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DISCHARGE CHARACTERISTICS OF 300 AMPERE-HOUR NI-ZN TRACTION CELLS

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SUMMARY

Preliminary tests were performed on a series connected pack of three 300 ampere-hour Lewis-designed nickel-zinc (LENZ) cells containing the Lewis improved inorganic-organic (I/O) separator and have other design features to optimize performance and cycle life. Formation tests, characteristic discharge tests at various constant currents, and a ramp power test at various discharge currents to find the maximu power delivered were carried out. Also measured was the cell case temperature of the middle cell during all tests. This data is preliminary and is part of a comprehensive test program on these Ni-Zn cells now underway at Lewis.

INTRODUCTION

Three,300 ampere-hour nickel-zinc (Ni-Zn) cells (LENZ 300-1) with the Lewis improved inorganic-organic (I/O) separator were tested in a 3-cell series connected pack for cell performance and general characteristics. They form part of a comprehensive program to evaluate these advanced state-of-the-art cells for cycle life over a range of test parameters.

Eighty-five, 300 ampere-hour Ni-Zn cells were received from the Yardney Electric Corporation built according to NASA-Lewis specifications. They incorporate the Lewis I/O separator and other design features to optimize performance and cycle life. They are equipped with a 25 psig pressure relief valve. Thirty cells from this lot were randomly selected for special life cycling tests that included nine different test parameters. Three cells from this lot of thirty were chosen for special preliminary performance and characterization tests. The preliminary program included cell formation, cell performance at various constant current discharges, cell case temperature at the above discharge currents and determination of the maximum power capability of the cells. In all, 14 tests were performed on the three cell packs and this report presents the data obtained.

Data Acquisition

Data acquisition for these tests was recorded locally at the facility by a DEC-Writer which utilized the Vidar data scanner. Individual cell voltages, total pack voltage, total current, and time were monitored and printed out. Data acquisition during discharges was taken in increments of one minute or faster. Also used for data recording purposes was a Rapid Electric Corporation ampere-hour integrator and a 2-pen recorder which monitored cell voltage and current for one cell of the series pack.

Description of Tests

The three cells were clamped tightly together with end boards and strapping and electrically connected in series. All intercell connections and connections to loads and power supplies were inspected for solidarity and tightness. The cells chosen were very closely matched in output character-

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istics (obtained from formation data) and were ideal for cell characterization and performance.

The first test on the 3-string pack was a forced discharge at -25 amperes D.C. as is recommended by Yardney because the electroformed nickel electrode has a residual charge resulting from the manufacturing process. This forced discharge insures that both the nickel and zinc electrodes are at the same level of charge. Each cell of the pack was discharged until its individual cell voltage was -0.8 volts.

The next three tests were formations summarized in Table I. The cells were charged at 45 and 33 amperes and discharged at 50-amperes constant current in each formation cycle except for the addition of a low-rate discharge at 20 amperes in the second cycle. The ampere-hour outputs obtained were low compared to our previous experience. The output obtainable was 242 ampere-hours after the third formation cycle.

Test 5 was a 50-ampere discharge to characterize performance. It is not considered representative as an additional formation cycle was undoubtedly required. Gratifyingly, the average outputs for the three cells improved from 242 to 260 ampere-hours.

Tests 6 to 13 were constant current discharged on the series cell string at rates of 100, 250, 300, 400, 50, 500, 575, and 700 amperes. Test 14 was a maximum power test in which the discharge current rate was ramped approximately every minute to 50, 100, 200, 300, 400, 500, 600, 700, 800, 900 and 960 amperes (maximum load capability). Table II summarizes the results of this test including cell temperature on one cell (#58) in the series string. The purpose of this test was to find the maximum power capability for these cells. It was limited to 960 amperes by the maximum capability of the electronic load available. All tests except for the forced discharge test (test #1) were terminated when any cell in the series string reached 1.0 volt.

Preliminary to the performance characterization tests, the 3-cell pack was charged at 38 amperes D.C. to a capacity of 300 ampere-hours. Fifteen minutes were allowed to elapse before a performance test was started. Room and cell case temperatures were monitored during the tests. The cell case temperature was measured in the pack between two adjacent cells near the positive terminal of one of the cells.

RESULTS AND DISCUSSION

Figure 1 shows the family of characteristic curves for the one cell (#58) of the 3-string pack at various constant current discharges (cell voltage as a function of delivered cell capacity). These characteristics performance curves were calculated from the data collected locally at the facility. These results were verified by the independent ampere-hour meter. Data was taken in increments of one minute. The cell open circuit voltage prior to test of 1.89 volts drops quickly with the application of a load. Table III summarizes the input-output capacities for this single cell and the calculated ampere-hour efficiency for the various discharge conditions.

Figure 2 displays cell power output and voltage as a function of discharge current. Cell temperature and delivered capacity is noted at each point. This data is the same cell (#58) as in the characterization tests (Figure 1). The data obtained from test 14 in which the discharge current was ramped from 50-to 960-amperes for the string. The maximum power available from these cells is close to 1050 watts. The 960-amperes discharge limit occurs very close to the maximum peak power that the cell can deliver. Based on a cell weight before test of 18.05 lbs. (8.18 kgs.) and 1027 watts available at 960 amperes the maximum power density available from this cell is at least 56.9 watts/lb. (125.6 watts/kg.). Cell weight after test 14 was 17.60 lbs. (8.00 kgs.). This results in a maximum peak power density available from the cell of 58.4 watts/lb. (128.4 watts/kg.). This cell weight loss will be discussed later. Figure 2 also displays the voltage decrease with increasing load. It behaves almost linearly from 1.8 to 1.05 volts at the 960-amperes discharge. One hundred, forty-six ampere-hours was removed at test termination or approximately one-half the cell capacity.

Figure 3 summarizes cell case temperature as a function of output (ampere-hour) at the various discharge rates. Temperature data was recorded for all but the 100-ampere discharge. An inconsistency was noted between the 250-and 300-ampere discharges. The higher rate should have resulted in a higher temperature. This anomaly was traced to the inadequate cable size to the electronic load, a single AWG #4/0, used up to 250-amperes. For 300 amperes and above, two #4/0 cables were used in parallel. Hence, when the 300-ampere test was run, the temperature rise was lower. This points up the importance of sizing cable and cell terminals to the current requirement. The minimum temperature rise above room temperature, was 101°F for the 50 ampere rate and 166°F for the 700-ampere rate.

Figure 4 presents the same data as in Figure 3 but displayed as the cell temperature as a function of (minutes) of discharge. One notes in this figure the overshoot temperatures after the tests were terminated and the cool down from the maximum cell temperature. The maximum temperature at the 700 ampere-rate after test termination was 182°F, an increase in temperature of 16°F from the end of the test. The time required to drop 1°F from the maximum temperature at the 700-ampere rate is on the order of 2 minutes, 4 minutes for the 575-ampere rate, 8 minutes for the 500-ampere rate, and 13 minutes for the 400-ampere rate. Figure 5 displays the temperature as a function of the power (watts) available from a cell.

Figure 6 shows power output (watts) as a function of cell current (amperes) obtained from Figure 1, the characteristic curves, at constant capacity output. Increments of 50 ampere-hours up to 250 ampere-hours are shown.

After termination of the last test (14) all three cells were weighed and the weight loss observed for each cell was 0.4 lbs. (1.82 kgs.). During the tests, no gassing or electrolyte spewing was noticed and cells were examined thoroughly for cell case leaks. The loss must be attributed to vaporization of water, amounting to 192 grams from each cell. This results in an increase of the KOH electrolyte concentration from 35% to 39.5% resulting in an increase of the cell internal resistivity from 1.9 ohm-cm to 2.2 ohm-cm.

Table I - Cell Formations - Tests 2-4

Cell No.	Formation #1 Charge (Amps)	Formation #1 Amp-Hours In	Formation #1 Discharge (Amps)	Formation #1 Amp-Hours Out	Formation #2 Charge (Amps)	Formation #2 Amp-Hours In	Formation #2 Discharge (Amps)	Formation #2 Amp-Hours Out	Formation #3 Charge (Amps)	Formation #3 Amp-Hours In	Formation #3 Discharge (Amps)	Formation #3 Amp-Hours Out
56	45	352	50	253	45	325	50/20	220	33	300	50	242
57	45	352	50	243	45	325	50/20	220	33	300	50	242
58	45	352	50	237	45	325	50/20	209	33	300	50	242

Note: Cell discharge cut-off voltage at 1.0 volts.

Table II - Test 14
Power Ramp

Cell No.	Current Amps	Cell Voltage	Watts Calculated	Amp Hours Out	Cell Case Temp (°F)
58	50	1.742	87	2.6	103
	100	1.710	171	8.5	103
	200	1.590	318	24.26	106
	300	1.541	462	35.0	107
	400	1.473	588	46.6	108
	500	1.407	705	63.0	112
	600	1.339	804	84.0	117
	700	1.289	903	96.0	121
	800	1.216	976	110.0	125
	900	1.130	1017	134.0	136
	960	1.07	1027	146.0	141

Table III - Input-Output Capacities
Tests 6 to 13

Test No.	Charge Amps	Charge A-H	Discharge Amps	Discharge A-H	A-H Eff. (%)
6	38	300	100	278	92.7
7			250	266	88.7
8			300	263	87.7
9			400	253	84.3
10			50	289	96.3
11			500	235	78.3
12			575	224	74.7
13			700	198	66.0

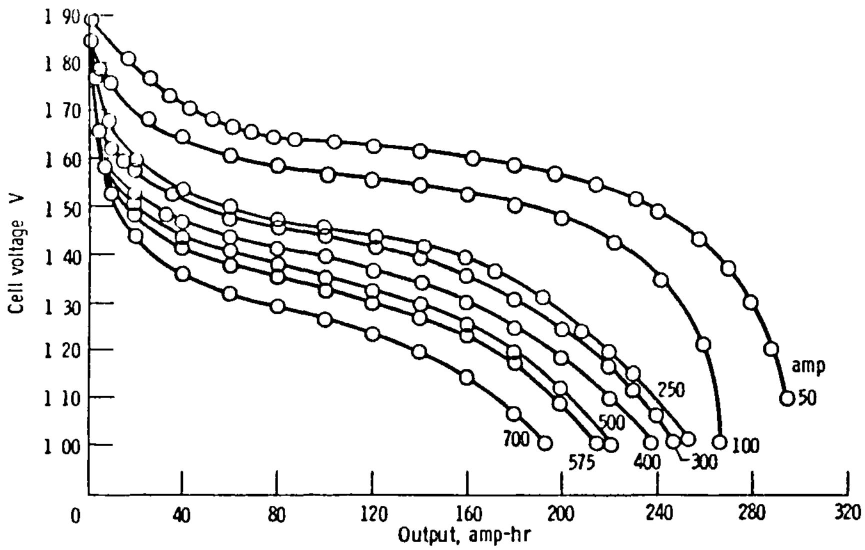

Figure 1 - Cell characteristics cell voltage as a function of output in ampere-hours at various discharge currents (amp) shown on each curve

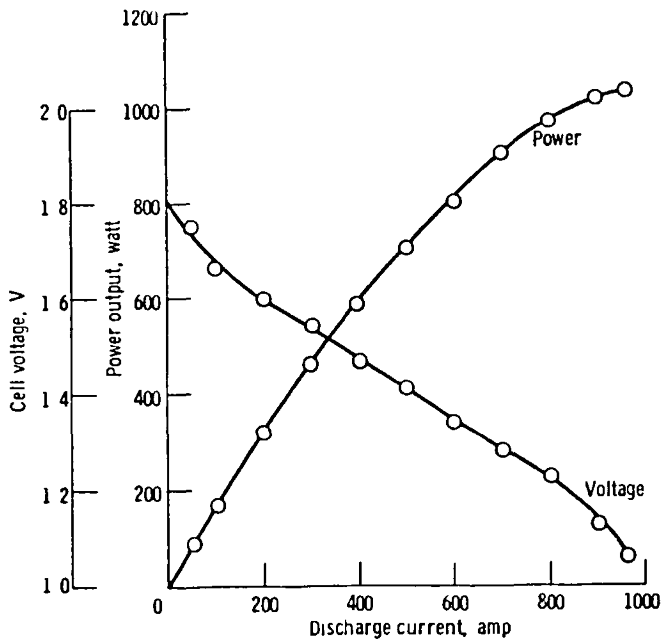

Figure 2 - Cell voltage and power output (watt) as a function of discharge current (amp)

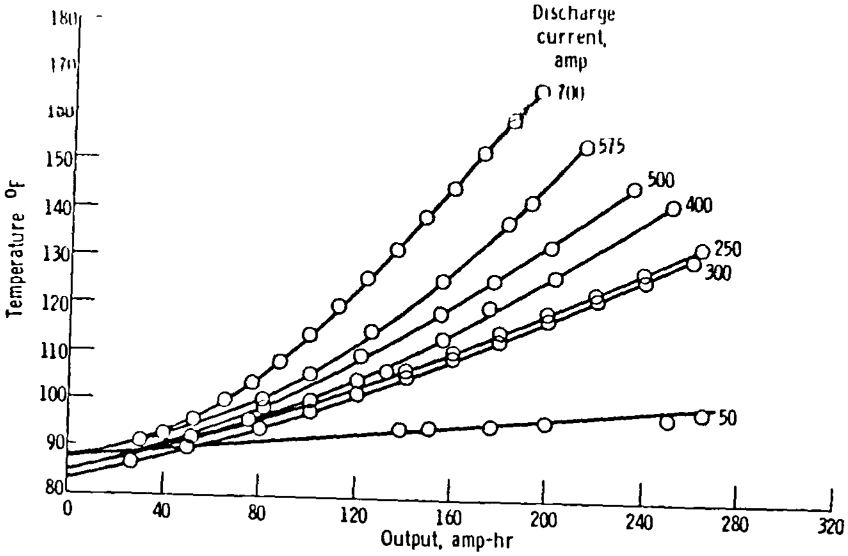

Figure 3 - Cell case temperature (°F) as a function of output (amp-hr) at various discharge currents (amp) shown on each curve

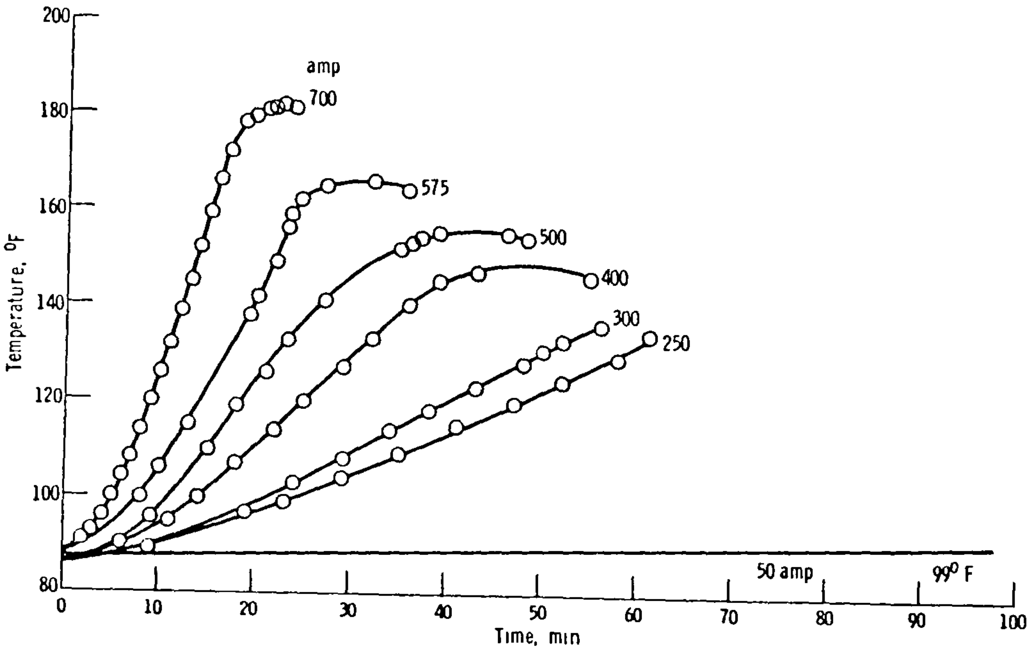

Figure 4 - Cell case temperature (°F) as a function of time (min) at various discharge currents (amp) shown on each curve

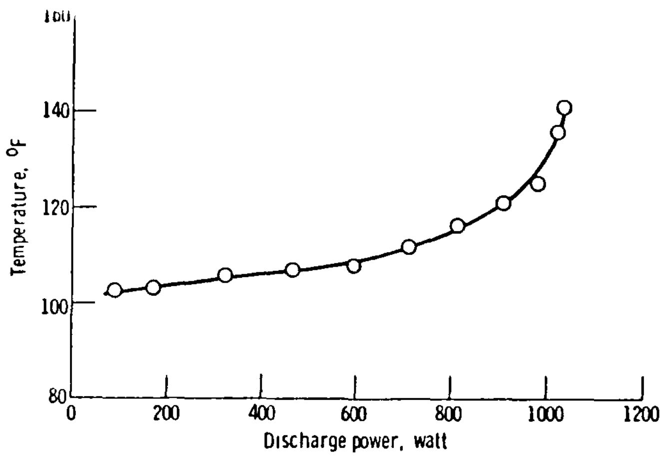

Figure 5 - Cell case temperature (^{0}F) as a function of ramped power output (watt)

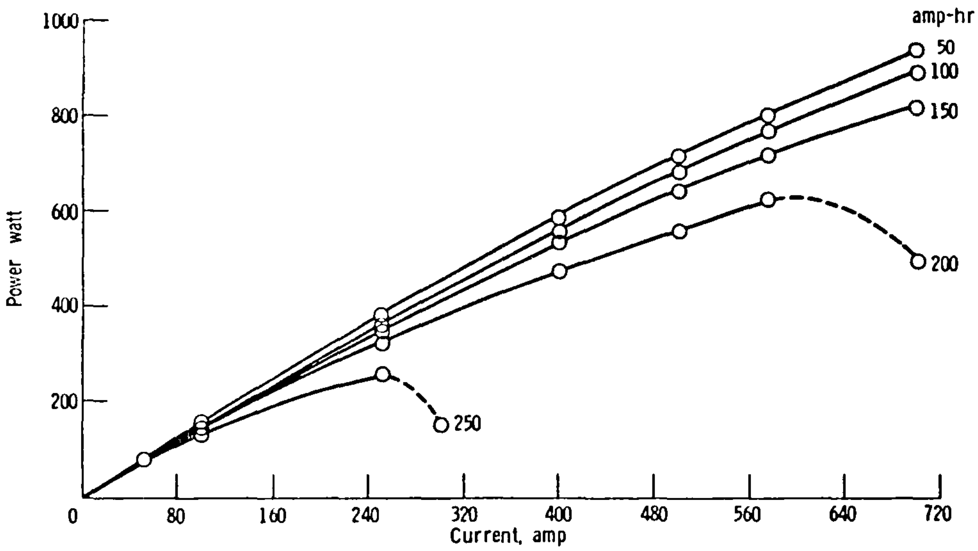

Figure 6 - Power output (watt) as a function of discharge current (amp) at various levels of capacity (amp-hr) removed shown on each curve

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15 Supplementary Notes

16 Abstract

Preliminary tests were performed on 300 amphere-hour nickel-zinc cells containing the Lewis improved inorganic-organic (I/O) separator. These cells also have other design features included to optimize performance and cycle life. The tests carried out were formation tests and characteristic discharge tests. Information obtained include case temperature and maximum power delivered. This data is preliminary and part of a comprehensive test program now underway at Lewis.

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