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Nickel-Hydrogen Cell Low-Earth-Orbit Life Test Update

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NICKEL-HYDROGEN CELL LOW-EARTH-ORBIT LIFE TEST UPDATE

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ABSTRACT

When individual pressure vessel (IPV) nickel-hydrogen (Ni/H_2) cells were selected as the energy storage system for Space Station Freedom in March of 1986, a limited database existed on life and performance characteristics of these cells in a low-earth-orbit (LEO) regime. Therefore, NASA LeRC initiated a Ni/H_2 cell test program with the primary objectives of building a test facility, procuring cells from existing NASA contracts, and screening several cell designs by life testing in a LEO 35% depth-of-discharge (DOD) scenario. A total of 40 cells incorporating 13 designs were purchased from Yardney, Hughes, and Eagle-Picher. Thirty-two of the cells purchased were 65 Ampere-hour (A-hr) nameplate capacity and eight cells were 50 A-hr. Yardney and Eagle-Picher cells were built with both the Air Force recirculating and the advanced back-to-back electrode stack configurations and incorporated 31 and 26% potassium hydroxide (KOH) electrolyte. Hughes cells were built with the back-to-back design and with both 31 and 26% KOH. Acceptance testing of the first delivered cells began in March of 1988, with life testing following in September of that year. Performance comparisons of these cells are made here while specifically addressing life test data relative to the design differences.

EXPERIMENTAL

Test Facility

Since Ni/H_2 cells produce hydrogen, the cells are housed inside two 93" x 29" x 43" explosion-proof test chambers for safety. One chamber runs at 10°C and the other runs at -5°C. Each cell is surrounded by an aluminum thermal sleeve with a flanged midsection where it is mounted vertically on a copper coldplate. The coldplates are cooled by a chiller located outside the chamber that circulates an ethylene glycol and water solution through channels in the coldplate. Each test chamber has a cooled N_2 purge that runs continuously during testing.

The test facility consists of 40 independent cell test positions. Each consists of a charge/discharge controller, a DC power supply, a temperature meter, and an Ampere-hour meter. The charge/discharge controllers allow for setting of the currents and the high and low voltage limits. Each cell has two thermocouples attached to the thermal sleeve midway between the flange and the top of the sleeve. One thermocouple is wired to the temperature meter which serves as an alarm if the temperature exceeds the allowable range. The other thermocouple is wired into the data acquisition system. The Ampere-hour meter is a safety device which prevents overcharging the cells. The DC power supplies are capable of a maximum charge and discharge current of 42 and 80 Amperes respectively. A Modicon 984 programmable controller conducts the timing and control functions for cycling the cells. It also monitors the safety systems in the lab and can terminate individual cell tests when a safety or performance parameter is violated [1].

The data acquisition function is handled by an ESCORT D system which was developed at NASA LeRC. Current, voltage, pressure, and temperature are recorded for each cell. The pressure is measured by a strain gauge that is attached to a dome of each cell. Watt-hours and Amp-hours are calculated for each cell on every scan. The system scans the data approximately every 2-3 seconds and every 25th scan is saved. The data is immediately stored locally in a microvax before it is transferred to a data collector. At this point the data can be retrieved or sent to a data base for graphical output.

Test Articles

Twelve 65 A-hr Ni/H_2 cells were purchased from Whittaker-Yardney Power Systems. Two cells for each of six design variants were delivered to NASA LeRC between September 1987 and August 1988. The six design variants allow for performance comparison between 31 and 26% KOH electrolyte, recirculating and back-to-back electrode configurations, and unit versus dual cell stacks. The cells with a back-to-back configuration also have a platinum catalyzed wall wick for enhanced thermal dissipation and oxygen management. All twelve cells have a separator consisting of a layer of asbestos and a layer of zircar.

Eight 65 A-hr cells were purchased from Hughes Aircraft Company. Four cells for each of two design variants were delivered to NASA LeRC in June of 1988. All eight cells are unit stack, back-to-back cell designs with serrated zircar separators. Four cells have 31% KOH and four have 26% KOH. The 26% KOH cells have four more electrode pairs than the 31% KOH cells to help lessen the capacity reduction associated with the lower electrolyte concentration.

Twelve 65 A-hr and eight 50 A-hr cells were purchased from Eagle-Picher Industries. Four cells for each of five design variants were delivered to NASA LeRC in December of 1988. The five design variants consist of unit and dual stacks, a recirculating electrode configuration with zircar separators and 31% KOH, and a back-to-back configuration with asbestos separators, a platinum catalyzed wall wick, and 26% KOH. A design matrix for each of the above cells is shown in Table 1.

Test Plan

Upon receipt, all cells underwent an incoming inspection which consisted of visual inspection, dimensional and weight measurements, impedance tests, and electrolyte leakage tests. All cells were then subjected to their first electrical checkout in acceptance testing. This consisted of capacity measurements at -5, 0, 10, 20, and 30°C as well as a 10°C, 72 hour open circuit charge retention test. All cells successfully completed these tests except for one Eagle-Picher cell (RNH-65-11-Z, S/N 10) which was diagnosed as having a manufacturing defect in the electrode lead bundles near the terminals. This resulted in a very high cell internal impedance. Two cells from each vendor were then subjected to a random vibration profile of three minutes duration in each of three axes. The maximum vibration load was 19.5 g/RMS. The cells were discharged during this test and no anomalies were recorded.

Characterization testing was then performed on one cell of each design variant. This 122 step test sequence allows for performance evaluation at various charge rates, discharge rates, temperatures, and states of charge. No cell was both vibration and characterization tested.

Life testing is performed at 35% DOD and at -5 and 10°C. A 90 minute LEO cycle is simulated consisting of a 55 minute charge (sunlight) period and a 35 minute discharge (eclipse) period. The 35% DOD was calculated based on the cell's nameplate capacity. An effort was made to have representation of each cell design variant at both test temperatures. This was accomplished for all designs except for the Yardney cells. All Yardney cells are on test at 10°C. This was done primarily to allow life testing to begin much earlier and to avoid a significant storage period.

The charge method used is a two-step constant current profile. During the first charge step (high charge), 95% of the A-hrs discharged in the previous cycle are returned in 42 minutes. The high charge current for the 65 and 50 A-hr cells is 30.6 A and 23.5 A respectively. The second charge step (low charge), of 13 minutes duration, returns the last 5% of the discharged A-hrs plus an amount of overcharge, to compensate for the inefficiencies of charge acceptance. The high and low charge times and the magnitude of the high charge current are held constant throughout the life test. The recharge ratio (A-hrs in/A-hrs out) is adjusted by varying the magnitude of the low charge current. As an example, for a recharge ratio of 1.04 the low charge current for a 65 and 50 A-hr cell would be 10.3 and 8.0 A respectively. Recharge ratios are adjusted to minimize the amount of overcharge and end-of-charge voltage (EOCV) and to maximize the end-of-discharge voltage (EODV). The two-step charge method allows for a high charge rate early in charge when charge efficiency is very good. This is followed by a low charge rate when the cell approaches 100% state of charge and goes into overcharge. At this point charge acceptance is poor and the production rate of oxygen and heat inside the cell is high. Using a low current at this point minimizes these life-shortening effects. The discharge is performed at a constant current for a 35 minute duration and does not change throughout the life test. The value of the discharge current for 65 and 50 A-hr cells is 39.0 and 30.0 A respectively.

LIFE TEST PERFORMANCE

In the following analyses, cell performance under a 35% DOD regime was evaluated relative to the effect of different design features. The following design features were studied: 26 vs 31% KOH, unit vs dual cell stacks, and recirculating vs back-to-back electrode arrangements. The effect of test temperature was also studied. Cell performance was evaluated based on the end of charge and discharge voltage trends, pressure trends, recharge ratio, and round trip Watt-hour efficiency (Watt-hrs discharged/Watt-hrs charged). The mass impact of the various cell designs were also considered. It should be noted that comparisons were made using only 2-4 cells of a particular design and that performance is based on observed trends to date. The characteristic that will most influence final design evaluation is cycle life.

Yardney

The design variable that has had the most effect on performance of the Yardney cells is electrolyte concentration. Cells containing 26% KOH consistently have higher end-of-discharge voltage and equal or lower end-of-charge voltage. On the average, the EODV for the 26% KOH cells is 20 mV higher and the EOCV is at most 20 mV lower than the 31% KOH cells. Figure 1 shows this effect of KOH concentration on voltage for two Yardney recirculating cells. These cells had been running at the same recharge ratio (RCR) until approximately cycle 9000 when the 31% KOH cell was raised from 1.03 to 1.035 because of low EODV.

There are two other factors to consider. The first is that all of the 26% KOH cells are able to run at a 0.5 to 1.0% lower RCR while maintaining a higher EODV than the 31% KOH cells. This reduction in overcharge may have beneficial life impacts. The lower RCR coupled with the improved voltage performance of the 26% KOH cells results in a 2-4% higher Watt-hr efficiency compared to the 31% KOH cells. The second factor concerns the effect of KOH on the cell's actual capacity. Acceptance data showed that the 26% KOH cells typically had about a 9% (6 A-hrs) reduction in capacity compared to the 31% KOH cells. When this is factored into the DOD calculation of life test, the 26% KOH cells are cycling at a 2.5% higher DOD. The 31 and 26% KOH cells average 34.5 and 37% DOD respectively, based on actual capacity. This may have a life-shortening effect on the 26% KOH cells; however, at this time the EODV shows no sign of this effect. The effects of lower RCR and higher DOD are not known yet, but there is data published that suggests that 26% KOH may increase cycle life [2].

Another effect of KOH concentration on cell performance relates to pressure trends. In all cases, the 31% KOH cells show a faster rise in operating pressure than the 26% KOH cells. Over the last year the 31% KOH cells have increased an average of 162 psi and the 26% KOH cells have increased an average of 74 psi. This is another benefit of 26% KOH. Lastly, the mass of the cells with 26% KOH is 20 g less than the 31% KOH cells. In summary, the lower KOH concentration suffers from lower capacity but has shown superior voltage, efficiency, and pressure performance to this point in life.

Comparison of performance for cells with a recirculating electrode stack vs a back-to-back stack with a catalyzed wall wick did not show significant differences. There is some spread in the data, and no clear performance differences in voltage, efficiency or pressure are evident. The back-to-back arrangement has 60 g less mass.

Unit and dual stack comparison shows that the dual stack has up to a 40 mV reduction in EOCV over the unit stack for both recirculating and back-to-back designs. The dual stack with a back-to-back arrangement also has up to a 30 mV increase in EODV compared to a unit stack with a back-to-back arrangement. Comparisons of unit vs dual stack for recirculating cells did not show this variance in discharge voltage. The dual stack with a back-to-back design, consequently, has about a 4% Watt-hr efficiency improvement over the unit stack with a back-to-back design. The dual stack obviously has greater mass than the unit stack. The difference is 80 g for the recirculating and 50 g for the back-to-back designs.

Overall, the dual stack cells are performing better than the unit stack cells on a voltage and efficiency basis. This may seem surprising since a dual stack has greater stack length and would be expected to have more internal resistance yielding poorer voltage performance compared to a unit stack. The explanation may lie with the fact that the nickel electrodes in the unit stack cells were built after some process changes were implemented following the dual stack nickel electrode build. Therefore, the difference in nickel electrodes may be the cause of the voltage variation.

The performance of the Yardney cells on test can be summarized as follows. Cells containing 26% KOH have a noticeable voltage improvement over cells containing 31% KOH. The 31% KOH cells have a faster pressure rise than the 26% KOH cells. Electrode stack configuration does not seem to affect cell performance; however, there is a significant mass savings of 60 g for the back-to-back configuration. The current performance status of these cells is shown in Table 1.

Hughes

As mentioned earlier, all 8 Hughes cells are unit stack, back-to-back designs with serrated zircar separators. Four cells have 31% KOH. The other 4 cells have 26% KOH and are identical except for the addition of 4 more electrode pairs in the stack. This results in approximately 50 g of added mass for the 26% KOH cells. One cell of each design is on test at 10°C and the other 3 cells per design are on test at -5°C. Therefore, the effects of temperature and KOH concentration are studied. It should be noted that the strain gauges on the six cells on test at -5°C have failed in less than 8000 cycles. Data from the strain gauges varies from periods of normal output to periods of out-of-range output. Since the data is suspect, it was not considered in the following analysis.

The effects of temperature on the Hughes cells were the same regardless of KOH concentration. The cells at -5°C are able to run at a 1-1.5% lower RCR while maintaining the same EODV as the cells at 10°C. This is partly due to the fact that lower temperatures cause an increase in voltage. Consequently, the charge voltage for the cells at -5°C is about 20 mV higher than the cells at 10°C. The net effect on Watt-hr efficiency is that the benefit of lower RCR is canceled by the higher charge voltage, and the efficiencies are approximately the same at both test temperatures.

The effect of KOH concentration can be analyzed at both test temperatures. At -5 and 10°C there are no significant voltage or efficiency differences between cells with different KOH concentration. There is some spread in the data, but all of the cells are currently running at 84-86% Watt-hr efficient. Figure 2 shows voltage trends for a 31 and a 26% KOH cell cycling at -5°C. These cells have been cycled at the same RCR. On the other hand, there is a difference in pressure trends for the two KOH concentrations. In the past year, the 31 and 26% KOH cells at 10°C have increased 140 and 60 psi respectively. The difference in cell capacity was again noticed during acceptance testing. Even though the 26% KOH cells have 4 more electrode pairs, their capacity was still 7% (5 A-hrs) lower than the 31% KOH cells. The DOD calculated based on actual capacity yields 30.5 and 33% for the 31 and 26% KOH cells respectively.

In summary, the Hughes cells at -5°C can be run at a significantly lower RCR and maintain stable performance. This may have beneficial life impacts due to the reduced amount of overcharge. The effect of KOH at -5 and 10°C was not significant. The 26% KOH cells have more mass and less capacity which means that they are running at a slightly higher actual DOD. Again, the 31% KOH cell shows an increased pressure rise over the 26% KOH cell at 10°C. The current performance status of these cells is shown in Table 1.

Eagle-Picher

Of the 20 Ni/H_2 cells delivered to NASA, one failed acceptance test as mentioned earlier and was not put on life test. Another cell (RNH-50-25, S/N 7) had very high charge and very low discharge voltage, but was placed on life test. The cell barely passed acceptance test and apparently has a high internal resistance. The cell voltage is stable; however, the efficiency is very low at 76.5%. The cell's performance is not consistent with the other cells of the same design and was not considered in the following analysis.

Test temperature is very influential on cell performance for the Eagle-Picher cells. Cells operating at the same RCR have lower charge voltages at 10°C compared to cells operating at -5°C. This is to be expected due to the temperature effect on voltage. However, all five cell designs show equal or higher end-of-discharge voltages at 10°C. This is contradictory to the expected temperature-voltage effect. The result is a 1-2% Watt-hr efficiency improvement.

A noteworthy temperature effect on all but 1 Eagle-Picher cell at -5°C has also been observed. The cell voltage at the end of the low charge period is equal to or greater than the voltage at the end of the high charge period. When the cell goes from high to low charge, the cell voltage drops in conjunction with the lower charge current. But by the end of the 13 minute low charge, the voltage has come up to or above the voltage plateau reached in high charge. This characteristic is unique to the Eagle-Picher cells. This contributes to the decreased Watt-hr efficiency at -5°C. Figure 3 shows these temperature effects on voltage for two back-to-back cells. These cells have been cycled at the same RCR.

The last temperature effect which is evident relates to cell pressure trends. Every cell at 10°C, regardless of design, is showing a significant pressure increase with life while the cells at -5°C are not. Depending on design, pressures at 10°C have risen 60 to 90 psi over the past year. Cells at -5°C have risen less than 30 psi in the same time. All strain gauges continue to function except for one at -5°C which failed after 1000 cycles.

Direct comparison of performance and KOH concentration cannot be made for the Eagle-Picher cells. Instead, two distinct designs incorporating several features are studied. One design is a recirculating stack with 31% KOH and zircar separators. The other design incorporates a back-to-back electrode configuration with 26% KOH, asbestos separators, and a platinum catalyzed wall wick.

Looking at the dual stack 65 A-hr cells first, the recirculating 31% KOH cells had an average acceptance capacity of 77 A-hrs while the back-to-back 26% KOH cells had 72 A-hrs. Consequently, both cells are running at less than 35% DOD based on actual capacity (29.6 and 31.7% DOD for the 31 and 26% KOH cells respectively). Comparison at both test temperatures show that the recirculating design has a 20-30 mV lower charge voltage than the back-to-back design while running at the same RCR. The EODV at 10°C is about 30 mV higher for the recirculating cells while only about 10 mV higher at -5°C. The resulting improvement in Watt-hr efficiency for the recirculating cells is 1.5% at 10°C and 0.8% at -5°C. Lastly, the back-to-back cells have about 150 g less mass than the recirculating cells.

The reason for difference in voltage performance between the two cell designs can be explained by the separators. The recirculating design has a zircar separator which has lower resistance than the asbestos separator in the back-to-back design. Lower resistance will allow for an improved voltage performance. The reason for using the asbestos separator with the back-to-back design and catalyzed wall wick are for enhanced oxygen and thermal management. This NASA design uses the high bubble pressure asbestos separator to force the oxygen generated at the nickel electrode out towards the vessel wall where it can recombine with hydrogen at the platinum catalyzed surface. This path is preferred over recombination at the hydrogen electrode because of the excessive localized heat produced as well as the potential damage that the hydrogen electrode may endure as a result of this recombination reaction [3].

Comparison of the same recirculating vs back-to-back design for the unit stack 50 A-hr cells shows similar results. Acceptance capacity for the recirculating and back-to-back cells averaged 55 A-hrs (31.5% actual DOD) and 52.5 A-hrs (33% DOD). At both temperatures the recirculating cells show a 10-20 mV lower charge voltage. Unlike the 65 A-hr cells, the 50 A-hr recirculating cells show a 20-30 mV improvement in EODV at both temperatures. The net result is a 3% improvement in Watt-hr efficiency for the recirculating cells over the back-to-back cells. Again the back-to-back cells have a significant mass savings of 180 g.

Other design comparisons including unit vs dual stack did not show significant voltage performance differences to date. There is a noticeable operating pressure difference between the unit and dual stack, however. The dual stacks are running at about 235 psi higher pressure than the unit stacks. This is due to the fact that the identical pressure vessel size was used for all 20 cells, and the dual stacks have a longer stack length than the unit stacks. This results in less free volume in the vessel for hydrogen to accumulate.

In summary, the Eagle-Picher cells are performing better at 10°C than at -5°C on a voltage and efficiency basis. The penalty is an increased pressure rise with cycling. Also, comparison of the recirculating and back-to-back design shows an advantage in performance for the recirculating cells. This can be accounted for by the difference in separator and KOH concentration. However, the back-to-back design has a significant mass savings. The current performance status of these cells is shown in Table 1.

CONCLUSIONS

As of May 1, 1991 all 39 cells on LEO life test at 35% DOD and at both -5 and 10°C show stable performance with no sign of near term failure. The cells have completed between 12,500 and 8,000 cycles. The recharge ratios to date have varied from 1.02 to 1.04 while efficiencies range from 80 to 88%. Cells from both Yardney and Hughes have crossed the two year mark (11,680 cycles), and the first Eagle-Picher cells should reach this milestone in June 1991. The effects of test temperature, KOH concentration and electrode configuration varied between cell vendors. For Yardney, the 26% KOH cells show a 2-4% Watt-hr efficiency improvement and a lower pressure rise with life than the 31% KOH cells. There is no significant difference in performance between the recirculating and back-to-back electrode stacks at this time. For Hughes, the only difference in performance based on KOH concentration is a slower pressure rise for the 26% KOH cells. The Hughes cells do show improved performance at -5°C as opposed to 10°C. The Eagle-Picher cells are operating more efficiently at 10°C than at -5°C. The penalty, however, is a faster pressure rise for cells operating at 10°C. The cells with a recirculating electrode stack, 31% KOH, and zircar separators have a noticeable improvement in voltage and Watt-hr efficiency over the cells with a back-to-back stack, 26% KOH, asbestos separators, and a platinum catalyzed wall wick. The back-to-back design, however, has 150 g less mass. Final evaluation of cell designs and test temperature effects will be made at the end of life.

REFERENCES

[1] Pease, G. M., "IPV Nickel-Hydrogen Cell Testing Facility," NASA LeRC Preliminary Information Report #211, 1988.

[2] Smithrick, J. J., and Hall S. W., "Effect of KOH Concentration on LEO Cycle Life of IPV Nickel-Hydrogen Flight Battery Cells," 1990 IECEC Proceedings, Vol. 3, pp 16-21.

[3] Gonzalez-Sanabria, O. D., "Effect of NASA Advanced Designs on Thermal Behavior of Ni/H_2 Cells," NASA-TM, No. 100197.

TABLE 1. LIFE TEST STATUS (May 1. 1991)

LOT NUMBER	S/N	A-HR CAP.	TEST TEMP	KOH (%)	RCR	EODV (VOLTS)	EOC PRESS (PSI)	WH-HR EFF (%)	CYCLE NUMBER	DESIGN FEATURES
YARDNEY										
YNHC-065-11	1	67.5	10°C	31	1.035	1.189	868	84.2	12.068	DUAL STACK
	2	66.6	10°C	31	1.035	1.184	789	84.1	12.083	RECIRCULATING
YNHC-065-11A	3	60.6	10°C	26	1.03	1.204	714	84.9	12.127	ASBESTOS/ZIRCAR SEPARATOR
	4	60.6	10°C	26	1.03	1.205	699	84.9	12.067	
YNHC-065-12	1	69.6	10°C	31	1.04	1.187	759	83.8	12.035	DUAL STACK
	2	63.9	10°C	31	1.04	1.168	862	80.8	9.935	BACK-TO-BACK
YNHC-065-12A	3	63.0	10°C	26	1.03	1.207	662	85.4	11,984	ASBESTOS/ZIRCAR SEPARATOR
	4	68.7	10°C	26	1.035	1.197	775	84.7	9,870	Pt CATALYZED WALL WICK
YNHC-065-13	1	74.0	10°C	31	1.035	1.191	782	82.8	8.390	UNIT STACK, ASB/ZIR SEP
	2	57.2	10°C	31	1.04	1.169	878	79.8	8.376	RECIRCULATING
YNHC-065-14A	1	61.9	10°C	26	1.04	1.183	759	80.7	8.393	UNIT STACK. ASB/ZIR SEP
	2	67.1	10°C	26	1.04	1.182	786	80.6	9.932	BACK-TO-BACK, Pt WALL WICK
HUGHES										
6078700-1	1	75.4	10°C	31	1.03	1.202	690	85.5	9.935	UNIT STACK
	2	73.9	-5°C	31	1.02	1.208	*	85.9	12.434	BACK-TO-BACK
	3	73.5	-5°C	31	1.02	1.191	*	83.9	12.404	SERRATED ZIRCAR SEPARATOR
	4	73.7	-5°C	31	1.02	1.198	*	85.1	12,464	
6078700-2	1	69.4	10°C	26	1.035	1.193	590	84.6	9.843	UNIT STACK
	2	69.1	-5°C	26	1.02	1.190	*	83.7	12.467	BACK-TO-BACK
	3	68.6	-5°C	26	1.02	1.208	*	85.7	12.459	SERRATED ZIRCAR SEPARATOR
	4	68.5	-5°C	26	1.02	1.208	*	86.2	12.468	
EAGLE-PICHER										
RNH-50-11-Z	1	56.0	-5°C	31	1.025	1.209	498	86.5	11.122	UNIT STACK
	2	53.6	-5°C	31	1.025	1.210	*	86.3	11.120	RECIRCULATING
	3	58.6	-5°C	31	1.03	1.213	554	85.6	8.571	ZIRCAR SEPARATOR
	4	54.2	10°C	31	1.025	1.230	597	88.0	8.168	
RNH-50-25	5	54.4	-5°C	26	1.03	1.179	474	83.1	11.121	UNIT STACK
	6	53.5	-5°C	26	1.035	1.168	508	82.3	11.103	BACK-TO-BACK. Pt WALL WICK
	8	52.9	10°C	26	1.03	1.207	511	85.3	8.166	ASBESTOS SEPARATOR
RNH-65-11-Z	9	77.2	10°C	31	1.03	1.215	828	86.0	8.393	DUAL STACK
	11	78.9	-5°C	31	1.03	1.212	811	84.9	8.574	RECIRCULATING
	12	76.3	10°C	31	1.025	1.219	828	86.4	8.167	ZIRCAR SEPARATOR
RNH-65-11-A	13	71.3	10°C	26	1.04	1.162	731	81.5	8.393	DUAL STACK
	14	72.8	-5°C	26	1.03	1.173	766	83.0	11.108	BACK-TO-BACK
	15	73.3	-5°C	26	1.03	1.186	790	83.8	8.570	ASBESTOS SEPARATOR
	16	70.9	10°C	26	1.03	1.210	814	85.4	8.168	Pt CATALYZED WALL WICK
RNH-65-9	17	73.7	-5°C	26	1.03	1.194	701	83.7	8.545	UNIT STACK
	18	73.5	-5°C	26	1.03	1.199	731	84.1	8.597	BACK-TO-BACK
	19	72.5	10°C	26	1.03	1.194	655	85.0	8.016	ASBESTOS SEPARATOR
	20	71.0	10°C	26	1.03	1.216	718	85.7	8.167	Pt CATALYZED WALL WICK

NOTES:
S/N - SERIAL NUMBER
A-HR CAP - INITIAL A-HR CAPACITY REPORTED AT 10°C AT A C RATE DISCHARGE TO 1.0 V
EOC PRESS - END OF CHARGE PRESSURE
* - STRAIN GAUGE FAILURE

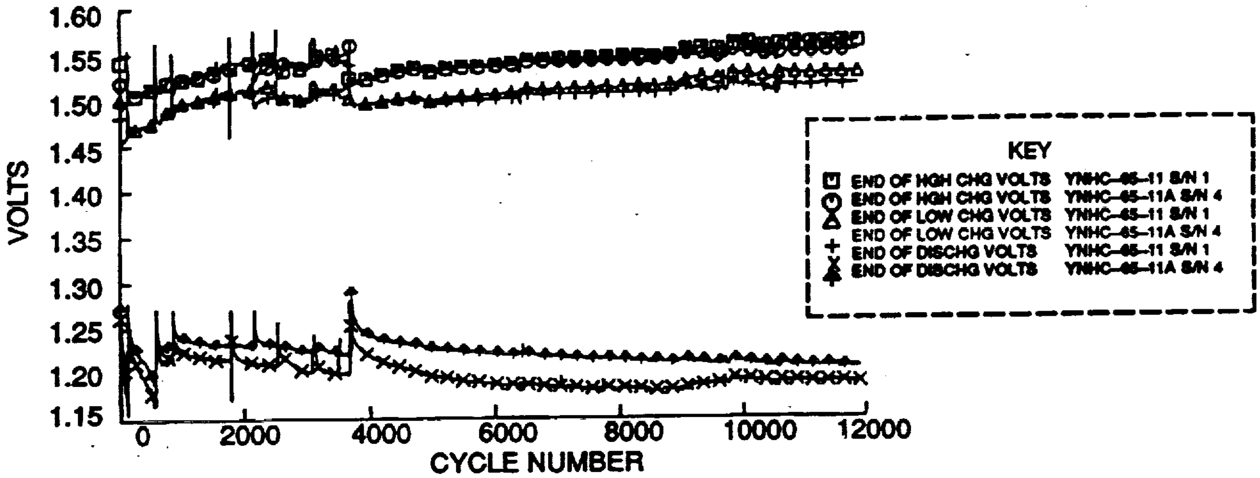

Figure 1 YARDNEY VOLTAGE TRENDS – 31% KOH (S/N 1) vs 26% KOH (S/N 4)

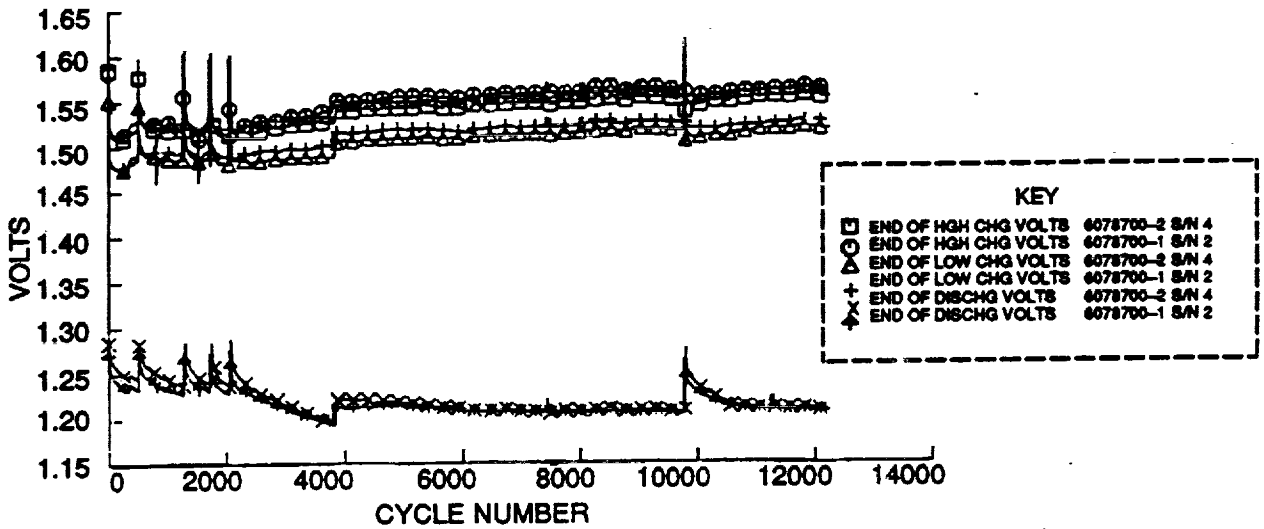

Figure 2 HUGHES VOLTAGE TRENDS – 31% KOH (S/N 2) vs 26% KOH (S/N 4)

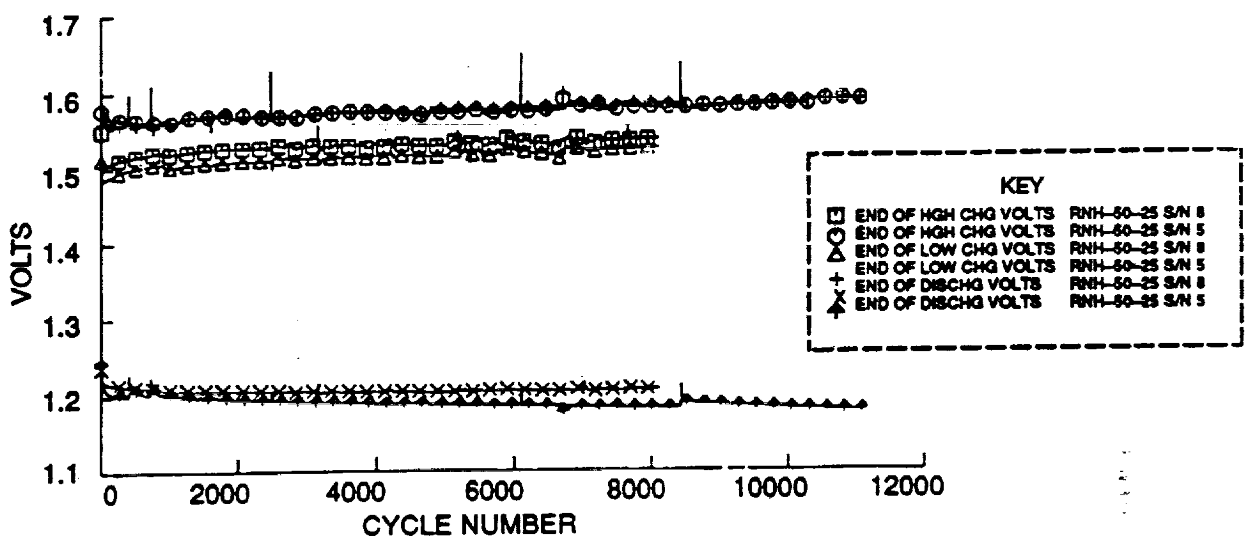

Figure 3 EAGLE–PICHER VOLTAGE TRENDS – 10° C (S/N 8) vs –5° C (S/N 5)

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

When individual pressure vessel (IPV) nickel-hydrogen (Ni/H_2) cells were selected as the energy storage system for Space Station Freedom in March of 1986, a limited database existed on life and performance characteristics of these cells in a low-earth-orbit (LEO) regime. Therefore, NASA LeRC initiated a Ni/H_2 cell test program with the primary objectives of building a test facility, procuring cells from existing NASA contracts, and screening several cell designs by life testing in a LEO 35% depth-of-discharge (DOD) scenario. A total of 40 cells incorporating 13 designs were purchased from Yardney, Hughes, and Eagle-Picher. Thirty-two of the cells purchased were 65 Ampere-hour (A-hr) nameplate capacity and eight cells were 50 A-hr. Yardney and Eagle-Picher cells were built with both the Air Force recirculating and the advanced back-to-back electrode stack configurations and incorporated 31 and 26% potassium hydroxide (KOH) electrolyte. Hughes cells were built with the back-to-back design and with both 31 and 26% KOH. Acceptance testing of the first delivered cells began in March of 1988, with life testing following in September of that year. Performance comparisons of these cells are made here while specifically addressing life test data relative to the design differences.

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