NASA / TM—2001-210598

Aerospace Nickel-Cadmium Cell Verification—Final Report

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January 2001

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Prepared for the
Long Beach Battery Conference 2001
sponsored by California State University, Long Beach
Long Beach, California, January 9–12, 2001

National Aeronautics and
Space Administration

Glenn Research Center

January 2001

Acknowledgments

The authors would like to thank the cell manufacturers for their cooperation and assistance with this technology assessment. We also acknowledge that Sanyo donated the five standard design Ni-Cd cells that were tested under this program.

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Aerospace Nickel-Cadmium Cell Verification—Final Report

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ABSTRACT

During the early years of satellites, NASA successfully flew "NASA-Standard" nickel-cadmium (Ni-Cd) cells manufactured by GE/Gates/SAFT on a variety of spacecraft. In 1992 a NASA Battery Review Board determined that the strategy of a NASA Standard Cell and Battery Specification and the accompanying NASA control of a standard manufacturing control document (MCD) for Ni-Cd cells and batteries was unwarranted. As a result of that determination, standards were abandoned and the use of cells other than the NASA Standard was required. In order to gain insight into the performance and characteristics of the various aerospace Ni-Cd products available, tasks were initiated within the NASA Aerospace Flight Battery Systems Program that involved the procurement and testing of representative aerospace Ni-Cd cell designs. A standard set of test conditions was established in order to provide similar information about the products from various vendors. The objective of this testing was to provide independent verification of representative commercial flight cells available in the marketplace today.

This paper will provide a summary of the verification tests run on cells from various manufacturers: Sanyo 35 Ampere-hour (Ah) standard and 35 Ah advanced Ni-Cd cells, SAFT 50 Ah Ni-Cd cells and Eagle-Picher 21 Ah Magnum and 21 Ah Super Ni-Cd™ cells from Eagle-Picher were put through a full evaluation. A limited number of 18 Ah and 55 Ah cells from Acme Electric were also tested to provide an initial evaluation of the Acme aerospace cell designs. Additionally, 35 Ah aerospace design Ni-MH cells from Sanyo were evaluated under the standard conditions established for this program. The test program is essentially complete. The cell design parameters, the verification test plan and the details of the test result well will be discussed.

Introduction

In the early 1970's NASA established Standard 20 Ah and 50 Ah Ni-Cd cell designs. General Electric was identified as the only qualified manufacturer of NASA Standard nickel-cadmium cells. Throughout the 1970's and early 1980's, a large number of successful flight programs utilized the conventional GE/Gates Ni-Cd cell designs. In the mid 1970's, Pellon Corporation, ceased production of Pellon 2505, the separator used in the NASA Standard cell designs. Supplies were stockpiled for future use. However, in the late 1980's, degradation of the stock of available Pellon 2505, combined with some plate problems, resulted in performance anomalies with the NASA Standard Ni-Cd cells. The use of replacement materials resulted in somewhat different operational characteristics for the NASA Standard Ni-Cd cells. Finally, in the early 1990's, NASA began to encounter a number of problems with the 50 Ah standard design cells onboard orbiting spacecraft. As a result, the NASA Deputy Administrator convened a NASA Battery Review Board in 1992.

The NASA Battery Review Board determined that the strategy of a NASA Standard Cell and Battery Specification and the accompanying NASA control of a standard manufacturing control document (MCD) for Ni-Cd cells and batteries was unwarranted. At the same time it noted that advanced Ni-Cd and Ni-H_2 technologies were maturing and alternate cell designs were becoming available from new sources. The Battery Review Board recommended that the NASA Aerospace Flight Battery Systems Program activities be expanded to provide independent verification of representative Ni-Cd and Ni-H_2 cells from various manufacturers. This paper summarizes the Ni-Cd cell verification activities that were initiated as a result of that recommendation.

Cell Verification Test Items

The cell verification test program involved verification testing of aerospace design cells from various manufacturers. The test articles were 21, 35 Ah advanced design Ni-Cd cells and 5, 35 Ah standard design Ni-Cd cells from Sanyo; 21, 50 Ah Ni-Cd cells from SAFT; 26, 21 Ah Magnum Ni-Cd cells and 26, 21 Ah Super Ni-Cd™ cells from Eagle-Picher, and 12 each, 18 Ah and 55 Ah aerospace design Ni-Cd cells from Acme Electric. Details of the cell designs are shown in Tables I through III. The Sanyo and SAFT cell designs represent conventional technology, cells with chemically impregnated plates and nylon separators; the Magnum and Super Ni-Cd™ cell designs incorporate advanced features like electrochemically impregnated plates and non-nylon separators. The Acme technology incorporates pasted fiber electrodes and polypropylene or nylon separators.

In addition to the Ni-Cd cells 25, 35 Ah Ni-MH cells, manufactured by Sanyo, were evaluated under similar test conditions to those used for the Ni-Cd cells. Design parameters for the Ni-MH cells are shown in Table I.

Cell Verification Test Plan

All cell testing being performed as part of this program was conducted at the Naval Surface Warfare Center, Crane, IN. The test plan for cells undergoing verification testing involved the following:

1) initial inspection of the cells upon receipt at Crane;
2) a repeat of portions of the manufacturer's acceptance tests to verify the performance demonstrated at the manufacturer's facility;
3) performance of the NASA Standard Acceptance Test Procedure (ATP) to establish baseline characteristics;
4) the establishment of V/T levels for each cell design;
5) vibration testing;
6) Low-Earth-Orbit (LEO) cycling at 40% DOD and 0^o, 20^o and 30^oC and accelerated geosynchronous-orbit (GEO) testing at 80% DOD and
7) the performance of destructive physical analysis on one cell of each design to establish baseline characteristics.

Details of the test conditions were discussed in a previous publication (1).

Test Results

The test program is nearly complete. Of the twenty-one packs on LEO testing, only five packs continue to cycle and of the five packs originally on GEO test, two continue to cycle. The remaining packs have failed.

The results of the tests listed under items 1 through 5 of the verification test plan were discussed in detail in previous publications (2,3,4). A summary of the test results follows.

Initial Inspection Upon Receipt of Cells

The incoming inspection testing showed that all cells tested as part of the verification test were leak free upon receipt at Crane.

Repeat of the Manufacturer's Acceptance Testing

For cells from each of the vendors, a representative performance/capacity determination cycle was repeated to verify performance demonstrated at the manufacturer’s facilities. For Sanyo cells, the results obtained at the factory were reproduced at Crane with the average group capacity measurements being within 1 Ah of one another. The Ni-MH cells from Sanyo exhibited very uniform capacities, however, the group exhibited a slightly lower capacity when tested at Crane, 36.2 Ah vs. 38.6 Ah based on tests at Sanyo.

Test results for the Eagle-Picher Magnum and Super Ni-Cd™ cells and the SAFT Ni-Cd cells agreed with those obtained at the manufacturer’s plant prior to cell shipment.

In the repeat of the manufacturer’s ATP run on the Acme cells, the capacities measured at Crane following a resistive let down were generally comparable or slightly higher than those measured at Acme. The steady state capacity measured at Crane for three of the four groups of the Acme cells was 10% less than that reported by the manufacturer.

NASA Standard Acceptance Testing

The NASA Standard ATP was designed to verify the lot-to-lot performance of the NASA Standard Cells. The NASA Standard ATP was run to provide a common baseline for information only. With minor exceptions, the cells from all of the manufacturers generally met all of the requirements that were established for the NASA Standard cell designs.

V/T Level Determination

The Standard NASA V/T curves were established in the early 1970's. They are a set of eight parallel lines separated by 20mV increments. The lines represent voltage limits that should be selected at various temperatures to achieve different levels of charge return. These curves, like the NASA ATP requirements are specific to the NASA Standard cell designs.

As part of this test program, unique V/T levels were established for each manufacturer via an approach that more closely relates to controlling the recharge ratio. Two sets of V/T curves were established for this test program. One was applied for the SAFT and Acme cells and the second was used for the Sanyo and EPI cells. Details of the V/T level determination and the results are documented in previous publications (1,3,4).

Vibration Testing

Vibration testing was completed on representative cells from each of the manufacturers. In all cases, the cells passed the vibration test with no voltage or current perturbations.

LEO Life Cycle Testing

All LEO testing was performed at 40% depth-of-discharge (DOD) based on nameplate capacity. The LEO regime was a 90-minute cycle with 60 minutes for charge and 30 minutes for discharge. The cells were tested in packs of five cells connected in series. The packs were charged at the 0.8C rate to the appropriate V/T cutoff, then the charge current was allowed to taper for the remainder of the charge period. The packs were discharged to 40% DOD at the 0.8C rate for the discharge portion of the orbit. Tests were run at 0^oC, 20^oC, or 30^oC. The results of the LEO life cycling tests are summarized in Figures 1 through 4. The figures show the end-of-charge voltages (EOCV), end-of-discharge-voltages (EODV) and recharge ratio as a function of cycle number for the minimum cell, maximum cell and the average of the five

cells in the pack. The Ni-Cd packs were grouped by test condition and the performance was plotted against a common range of cycles on the x-axis to aid in the comparison of results between test conditions and manufacturers. The packs were run with an attempt to minimize recharge ratio while maintaining a stable EODV. Throughout the LEO life testing, V/T levels were increased when the pack exhibited a relatively low recharge ratio combined with a decline in EODV. The manufacturer specific V/T curves generated as part of this program were used when adjusting V/T levels. Failure is defined as the point where the EODV falls below 1.0 volt and does not respond to recharge ratio adjustments, or where the pack becomes unmanageable on cycling, or where other unfavorable conditions, such as pack swelling or cell leakage, are observed.

NASA Standard Stress Test Conditions - The majority of the testing was performed under the NASA Standard Stress Test conditions - 40% DOD and 20°C. Cells are generally found acceptable for flight if they can perform successfully for two years, or 12,000 cycles under these test conditions. The results of the testing under the NASA Standard Stress Test conditions are shown in Figure 1.

The tests were not all started at the same time. To date, testing on the Sanyo, SAFT and Acme cells has been completed. The testing of the Eagle-Picher Magnum and Super™ Ni-Cd cells is continuing and scheduled for termination at the end of February 2001.

The packs of Acme 18 Ah and 55 Ah cells exhibited very uniform, stable performance over the cycle period. The 55 Ah pack from Acme with polypropylene separators was the first to fail at 7955 cycles. The remaining packs of Acme cells exhibited similar cycle performance, all failing at approximately 10,300 cycles. These were the first aerospace design cells produced by Acme. The prototype cells performed very well considering the maturity of the design. Acme indicated that design modifications and processing changes could be instituted to address the limitations of these cells.

The SAFT pack was discontinued at 18,730 cycles. They exceeded the two-year LEO cycle requirement with EODV's >1.0 volt, however, the cells exhibited relatively low EODV's, between 1.0 and 1.1 volts and required recharge ratios in the range of 115-125% to maintain the EODV.

The standard and advanced design Ni-Cd cell packs from Sanyo cycled in excess of 4.5 and 5.5 years respectively under the NASA Standard Stress Test conditions. (Only the advanced Ni-Cd pack data is shown in Figure 1.) The Sanyo cell packs required very low recharge ratios to maintain their EODV's but exhibited a fairly rapid decline in EODV as a function of cycles thus requiring frequent adjustments to the V/T levels. The EOCV for the Sanyo pack increased from 1.42 to 1.50 volts over the 32,326 cycles the pack performed.

The Eagle-Picher Magnum and Super Ni-Cd™ packs have accumulated 26,430 and 25,511 cycles respectively. These packs continue to cycle. These packs generally required frequent adjustments in V/T levels to maintain EODV and operated with an EODV less than 1.10 volts. Both Eagle-Picher packs exhibited stable EOCV performance at approximately 1.42 – 1.44 volts.

Low Temperature Stress Test Conditions - The results of the low temperature stress test are shown in Figure 2. This test consisted of 40% DOD cycling at 0°C. Ni-Cd cell packs from Sanyo, SAFT and Eagle-Picher were tested under this regime. To date only the SAFT pack has failed under these test conditions (25,518 cycles). Current cycle numbers are 34,740 cycles for the Sanyo Advanced design pack and 26,296 and 25,597 cycles for the Eagle-Picher Super and Magnum Ni-Cd packs. The Eagle-Picher Super Ni-Cd™ exhibited the highest EODV performance of all of the packs tested at 0°C. The EODV degraded from 1.15 volts at the start of LEO testing to 1.10 volts over the first 18,000 cycles. The pack exhibited a more rapid degradation in EODV over the next 6,000 cycles from 1.10 volts to 1.05 volts. An increase in the recharge ratio at 24,000 cycles raised the EODV to 1.10 volts. The EP Magnum pack showed an EODV of 1.15 volts over the first 14,000 cycles, then gradually degraded to <1.05 volts over the next 4,000 cycles, then remained stable at 1.03-1.05 volts over the last six thousand cycles. The Sanyo cell pack exhibited a slow decay in EODV from 1.15 volts to 1.05 volts over 28,000 cycles. An increase in the recharge ratio at 18,000 cycles resulted in raising the EODV to 1.10 volts.

High Temperature Stress Test Conditions - Figure 3 summarizes the results for the high temperature stress test that was run at 40% DOD and 30°C. All of the cell packs tested under these conditions have failed. The SAFT pack could not maintain an EODV >1.0 volt under these severe test conditions. At 2,200 cycles the pack was removed from test, reconditioned and returned to test at 10°C where it operated successfully for an additional 22,000 cycles. The Sanyo pack exhibited a constant increase in EOCV over its 15,900 cycles. Recharge ratios ranging from 102 to 106% were required to maintain the EODV at 30°C. At 15,900 cycles the pack exhibited some slight swelling and was removed from test. Again the Eagle-Picher Super Ni-Cd™ and Magnum Ni-Cd packs exhibited very similar performance. Both packs initially required very high recharge ratios to maintain the EODV's. The recharge ratio gradually decreased from 120% to ~105% over the first 4,000 cycles and remained fairly stable thereafter. The Super Ni-Cd™ pack showed more dispersion than the Magnum pack and failed at 17,193 cycles while the Magnum pack achieved 20,431 cycles to failure. The Sanyo and Eagle-Picher cells demonstrated significant life under these very stressful test conditions. The performance of the Sanyo cells is also impressive as these cells contained nylon separators that are subject to degradation at the higher temperatures.

Ni-MH LEO Test Results - The LEO cycle test results on the Sanyo Ni-MH cells are summarized in Figure 4. These tests were all run at 40% DOD and different temperatures, 0^o, 20^o (2-packs) or 40^oC. In general, the Ni-MH packs demonstrated slightly lower EODV's and significantly fewer cycles to failure than Ni-Cd packs cycled under similar conditions and more specifically than Sanyo Ni-Cd packs tested under similar conditions. The Ni-MH packs tested under the NASA Standard Stress Test conditions exhibited 15,243 and 15,763 cycles compared to the Sanyo Ni-Cd packs which achieved 28,241 and >30,864 cycles. Even though the Ni-MH cells exhibited lower cycle life that Ni-Cd cells tested under similar conditions, the packs demonstrated cycle life in excess of two years under the NASA Standard Stress Test conditions, which indicates they would have acceptable performance for nominal LEO missions. Testing at the temperature extremes showed similar results with the cycle life demonstrated for the Ni-MH cells being less that 50% of the life demonstrated for Sanyo Ni-Cd cells tested under similar conditions.

GEO Life Cycle Testing

The accelerated GEO testing involves a simulation of the seasonal variations during eclipse period followed by a shortened two-week sun period. The maximum DOD on the pack is 80%. The cells are charged at C/10 to 105% charge return followed by a trickle charge for the remainder of the charge time. The full sun periods are simulated with a C/100 trickle charge.

Two of the four Ni-Cd packs on GEO test have failed. The Eagle-Picher Magnum pack exhibited the poorest GEO performance of those tested. One cell of the five-cell pack exhibited a low EODV (<1.0 volt) and was removed from the pack during the fourth shadow period. A second cell dropped below the cutoff during the fifth eclipse period. The pack did not respond to reconditioning and was removed from cycling following the fifth shadow period. The SAFT pack was the next to fail. This pack was removed from test following the twenty-first eclipse when the cells began to exhibit temperature excursions during charge. The pack was reconditioned following the nineteenth eclipse period. This led to an increase in the EODV from 0.85 volts for the lowest cell to ~1.03 volts on the subsequent eclipse. However the recovery was short-lived, with the EODV falling below 1.0 volt during the twenty-first eclipse.

The Sanyo pack and the Eagle-Picher Super Ni-Cd™ pack continue to cycle. The Sanyo has completed thirty seven shadow period with the EODV of the lowest cell remaining at ~1.02 volts. The EP-Super Ni-Cd™ pack was started after the Sanyo pack and has also performed quite well through twenty-nine eclipse periods to date. For comparison purposes, performance for both packs remaining on test was evaluated through the first twenty-nine eclipse periods. Both packs performed quite well. The Sanyo pack exhibited more uniform pack performance throughout the cycle time. EODV for the lowest cell in the Sanyo pack for eclipse twenty-nine was 1.05 volts, with a pack average of 1.07 volts. The EP Super Ni-Cd™ pack had slightly higher voltages but more spread between the individual cells with the lowest cell reading ~1.05 volts and the average of the five cells at 1.08 volts. Both packs ran at about 106% recharge throughout the twenty-nine eclipse period.

Finally, the Sanyo Ni-MH cycled through eighteen eclipse periods before being removed from test for a low EODV and increasing EOCV. The pack ran at about 106% recharge throughout its life.

Concluding Remarks

The NASA sponsored aerospace Ni-Cd Verification test program has been completed. Aerospace Ni-Cd and Ni-MH cells from SAFT, Sanyo, Acme, and EP were evaluated in a one-time snapshot of 'representative' cells. The cells produced by Sanyo and EP demonstrated performance that indicates suitability for nominal LEO missions. The Sanyo and EP-Super Ni-Cd™ cells also demonstrated acceptable performance for GEO applications as well. Indeed, since this program was initiated, NASA and other users have successfully flown alternate technologies for a variety of LEO and GEO missions.

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TABLE I - CELL DESIGN PARAMETERS FOR SANYO AND SAFT CELLS

PARAMETER	SANYO N-35S/L1[1]		SAFT - VOS50AKBC		SANYO NI-MH	
	POSITIVE ELECTRODE	NEGATIVE ELECTRODE	POSITIVE ELECTRODE	NEGATIVE ELECTRODE	POSITIVE ELECTRODE	NEGATIVE ELECTRODE
ELECTRODE DIMENSIONS (mm)	104.4 x 100 x 0.63	104.4 x 100 x 0.80	150 x 110 x 0.79	150 x 110 x 0.92	104.4 x 80 x 0.603	104.4 x 80 x 0.45
PLAQUE POROSITY	85%	86%	N/A	N/A	84%	N/A
LOADING LEVEL	2.43 g/cc void	3.0 g/cc void	13.8 g/dm^2	18 g/dm^2	2.43 g/cc void	N/A
NUMBER OF PLATES	13	14	13	14	16	17
IMPREGNATION	CHEMICAL	CHEMICAL	CHEMICAL	CHEMICAL	CHEMICAL	N/A
CAPACITY THEORETICAL ACTUAL UTILIZATION	46.8 Ah 42.6 Ah 91%	101.0 Ah 69.7 Ah 69%	49.94 Ah[2] 61 Ah 57 Ah[3]	88.89 Ah[2] 109.8 Ah 96.9 Ah[3]	44.7 Ah 40.7 Ah 92%	79.1 Ah 290mAh/g
NEG:POS RATIO	1.64		1.8		1.94	
SEPARATOR	FT215N - WASHED NYLON, 98g/m^2, 0.22 mm thick		FTR3, 50 g/m^2 0.28 mm thick		NYLON - 95g/m^2 0.22mm thick	
PRE CHG CAPACITY	12 Ah		5 -15 Ah		0	
ELECTROLYTE	98g, 31% KOH		218 g, 31 % KOH		91g, 31% KOH,	
PLATE TREATMENT	NEGATIVE - ORGANIC PLATE TREATMENT		NONE		NONE	
CELL DIMENSIONS (mm)	115.2 x 106.9 x 25.2		200.5 x 113.8 x 31.5		95.2 x 106.9 x 25.2	
CELL WEIGHT	1050 g		1980 g		872 g	
CELL CAPACITY	38.7 Ah		50 Ah/61 Ah		37.4 Ah (actual @ 10^{o}C)	

[1] 1N-35S/G0 design parameters are identical to N-35S/L1 except for unwashed separator and untreated negative plates
[2] SAFT values are for nominal capacity [3] SAFT values are for guaranteed minimum capacity

TABLE II - CELL DESIGN PARAMETERS FOR EAGLE-PICHER SUPER Ni-Cd™ AND MAGNUM Ni-Cd CELLS

PARAMETER	EP - SUPER Ni-Cd™		EP-MAGNUM	
	POSITIVE ELECTRODE	NEGATIVE ELECTRODE	POSITIVE ELECTRODE	NEGATIVE ELECTRODE
ELECTRODE DIMENSIONS (mm)	92.2 x 89.9 x 0.71	92.2 x 89.9 x 0.81	92.2 x 89.9 x 0.74	92.2 x 89.9 x 0.81
PLAQUE POROSITY	84%	84%	84%	84%
LOADING LEVEL g/cc void	1.65±0.2	2.1±0.2	1.65±0.2	2.1±0.2
NUMBER OF PLATES	13	14	13	14
IMPREGNATION	ELECTRO-CHEMICAL	ELECTRO-CHEMICAL	ELECTRO-CHEMICAL	ELECTRO-CHEMICAL
CAPACITY THEORETICAL ACTUAL UTILIZATION	28.2 Ah 23.5 Ah 87%	56.3 Ah	28.7 Ah 24.4 Ah 87%	56.3 Ah
NEG:POS RATIO	2.0		1.99	
SEPARATOR	ZIRCONIUM OXIDE W/POLYMER IMPREGNATION		POLYPROPYLENE W/ POLYMER IMPREGNATION	
PRE CHG CAPACITY	30-40% OF EXCESS NEG		30-40% OF EXCESS NEG	
ELECTROLYTE	99g, 31% KOH, PROPRIETARY ADDITIVE		91g, 31% KOH, PROPRIETARY ADDITIVE	
PLATE TREATMENT	NONE		NONE	
CELL DIMENSIONS (mm)	118.6 x 95.0 x 28.8		118.6 x 95.0 x 28.8	
CELL WEIGHT	977 g		948 g	
CELL CAPACITY	24.4 Ah (ACTUAL @10^{o}C)		24.4 Ah (ACTUAL @10^{o}C)	

Fig 1 – End of half cycle voltages vs. cycle numbers for cells from all manufacturers – NASA Standard Stress Test conditions, 40% DOD, 20°C x-Vavg, ◊Vmax, ∆ Vmin, - % Recharge

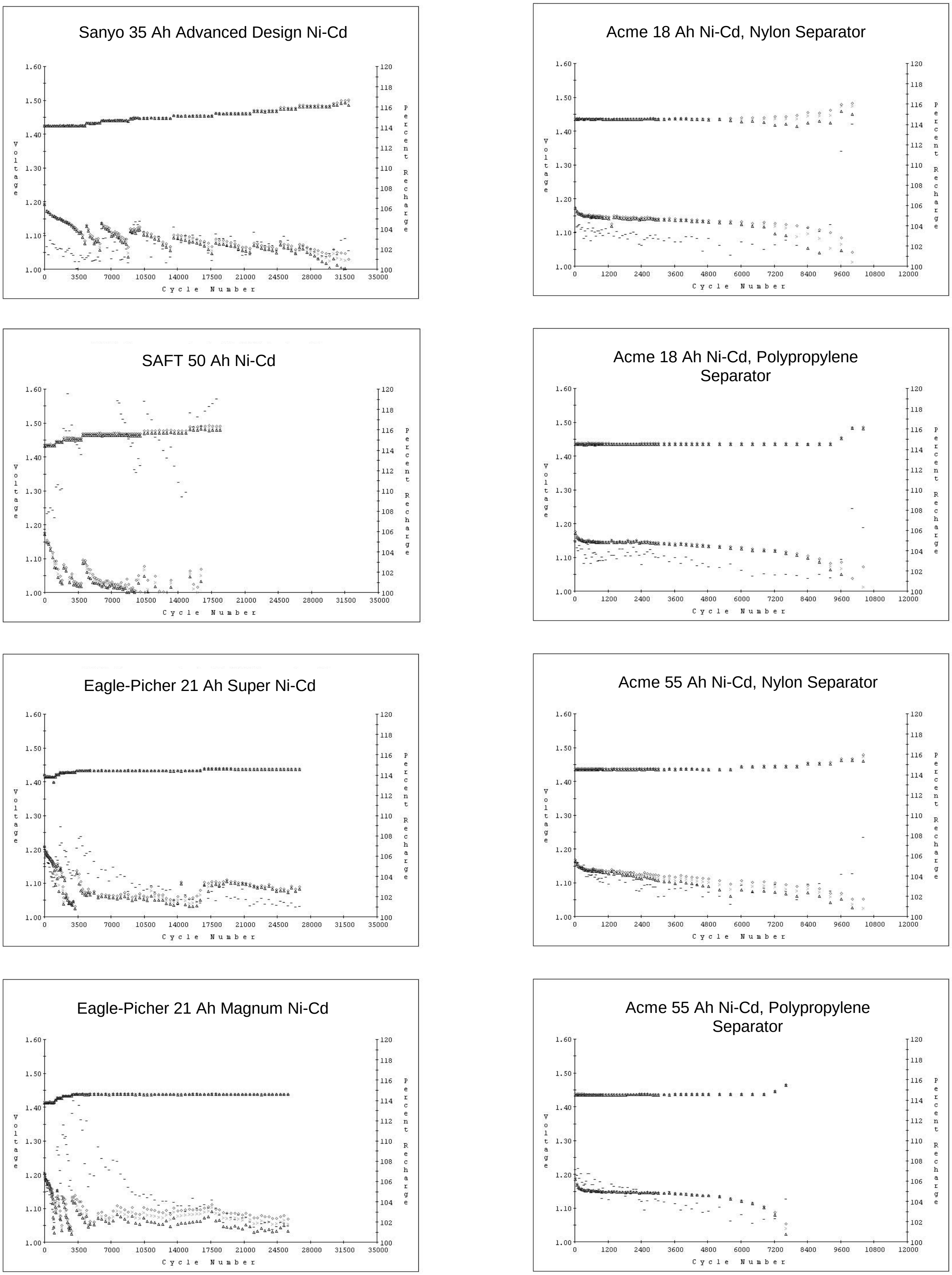

Fig. 2 – End of half cycle voltages vs. cycle number for low temperature stress test conditions – 40% DOD, 0°C. x Vavg, ◊ Vmax, ∆ Vmin, -% Recharge

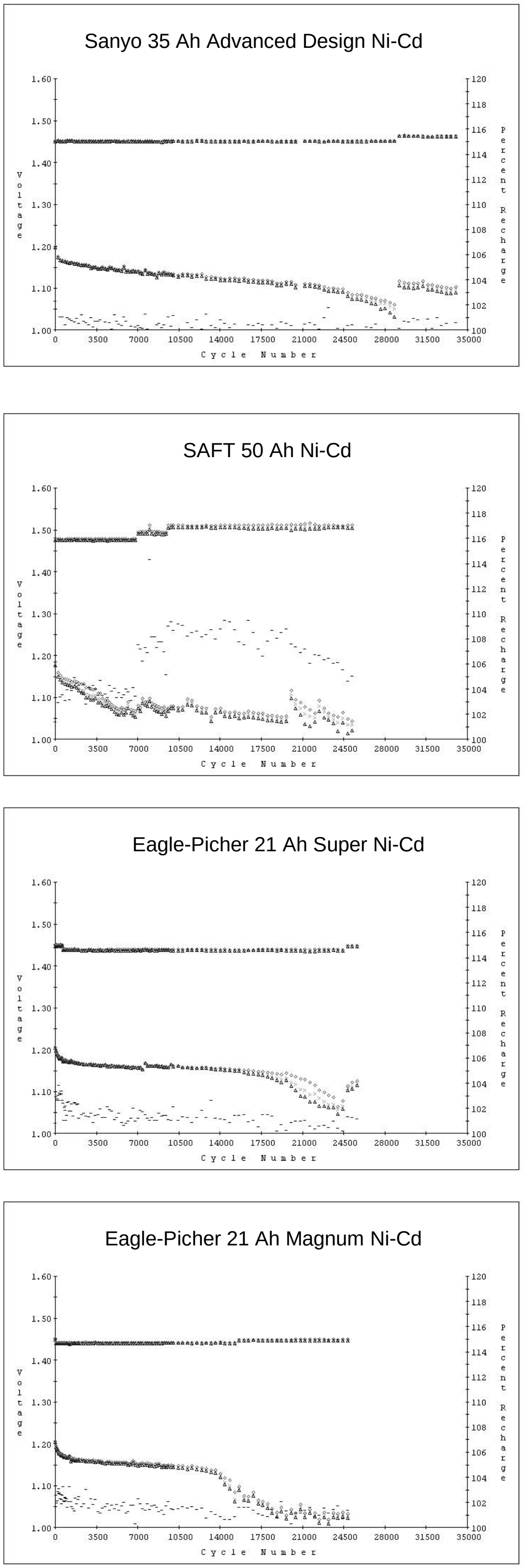

Fig. 3 – End of half cycle voltages vs. cycle number for high temperature stress test conditions – 40% DOD, 30°C. x Vavg, ◊ Vmax, ∆ Vmin, -% Recharge

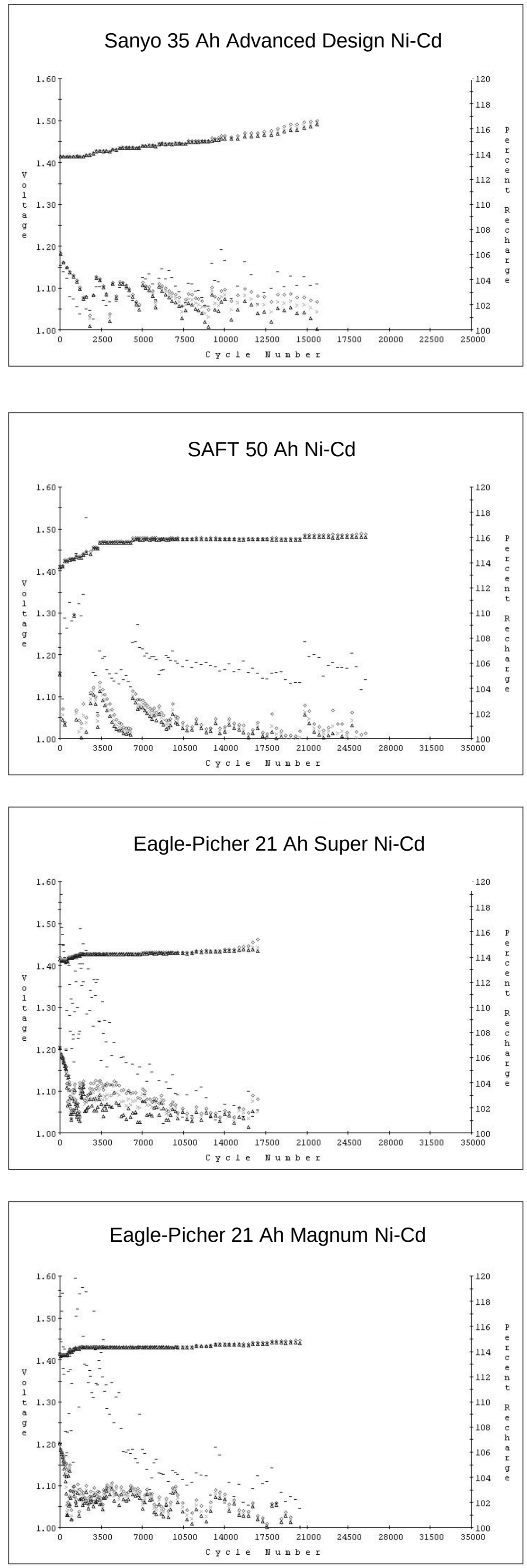

Fig 4 – End of half cycle voltages vs. cycle number for Sanyo Ni-MH cells at all stress test conditions – 40% DOD and various temperatures. x Vavg, ◊Vmax, ∆ Vmin, -%Recharge

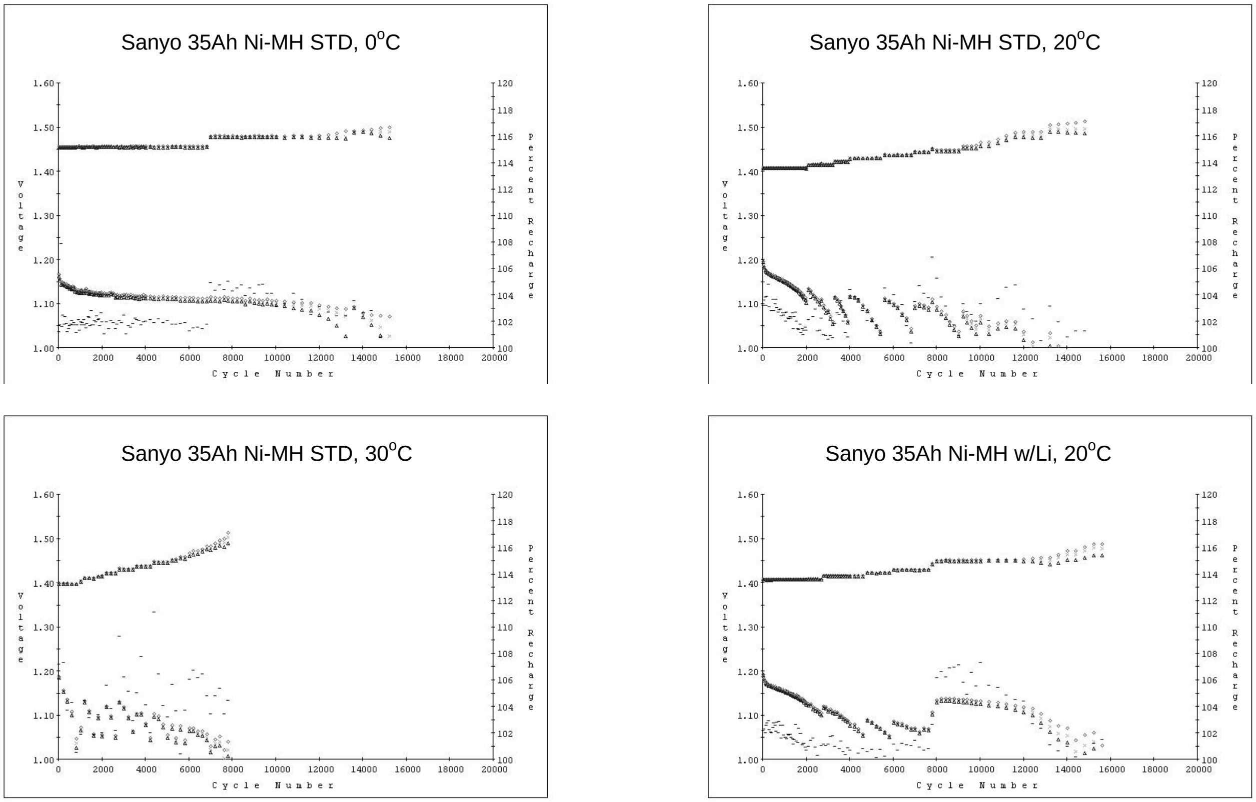

TABLE III – CELL DESIGN PARAMETERS FOR ACME CELLS

	SPFNC-X18		SPFNC-X55	
PARAMETER	**POSITIVE ELECTRODE**	**NEGATIVE ELECTRODE**	**POSITIVE ELECTRODE**	**NEGATIVE ELECTRODE**
ELECTRODE DIMENSIONS (mm)	95 x 62 x 1.44	95 x 62 x .82	116 x 110 x 1.44	116 x 110 x 0.78
PLAQUE POROSITY (%)	81	79	79	78
LOADING LEVEL (g/cc void)	1.51	2.42	1.51	2.63
NUMBER OF PLATES	8	16	12	24
IMPREGNATION PROCESS	MECHANICAL VIBRATION	MECHANICAL VIBRATION	MECHANICAL VIBRATION	MECHANICAL VIBRATION
PLATE TREATMENT	N/A	ANTI-AGGLOMERATE	N/A	ANTI-AGGLOMERATE
THEORETICAL CAPACITY	20.6 Ah	60.8 Ah	66.8 Ah	202.2 Ah
SEPARATOR	**NYLON**	**POLYPROPYLENE**	**NYLON**	**POLYPROPYLENE**
% UTILIZATION OF POSITIVE	91	91	90	90
NEG:POS RATIO	2.78	2.78	3	3
THEORETICAL CD RESERVE				
CHARGED (Ah)	25.2	25.2	92.4	94.4
DISCHARGED (Ah)	15	15	43	41
ELECTROLYTE - (g) 8M KOH, 0.8M LIOH	85	89	231	246
CELL WEIGHT(g)	722 +/- 3	725 +/- 3 g	2120 +/- 7	2080 +/- 7
CELL DIMENSIONS (mm)	115 x 54 x 168		67 x 35 x 141	
CELL CAPACITY	18.8 +/ 0.5		59.5 +/- 1	

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 2001	Technical Memorandum

4. TITLE AND SUBTITLE

Aerospace Nickel-Cadmium Cell Verification—Final Report

5. FUNDING NUMBERS

WU–755–A4–08–00

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field
Cleveland, Ohio 44135–3191

8. PERFORMING ORGANIZATION REPORT NUMBER

E–12556

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546–0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TM—2001-210598

11. SUPPLEMENTARY NOTES

Prepared for the Long Beach Battery Conference 2001 sponsored by California State University, Long Beach, Long Beach, California, January 9–12, 2001. Michelle A. Manzo, NASA Glenn Research Center, D. Michael Strawn and Stephen W. Hall (retired), Naval Surface Warfare Center, Crane Division, 300 Highway 361, Code 6095, Crane, Indiana 47522. Responsible person, Michelle A. Manzo, organization code 5420, 216–433–5261.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Categories: 20 and 44 Distribution: Nonstandard

Available electronically at http://gltrs.grc.nasa.gov/GLTRS

This publication is available from the NASA Center for AeroSpace Information, 301–621–0390.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

During the early years of satellites, NASA successfully flew "NASA-Standard" nickel-cadmium (Ni-Cd) cells manufactured by GE/Gates/SAFT on a variety of spacecraft. In 1992 a NASA Battery Review Board determined that the strategy of a NASA Standard Cell and Battery Specification and the accompanying NASA control of a standard manufacturing control document (MCD) for Ni-Cd cells and batteries was unwarranted. As a result of that determination, standards were abandoned and the use of cells other than the NASA Standard was required. In order to gain insight into the performance and characteristics of the various aerospace Ni-Cd products available, tasks were initiated within the NASA Aerospace Flight Battery Systems Program that involved the procurement and testing of representative aerospace Ni-Cd cell designs. A standard set of test conditions was established in order to provide similar information about the products from various vendors. The objective of this testing was to provide independent verification of representative commercial flight cells available in the marketplace today. This paper will provide a summary of the verification tests run on cells from various manufacturers: Sanyo 35 Ampere-hour (Ah) standard and 35 Ah advanced Ni-Cd cells, SAFT 50 Ah Ni-Cd cells and Eagle-Picher 21 Ah Magnum and 21 Ah Super Ni-Cd™ cells from Eagle-Picher were put through a full evaluation. A limited number of 18 and 55 Ah cells from Acme Electric were also tested to provide an initial evaluation of the Acme aerospace cell designs. Additionally, 35 Ah aerospace design Ni-MH cells from Sanyo were evaluated under the standard conditions established for this program. The test program is essentially complete. The cell design parameters, the verification test plan and the details of the test result will be discussed.

14. SUBJECT TERMS

Battery; Ni-Cd

15. NUMBER OF PAGES

14

16. PRICE CODE

A03

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	