NASA Technical Memorandum 100936

Small Scale Bipolar Nickel-Hydrogen Testing

(NASA-TM-100936) SMALL SCALE BIPOLAR NICKEL-HYDROGEN TESTING (NASA) 10 p CSCL 10C

N88-25059

Unclas
G3/44 0149240

Michelle A. Manzo
Lewis Research Center
Cleveland, Ohio

Prepared for the
33rd International Power Sources Symposium
sponsored by the Department of the Army
Cherry Hill, New Jersey, June 13–16, 1988

NASA

SMALL SCALE BIPOLAR NICKEL-HYDROGEN TESTING

Michelle A. Manzo
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

SUMMARY

Bipolar nickel-hydrogen batteries, ranging in capacity from 6 to 40 A-hr, have been tested at the NASA Lewis Research Center over the past 6 years. Testing in small scale, 1 A-hr bipolar nickel-hydrogen stacks has been initiated as a means of screening design and component variations for bipolar nickel-hydrogen cells and batteries. Four small scale batteries have been built and tested. Characterization and limited cycle testing were performed to establish the validity of test results in the scaled down hardware. The results show characterization test results to be valid. LEO test results in the small scale hardware have limited value.

E-4216

INTRODUCTION

The NASA Lewis Research Center has been involved in the design, verification, and testing of bipolar nickel-hydrogen batteries over the last 6 years. Two 6 A-hr (4- by 8-in.) stacks and two 40 A-hr (8- by 24-in.) bipolar nickel-hydrogen stacks have been constructed to verify the bipolar concept and demonstrate electrochemical performance and active cooling techniques. Construction of these stacks is complicated and time consuming. It is not feasible to conduct routine screening and component evaluations with these large stack configurations. Therefore, hardware for 1 A-hr (2- by 2-in.) bipolar stacks, pressure vessels to house the stacks and test stands to cycle the stacks have been designed and fabricated for use in routine testing and evaluation of bipolar components and design modifications.

Testing in the 2- by 2-in. bipolar stacks offers a method for screening potential components for incorporation into larger stacks. The small scale hardware can easily be used to evaluate design variables, electrolyte fill procedures, oxygen recombination schemes, and components such as hydrogen electrodes, thick versus thin nickel electrodes, new concepts for electrolyte reservoir plates, and new separator materials.

Four 2- by 2-in. stacks were built to resemble the higher capacity bipolar stacks that were tested. Characterization and limited cycle testing were performed to establish the validity of tests in the scaled down hardware. Details of stack construction, test procedures, the results of the tests performed on the 2- by 2-in. stacks and their relationship to the tests run on their counterparts (two 6 and one 40 A-hr battery) will be discussed.

STACK CONSTRUCTION PARAMETERS

The four initial, 1 A-hr, 2- by 2-in. stacks were built to resemble their 6 and/or 40 A-hr counterparts. The construction parameters for the four 2- by

2-in. bipolar stacks and their relationships to the larger stacks are summarized in table I. Five cell stacks were assembled for evaluation with the 2- by 2-in. hardware whereas ten cell stacks were constructed with the larger hardware. Construction techniques and details for the larger stacks are discussed in references 1 to 3. A discussion of the component specifications for the four 2- by 2-in. stacks and their relationship to the original stacks follows.

Gas Screen

The gas screen used in all of the stacks discussed was nickel Exmet 5Ni35-1/0 by 0.060. It was compressed from 0.060 to 0.040 in. to fit into the cavity designed for the hydrogen electrode and gas screen.

Hydrogen Electrode

All of the original stacks had the same type of hydrogen electrode. It was manufactured by Life Systems, Inc. (LSI) and consisted of a platinum/Teflon mixture deposited on a gold plated nickel screen. The first three 2- by 2-in. stacks were built with "good" electrodes, based on a polarization screening test, and the fourth stack was built identical to the third with the exception of the hydrogen electrodes. In three of the five cells the hydrogen electrode was split 60:40 with 40 percent of the area representing an electrode with high polarization and the remaining 60 percent an electrode with acceptable polarizations.

Separator and Wick Rings

The separator used in all of the stacks was beater treated asbestos (BTA). Two layers were used in the second 4- by 8-in. stack and in stack II of the 2- by 2-in. stacks and three layers in all of the others. Five layers of fuel cell grade asbestos (FCGA) composed the wick rings.

Nickel Electrode

The first 6 A-hr stack was constructed with electrodes available. The nickel electrodes used were chemically impregnated to a loading of 2.1 g/cm^3 void. Electrochemically impregnated electrodes, loaded to 1.6 g/cm^3 void were used in all subsequent builds. This relationship was maintained in the 2- by 2-in. stacks. All of the nickel electrodes were obtained from Eagle Picher (EP).

Electrolyte Reservoir Plate (ERP)

An electrolyte reservoir plate was incorporated into each cell. The material used was a foam metal, initially 100 mils thick compressed to 43 mils for the first stack and stack I of the 2- by 2-in. stacks and individually sized to result in the same separator compression in the following three stacks and their 2- by 2-in. counterparts. The nominal thickness was 43 mils in stack II and 90 mils in stacks III and IV. In stack I there were slots cut into the ERP to allow the introduction of recombination strips, which consisted of platinum hydrogen electrode strips encased in Gortex tubes. These slots provided an area for nickel expansion (ref. 4) and were eliminated in later builds. In stacks II to IV the slots were replaced with grooves leaving a solid area of ERP against the nickel electrode face.

Bipolar Plates

The 6 A-hr stack used hardware loaned by LSI. The bipolar plates, as received, were gold plated nickel. The plating was removed for the rebuild and the areas where electrical conduction was not required were Teflon coated in an effort to reduce shunt currents caused by electrolyte leakage around the edges of the bipolar plates. The bipolar plates for the 40 A-hr builds were also Teflon coated. In the 2- by 2-in., the first stack had gold plated nickel bipolar plates, stack II had nickel bipolar plates with Teflon coated edges, and stacks III and IV had uncoated nickel bipolar plates.

Frame Thickness

The original frames, loaned from LSI and used for the first two builds, were 150 mils thick as were the frames used in stacks I and II. The 40 A-hr build used thicker frames of 195 mils. This thickness was matched in stacks III and IV.

Cell Fill Procedure

The original 6 A-hr bipolar stack was activated with a vacuum backfill through manifolds at either end of the stack. Shunt currents were evident an effort was made to minimize electrolyte paths by modifying the fill procedure for subsequent battery builds. In the modified procedure, each cell was activated individually upon construction. This modified procedure was used in all of the 2- by 2-in. stacks.

BATTERY TEST PROCEDURES

The general procedure used for testing the bipolar stacks consists of formation/capacity determination cycles, characterization tests run at various charge and discharge rates, as well as various hydrogen pressures, and in the case of the 40 A-hr stack various temperatures, and LEO cycle testing at 40 or 80 percent depth of discharge (DOD). Occasionally, 72 hr open-circuit stands were performed with the battery in the charged state in order to detect the presence and severity of possible shunt currents. Full details of the testing and the results for the 6.5 and 40 A-hr stacks are available in references 1 to 3. Testing of the 2- by 2-in. stacks was, for comparison purposes, planned to parallel as closely as possible the original tests run on the larger capacity batteries.

The formation cycles run consisted of a C/10 charge for 16 hr and a C/4 rate discharge. These cycles were also used to determine a baseline capacity for each individual battery. The 2- by 2-in. stacks were then characterized as follows: The batteries were charged at the C/4, C/2, and C rates in combination with the discharge rates of C/4, C/2, C, and 2C. Twelve characterization cycles were run in all. A 72 hr open-circuit stand was run after the characterization cycles. The batteries were fully charged at the C rate, left on open circuit for 72 hr, then discharged at the C/4 rate. The difference in capacity when compared to a similar cycle without the stand time gives an indication of the presence of shunt currents. Stacks I to III were LEO cycled at 80 percent DOD and stack IV was LEO cycled at 40 percent DOD. Capacity determination cycles, using rates representative of those required for the LEO testing were run prior to the LEO tests.

RESULTS AND DISCUSSION

The characterization performance of stacks I and II very closely paralleled the results found in their higher capacity counterparts. The first 4- by 8-in. stack had lower capacity and higher cell operating voltages for a specified set of charge discharge conditions than did the second stack with electrochemically impregnated nickel electrodes. These differences were verified in the 2- by 2-in. stacks as shown in figure 1. Stack I of the 2- by 2-in. had a capacity of 0.90 A-hr which ratios to 7.2 A-hr for its 4- by 8-in. counterpart. The capacity of the second 2- by 2-in. stack was measured at 1.0 A-hr which ratios to 8 A-hr for its higher capacity counterpart. The original stacks were rated at 6.5 and 8 A-hr respectively, indicating good agreement in the results in tests using the small and large hardware. Stack I and its high capacity counterpart typically operated at 1.3 V (midpoint voltage) on a C/4 rate discharge. Stack II and its mate both operated at 1.26 V under the same conditions, again indicating good agreement. Unfortunately there were a number of changes made in the construction of the first two 6 A-hr stacks and their 1 A-hr copies so it is not possible to tell at this point what component and/or variable is responsible for the performance differences. The major differences that might be responsible for the performance variations in stacks I and II are the nickel electrode type (chemically versus electrochemically impregnated) and the bipolar plates (gold plated nickel versus pure uncoated nickel with Teflon coated edges). The nickel electrode type will effect both capacity and voltage performance and the gold plated bipolar plate may offer a lower contact resistance between components which would result in lower polarization and higher voltage performance. It is apparent that the 2- by 2-in. stacks are an appropriate test vehicle to further evaluate the effects of these parameters and the contribution of each to the cells performance.

The same comparisons can be made for stack III and the 40 A-hr bipolar battery. Capacity measured at the C/4 rate to an average of 1.0 V per cell was 0.88 A-hr for the 2- by 2-in. stack. This ratios to 42 A-hr for the 8- by 24-in. hardware which is in agreement with the measured capacity under similar conditions. Cell operating voltage at the midpoint was 1.26 V for both batteries.

The hydrogen electrodes used in the first 6 A-hr stack performed very well. However, materials or manufacturing variables developed, resulting in an inconsistent product and questionable performance, namely high polarizations, in some of the electrodes prepared for the subsequent builds. An effort was made to screen the electrodes used for the builds and only the best were used. However, we could not be sure of consistent performance over the entire electrode area. Therefore, in order to determine the effects of hydrogen electrodes with high polarizations upon cell performance stack IV was constructed identical to stack III but with three of the five cells having hydrogen electrodes with known large inactive areas which exhibited high polarizations. Cells 1 to 3 of the five cell stack had hydrogen electrodes in which 40 percent of the area was known to be inactive. A discharge plot for this battery is shown in figure 2. It can be seen that the cells with the known bad hydrogen electrode, cells 1 to 3, operated at lower voltage and had less capacity than cells 4 and 5. This indicates that the cells with bad hydrogen electrode areas will most likely operate at a higher relative current density in the areas opposite to the "good" hydrogen electrode. This will result in lower voltage performance and lower capacity as all of the nickel electrode is not easily accessible for discharge. Since the capacity delivered from cells 1 to 3 at the C/4 rate is about 85 percent of that obtained from cells 4 and 5, it can be concluded that some of the capacity of the nickel electrode in the areas adjacent to the "bad" hydrogen electrodes is available at the low rates. For the 2C rate discharge shown in figure 2, the battery cutoff at low voltage before cells 4 and 5 reached the cell cutoff so performance could not be fully evaluated. However cells 1 to 3 reached the 1.0 V cutoff at 73 percent of the total capacity removed to battery cutoff which is a reduction in performance at the higher discharge rates over the C/4 rate discharge.

Comparison of the 2- by 2-in. battery performance on the open-circuit stand tests gives an indication of the effectiveness of the Teflon coating in reducing shunt currents. Table II summarizes the results. Stack II, the only stack with Teflon coated bipolar plates exhibited the highest capacity retention on open-circuit stand at 91 percent. Stacks I, IV, and III followed at 80, 74, and 53 percent retention respectively. A 20 to 30 percent loss over 72 hr is common for nickel-hydrogen cells. Stack III at 50 percent loss exhibits a problem with shunt currents which reflected in the LEO cycle tests subsequently run.

The LEO testing of the 2- by 2-in. stacks did not correlate with the original stacks as well as the characterization testing did. In general, the 2- by 2-in. stacks exhibited a higher rate of degradation of end-of-discharge voltage versus cycles than did their higher capacity counterparts. Shunt currents and cell electrolyte loss resulting in performance degradation over the course of cycling were experienced. The 2- by 2-in. stacks did not have any gaskets or seals between cells, whereas some seal was present in the larger capacity batteries. The hardware should be modified to incorporate a seal if long term LEO testing is required.

CONCLUSIONS

The results of the testing in the four initial 2- by 2-in. stacks indicate that they provide a valuable means for quickly screening performance variations resulting from component differences in bipolar stacks. They require much less preparation and smaller quantities of materials for screening. However, as presently configured, the hardware should not be used for life cycle testing as electrolyte management cannot be controlled over long periods of time.

REFERENCES

1. Cataldo, R.L.: Test Results of A Ten Cell Bipolar Nickel-Hydrogen Battery. Energy for the Marketplace (18th IECEC), Vol. 4, American Institute of Chemical Engineers, 1983, pp. 1561-1567. (NASA TM-83384.)

2. Cataldo, R.L.: Life Cycle Test Results of A Bipolar Nickel-Hydrogen Battery. Energy for the Twenty-First Century (20th IECEC), Vol. 1, Society of Automotive Engineers, 1985, pp. 1.346-1.351. (NASA TM-87046.)

3. Cataldo, R.L.: Parametric and Cycle Tests of a 40-A-hr Bipolar Nickel-Hydrogen Battery. Advancing toward Technology Breakout in Energy Conversion (21st IECEC), Vol. 3, American Chemical Society, 1986, pp. 1547-1553. (NASA TM-88793.)

4. Manzo, M.A., et al.: Teardown Analysis of a Ten Cell Bipolar Nickel-Hydrogen Battery. Advanced Energy Systems - Their Role in our Future (19th IECEC), Vol. 1, American Nuclear Society, 1984, pp. 270-278. (NASA TM-83618.)

TABLE I. - IDENTIFICATION OF 2- BY 2-IN. STACK COMPONENTS AND THEIR HIGHER CAPACITY COUNTERPARTS

	Stack			
	I	II	III	IV
	Counterpart			
	6.5 A-hr, 4- by 8-in.	8 A-hr, 4- by 8-in.	40 A-hr, 8- by 24-in.	40 A-hr, 8- by 24-in.
Gas screen	5Ni35-1/0 by 0.060 compressed to 0.042 in.	5Ni35-1/0 by 0.060 compressed to 0.042 in.	5Ni35-1/0 by 0.060 compressed to 0.042 in.	5Ni35-1/0 by 0.060 compressed to 0.042 in.
Hydrogen electrode	LSI	LSI	LSI	LSI/combination of high and low polarizations
Separator	3 layers BTA	2 layers BTA	3 layers BTA	3 layers BTA
Wick rings	5 layers FCGA	5 layers FCGA	5 layers FCGA	5 layers FCGA
Nickel electrode	EP chemically impregnated	EP electrochemically impregnated	EP electrochemically impregnated	EP electrochemically impregnated
ERP	100 mils compressed to 43 with slots	Individually sized from 100 to 43 mils	Individually sized from 100 to 90 mils	Individually sized from 100 to 90 mils
Bipolar plates	Gold plated	Teflon coated, rough surface	No treatment	No treatment
Fill method	Individual component fill	Individual component fill	Individual component fill	Individual component fill
Frame thickness	150 mils	150 mils	195 mils	195 mils

TABLE II. - COMPARISON OF STACK DISCHARGE CAPACITY WITH AND WITHOUT A 72-hr OPEN-CIRCUIT STAND

[Capacity (A-hr) following C rate charge and C/4 rate discharge.]

Stack	No open-circuit stand	72-hr open-circuit stand	Capacity loss, percent
I	0.93	0.76	18.2
II	1.04	.95	8.6
III	.86	.45	47.6
IV	.87	.65	25.2

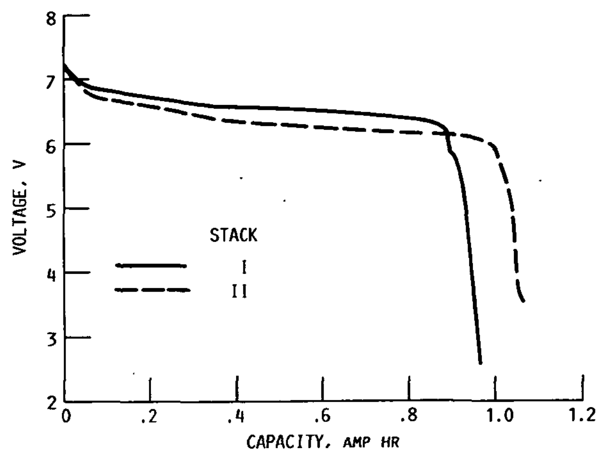

FIGURE 1. - COMPARISON OF DISCHARGE PERFORMANCE FOR STACKS I AND II, C RATE CHARGE FOLLOWED BY C/4 RATE DISCHARGE.

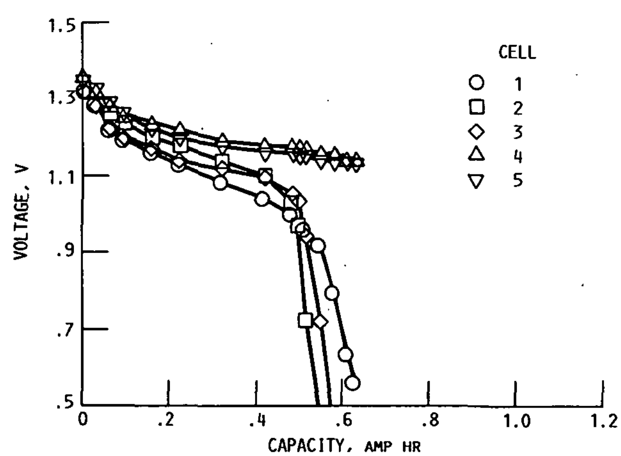

FIGURE 2. - STACK IV, 2 C RATE DISCHARGE PERFORMANCE.

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No. NASA TM-100936	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Small Scale Bipolar Nickel-Hydrogen Testing		5. Report Date
		6. Performing Organization Code
7. Author(s) Michelle A. Manzo		8. Performing Organization Report No. E-4216
		10. Work Unit No. 506-41-21
9. Performing Organization Name and Address National Aeronautics and Space Administration Lewis Research Center Cleveland, Ohio 44135-3191		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546-0001		14. Sponsoring Agency Code

15. Supplementary Notes

Prepared for the 33rd International Power Sources Symposium sponsored by the Department of the Army, Cherry Hill, New Jersey, June 13-16, 1988.

16. Abstract

Bipolar nickel-hydrogen batteries, ranging in capacity from 6 to 40 A-hr, have been tested at the NASA Lewis Research Center over the past six years. Testing in small scale, 1 A-hr bipolar nickel-hydrogen stacks has been initiated as a means of screening design and component variations for bipolar nickel-hydrogen cells and batteries. Four small scale batteries have been built and tested. Characterization and limited cycle testing were performed to establish the validity of test results in the scaled down hardware. The results show characterization test results to be valid. LEO test results in the small scale hardware have limited value.

17. Key Words (Suggested by Author(s)) Nickel-hydrogen batteries Bipolar batteries Batteries	18. Distribution Statement Unclassified – Unlimited Subject Category 44

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No of pages	22. Price*
Unclassified	Unclassified	8	A02

NASA FORM 1626 OCT 86

*For sale by the National Technical Information Service, Springfield, Virginia 22161

National Aeronautics and
Space Administration

Lewis Research Center
Cleveland, Ohio 44135

SECOND CLASS MAIL

ADDRESS CORRECTION REQUESTED

NASA