----	----	----	9.69	2.77	12.46
III	11	002	12.60	1.61	1.41	1.35	1.36	1.37	1.37	1.37	1.37	1.35	1.30	1.14	----	----	10.73	1.49	12.22
	12	003	11.70	1.57	1.37	1.35	1.37	1.38	1.38	1.39	1.38	1.35	1.25	1.16	----	----	10.31	1.14	11.45

discovered during periodic calibration of the meter and was rectified immediately.

At one point during the Cycle Life Test program, the cells were removed from the Automatic Cell Cycler and given a formation/conditioning cycle. The sequence of operations followed in performing this formation/conditioning cycle and the results of each operation in the sequence are given in Table XXI.

Table XXII contains a summary of the performance of each cell during the Cycle Life Testing sequence. The summary is divided into three (3) sections and gives the performance both before and after the formation/conditioning cycles and the change from the 12 ampere (1C) to the 6 ampere (C/2) discharge rate.

The Cycle Life Testing was terminated at the end of the Period of Performance of the contract. Two (2) of the cells had experienced cell case rupture due to a random equipment malfunction which allowed the cells to be discharged to a point where cell voltage was a negative value. Only one (1) of the other ten (10) cells (Group 7 cell S/N 003) failed in that it would not accept charge during Cycle No. 89.

TABLE XXI

FORMATION/CONDITIONING CYCLES DATA
EXPERIMENTAL 12AH SEALED
SILVER-ZINC CELLS

TEST SEQUENCE											
GROUP NO.	CELL NO.	REMOVED FROM AUTOMATIC CELL CYCLER AFTER		OPEN CIRCUIT VOLTAGE	DISCHARGE OUTPUT AT 1.8A TO 1.00 V	DRAIN OUTPUT AT 0.6A TO 1.00 V	TOTAL OUTPUT	CHARGE INPUT AT 0.3A TO 2.00 V	DISCHARGE OUTPUT AT 1.8A TO 1.00 V	DRAIN OUTPUT AT 0.6A TO 1.00 V	TOTAL CYCLE OUTPUT
		CYCLE	FUNCTION								
		#	(CHARGE/DISCHG)	(V)	(AH)	(AH)	(AH)	(AH)	(AH)	(AH)	(AH)
5	001	40	DISCHARGE	1.598	1.12	0.85	1.97	11.70	11.06	0.86	11.92
	004	40	DISCHARGE	1.598	2.95	1.11	4.06	11.70	11.11	0.80	11.91
6	001	40	DISCHARGE	1.601	5.17	0.76	5.93	12.45	10.95	0.28	11.23
	002	26	DISCHARGE	1.596	5.38	0.44	5.82	12.45	11.73	0.15	11.88
7	002	43	DISCHARGE	1.583	3.27	1.33	4.40	11.40	10.56	1.22	11.78
	003	54	DISCHARGE	1.597	3.41	1.85	5.26	12.45	11.51	1.24	12.75
8	001	40	CHARGE	1.855	6.53	0.81	7.34	11.55	11.00	0.93	11.93
	003	43	DISCHARGE	1.579	3.36	0.92	4.28	11.55	10.78	1.00	11.73
9	002	24	CHARGE	1.857	7.37	0.93	8.30	12.45	11.80	0.94	12.74
	004	1	DISCHARGE	1.597	3.30	0.61	3.91	13.50	12.90	0.55	13.45
11	002	40	DISCHARGE	1.597	4.95	0.56	5.51	12.45	12.36	0.40	12.76
12	003	40	DISCHARGE	1.597	3.73	0.82	4.55	11.40	10.98	0.72	11.70

TABLE XXII

SUMMARY OF CYCLE LIFE TESTING EXPERIMENTAL 12AH SEALED SILVER-ZINC CELLS

TEST SEQUENCE		TEST CYCLES AT 1C RATE					FORMATION/CONDITIONING CYCLES (SEE TABLE XXI)	TEST CYCLES AT 1C RATE					CHANGE TEST DISCHARGE RATE TO C/2	TEST CYCLES AT C/2 RATE					TOTAL TEST CYCLES	NOTES
GROUP NO.	CELL NO.	NO. OF TEST CYC.	MAXIMUM CAPACITY OUTPUT (AH)	MAXIMUM CAPACITY CYC. NO. (#)	MINIMUM CAPACITY OUTPUT (AH)	MINIMUM CAPACITY CYC. NO. (#)		NO. OF TEST CYC.	MAXIMUM CAPACITY OUTPUT (AH)	MAXIMUM CAPACITY CYC. NO. (#)	MINIMUM CAPACITY OUTPUT (AH)	MINIMUM CAPACITY CYC. NO. (#)		NO. OF TEST CYC.	MAXIMUM CAPACITY OUTPUT (AH)	MAXIMUM CAPACITY CYC. NO. (#)	MINIMUM CAPACITY OUTPUT (AH)	MINIMUM CAPACITY CYC. NO. (#)		
5	001	40	4.9	3	3.7	40		15	3.4	1	2.0	15		44	8.2	23	6.3	16	99	(1)
	004	40	4.7	3	2.2	40		10	3.9	1	2.3	10		54	7.0	15	4.7	54	104	
6	001	40	3.9	3	1.4	40		-	-	-	-	-		58	7.2	4	2.8	58	98	
	002	26	4.0	3	1.3	26		-	-	-	-	-		68	7.2	4	3.1	68	94	
7	002	43	4.7	10	1.5	43		11	3.8	1	2.0	11		49	6.2	12	3.8	49	103	
	003	54	4.8	10	1.4	54		-	-	-	-	-		34	7.9	4	5.9	34	88	(2)
8	001	40	5.0	10	1.5	40		14	4.0	1	1.3	14		35	5.1	8	3.3	35	89	
	003	43	4.0	3	1.5	43		16	3.4	1	1.1	16		37	5.6	1	4.9	37	96	
9	002	24	4.3	10	1.9	24		-	-	-	-	-		42	6.0	12	3.0	40	66	(1)
	004	1	4.0	1	-	-		-	-	-	-	-		82	5.5	3	1.4	82	83	
11	002	40	5.6	6	1.6	40		15	3.6	3	2.9	15		43	5.6	16	3.5	43	98	
12	003	40	5.6	10	1.7	40		13	3.2	3	2.1	13		44	6.2	14	3.6	44	97	

NOTES:
(1) Equipment Malfunction - Cell Case Rupture
(2) No Charge Acceptance - Cycle 89

CONCLUSIONS

Observations made during the fabrication, experimentation and testing performed in this program lead to the following conclusions relative to sealed silver-zinc rechargeable battery cells using flexible inorganic separators:

1. The performance of inorganic separators in silver-zinc cells is effected significantly by the method used to impregnate (treat) the asbestos substrate with polyphenylene oxide.

2. The drying rate of solvents used in compounding ceramic filled slurries used in the fabrication of inorganic separators effects the integrity and flexibility of the coatings of slurry on the substrate.

3. The thickness of the coating of ceramic filled slurry applied to separator substrates effects the initial performance of cells using inorganic separators. The use of thicker coatings may require additional soaking time to realize full cell capacity.

4. A positive electrode made by continuous process methods using carefully selected silver active materials can be incorporated in the HS40-7 cell configuration resulting in improved capacity maintenance during cycle life.

5. The attachment of conductor leads to positive electrodes made by continuous process methods can be accomplished effectively by welding leads to either surface of the electrode in the lead attachment area.

6. The formulation, fabrication and application of absorber mats for negative electrodes has a significant effect on the capacity maintenance and performance of sealed silver-zinc cells during cycle life.

7. The design of sealed silver-zinc cells using inorganic separators must relate carefully the desired cell performance to the physical and electrical characteristics of this type of cell as typified by the HS40-7 configuration. Particular design emphasis must be applied to terminal sealing methods, adequate allowance for cell stack thickness, and sufficient electrode surface area to meet the current density levels of the particular cell application.