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SODIUM/SULFUR EVALUATION AT SNL

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Sandia National Laboratories (SNL) has been involved in the evaluation of the sodium/sulfur technology for several years. Until recently, the effort concentrated on the performance of single cells. Recently, the evaluation of 4-cell strings was initiated. The majority of the activity during the past two years has focused on cells from Chloride Silent Power, Limited (CSPL). To date, four groups of PB cells and 4-cell strings, which consisted of PB cells, have been evaluated. The first group of ten cells delivered to Sandia were on test for approximately one year. The majority of these cells failed due to corrosion problems in the sulfur seal. However, two cells completed over 800 cycles, and one of these cells completed nearly 1600 cycles. Other results from this first group of cells were presented at the previous contractors' conference and will not be discussed at this meeting. In addition, cells from Powerplex and Ceramatec have been evaluated, but due to limited abstract space, the results of these tests will also not be discussed.

The second group of cells delivered to SNL consisted of two cells that were assembled under the most favorable conditions at CSPL. The components for these cells were hand picked and quickly assembled to reduce contamination problems. The only major change in cell construction from the first group was the use of a new, improved seal design (Mark 3). The third group of deliverables consisted of an additional six cells and two 4-cell strings. The only difference between the second and third groups was that group three came from an larger production lot. None of these cells and strings had been cycled, and thus a break-in procedure provided by CSPL was followed before evaluation tests were conducted. Table 1 shows the types of tests performed and the total number of cycles accumulated on the second and third groups of cells and strings.

An observation early in cycle life indicated that all the cells had a charge-acceptance problem when charged at the C/3 rate. It should be noted that a typical charge rate for an electric vehicle or load-leveling sodium/sulfur battery could be as low as C/8. Because of this, numerous cycles were run on each cell to determine the extent of the problem. Figure 1 is a typical plot showing the effect that temperature and charge current had on cell capacity. This charge-acceptance problem, however, seemed to diminish with cycle life. Other experimenters suggested that an over-discharge or over-charge cycle on the cells would reduce the charge-acceptance problem. These tests were performed on several cells, and the results were inconclusive. The cause of this charge-acceptance problem is still unclear, however, phenomenon related to the positive electrode are probable (e.g., lack of electrolyte and graphite fiber wetting, structure inconsistency).

As shown in Table 1, several other types of tests were conducted on these cells. Figure 2 is a plot showing the peak power of a cell at four depths-of-discharge. The low peak power value at full state-of-charge was due to the high resistance that cells experience when fully charged. The measured peak power values at 20% and 50% depth-of-discharge were approximately 170 W/Kg.

A set of parametric tests were performed on a 4-cell string, and the results are shown in Figure 3. These tests were all performed at 340°C, which is a typical projected operating temperature for an electric vehicle. As expected, the capacity of the string diminished with both an increase in discharge and charge rate.

All of the cells experienced at least 300 cycles before being removed from test, and two cells that are on a life cycle test have accumulated over 600 cycles with only a slight loss in capacity. None of the cells and strings from the second and third group have failed, and when charged at the lower rates, their performance is quite good.

The forth set of deliverables that Sandia received consisted of ten cells and three 4-cell strings. Five of these cells and one 4-cell string had each experienced 47 cycles at CSPL. Testing of these cells at both CSPL and SNL allowed us to compare results such as cell resistance and capacity. The remainder of the cells and strings had not been heated to operating temperature. All of the cells and strings delivered in this shipment had the Mark 3 seal design. In addition, a safety can was inserted between the sodium and beta" alumina electrolyte. Six cells and two 4-cell strings, which consisted of previously tested and unheated cells, were selected from this shipment and placed on test.

Early test results indicate that the cells have the charge-acceptance problem that was observed on the earlier deliverables. Figure 4 is a plot showing the loss in capacity over six consecutive tests at four different charge rates. The first test plotted for each curve represents a baseline cycle that was run at a 3-amp discharge rate to an end-of-discharge open-circuit voltage of 1.9 volts. The charge rate for a baseline cycle was 2 amps to an end-of-charge voltage of 2.4 volts. All of the tests were run under the same discharge conditions, and the only value that changed was the charge rate. The end-of-charge voltage also remained the same (2.4 volts) for all cycles. The temperature was 350°C. These tests will be repeated later in cycle life to confirm if these charge-acceptance problems diminish. Results at CSPL and SNL have indicated that the charge-acceptance effects do indeed diminish with time. In addition to the charge rate problem, three cells appeared to have a higher than normal end-of-discharge cell resistance. These cells are presently being removed from test so that the high resistance behavior can be investigated. The capacity and resistance measurements on the cells and strings that were tested at both CSPL and SNL were in good agreement, with the exception of one cell that experienced an increase in resistance.

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TABLE 1
STATUS OF CSPL CELLS AND STRINGS AS OF 7/25/89
(GROUPS 2 & 3)

CELL OR STRING NO.										
464	465	469	470	471	472	475	476	473	474	TESTS CONDUCTED
X	X	X	X	X	X					Chg. acceptance @ 330 C
X	X	X	X	X	X	X	X	X	X	Chg. acceptance @ 340 C
X	X	X	X	X	X	X	X	X	X	Chg. acceptance @ 350 C
X	X	X	X	X	X				X	Chg. acceptance @ 375 C
		X			X	X	X			Deep-discharge (1.76V)
					X					Over-charge
X	X	X	X	X	X					Cap. vs. dischg. rate
				X					X	Parametric
X		X								SFUDS79
X		X								Peak power
		X	X							Life cycle
457	487	615	710	527	398	569	307	394	374	Number of cycles run
94	99	95	93	93	95	96	99	95	96	% of initial capacity
*	*				*	*	*	*		* Removed from test

473 & 474 - 4-cell strings

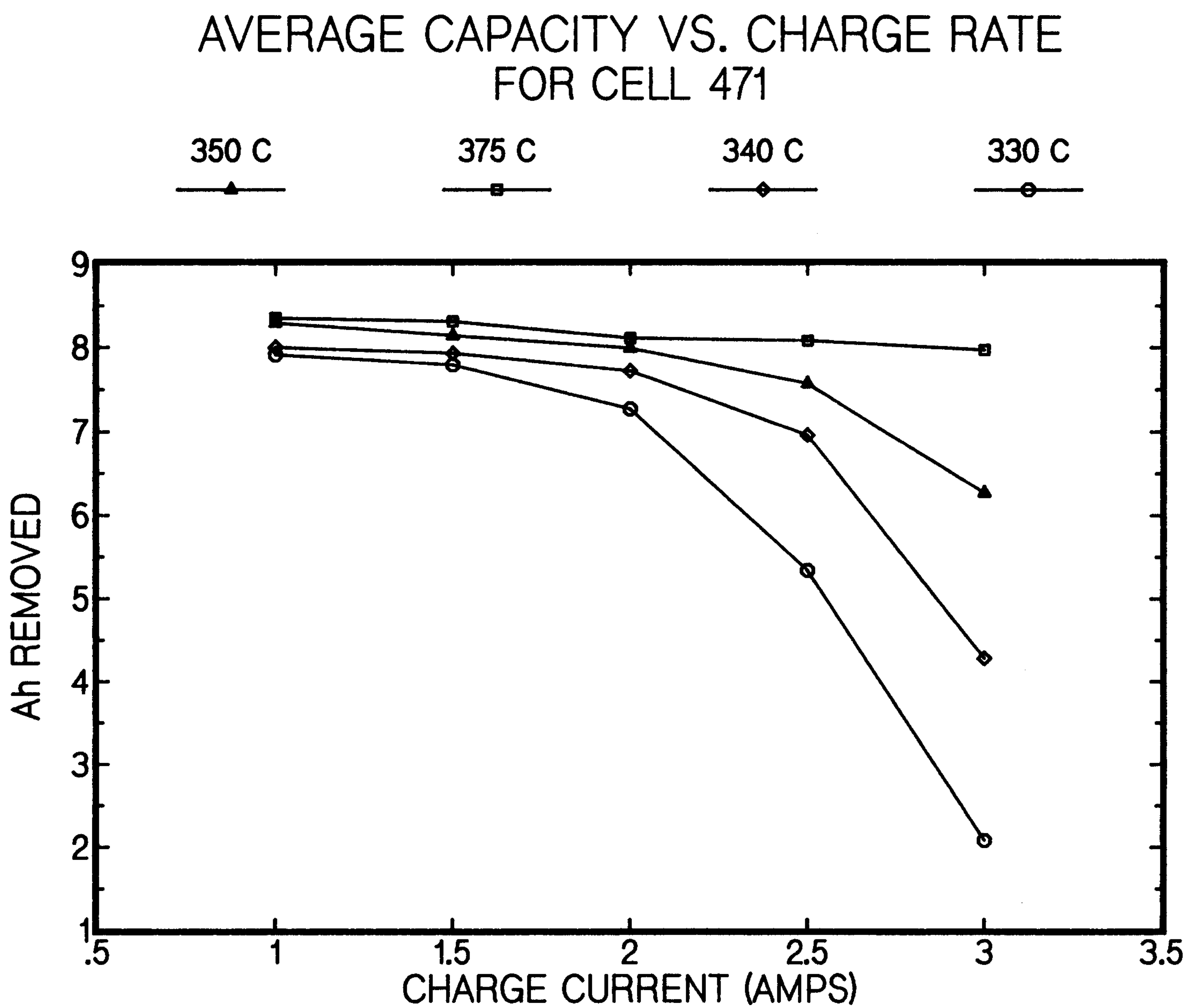

AVERAGE CAPACITY VS. CHARGE RATE
FOR CELL 471
350 C
375 C
340 C
330 C
9
8
7
6
5
4
3
2
1
Ah REMOVED
.5
1
1.5
2
2.5
3
3.5
CHARGE CURRENT (AMPS)

FIGURE 1

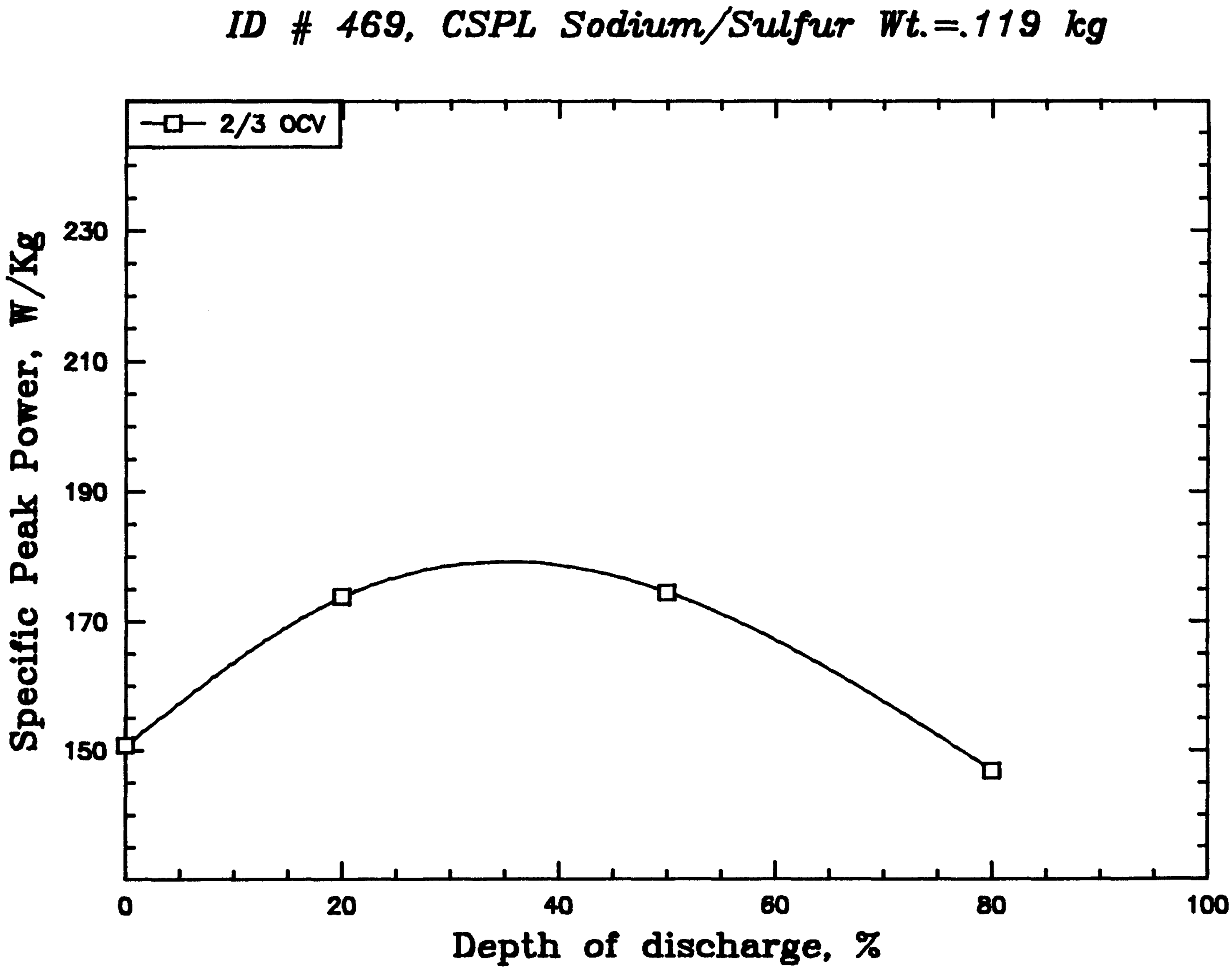
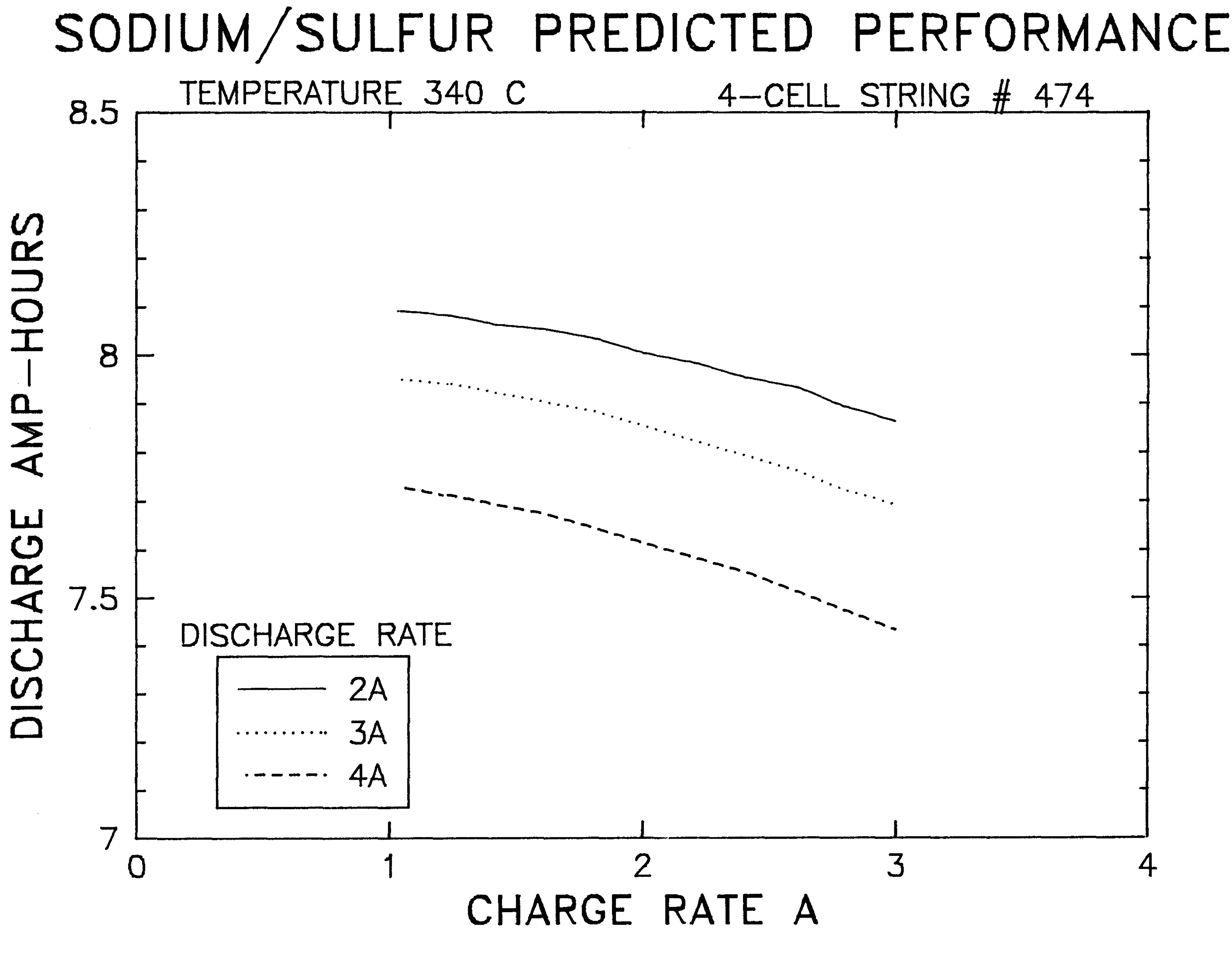

ID # 469, CSPL Sodium/Sulfur Wt.=.119 kg
2/3 OCV
Specific Peak Power, W/Kg
230
210
190
170
150
0
20
40
60
80
100
Depth of discharge, %

FIGURE 2



SODIUM/SULFUR PREDICTED PERFORMANCE
TEMPERATURE 340 C
4-CELL STRING # 474
DISCHARGE AMP-HOURS
8.5
8
7.5
7
0
1
2
3
4
CHARGE RATE A
DISCHARGE RATE
2A
3A
4A

FIGURE 3

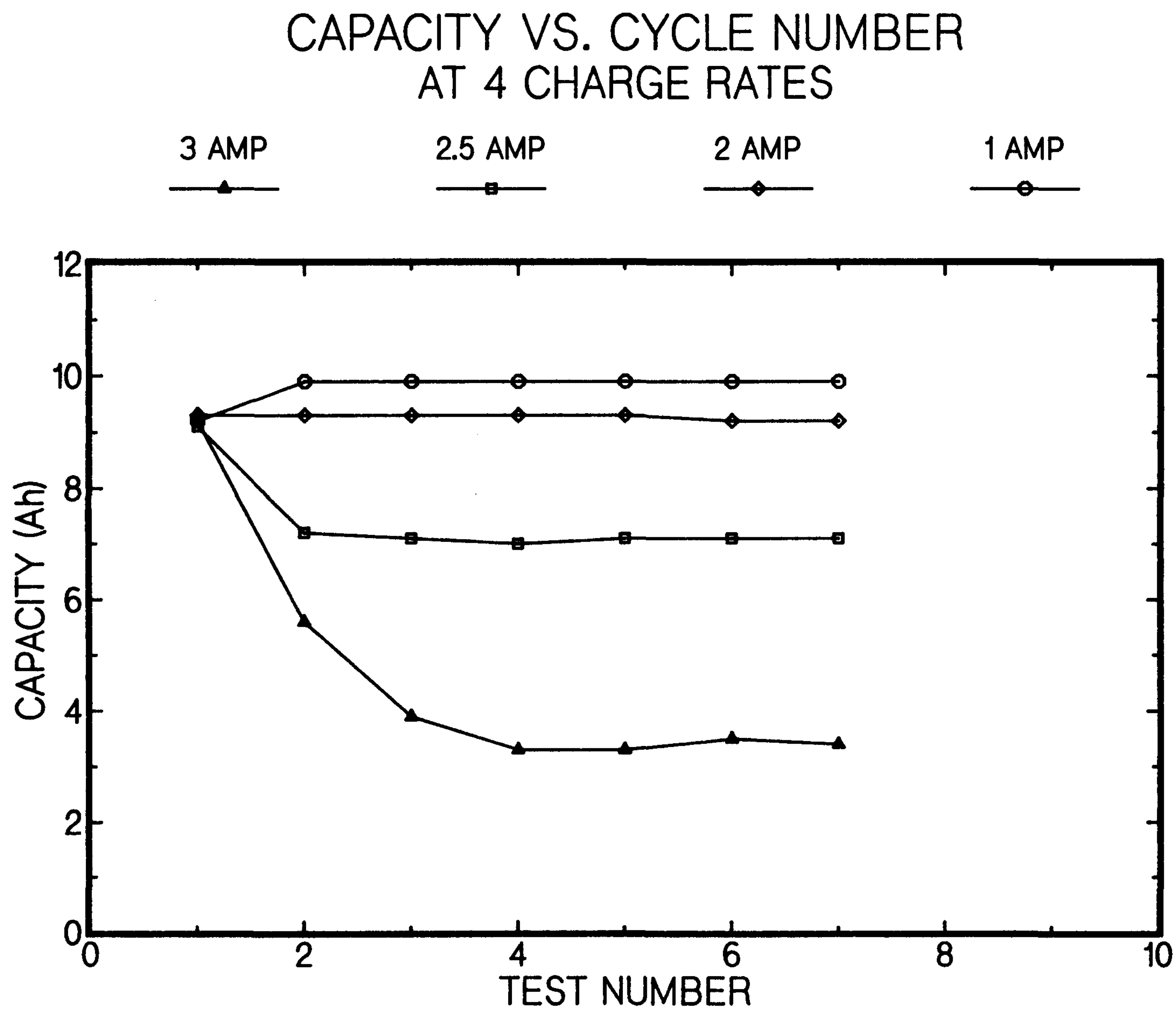

CAPACITY VS. CYCLE NUMBER
AT 4 CHARGE RATES
3 AMP
2.5 AMP
2 AMP
1 AMP
CAPACITY (Ah)
0
2
4
6
8
10
12
TEST NUMBER
0
2
4
6
8
10

FIGURE 4