N87-11081

TEST RESULTS OF JPL $LiSOCl_2$ CELLS

G. HALPERT, S. SUBBARAO, S. DAWSON, V. ANG, E. DELIGIANNIS

JPL has been involved in the development of high rate $Li-SOCl_2$ cells for various applications. The goal is to achieve 300 watt-hours per kilogram at the C/2 (5 amp) rate in a "D" cell configuration. The JPL role is to develop the understanding of the performance, life, and safety limiting characteristics in the cell and to transfer the technology to a manufacturer to produce a safe, high quality product in a reproducible manner.

The approach taken to achieve the goals is divided into four subject areas:

Cathode processes and characteristics
Chemical reactions and safety
Cell design and assembly
Performance and abuse testing

Last year, I described the results of what was termed a "first generation" design. In this initial work, the goal was to evaluate positive versus negative limited and case positive versus case negative designs. The cell was not optimized for anode, cathode, or thionyl chloride capacities.

To fabricate these cells required an evaluation of the cathode processing steps. There are several steps included in the preparation of cathode including mixing order and speed, composition of the mix, rolling/pressing method, and curing procedure. These steps were evaluated by characterization of the cathode. The final product utilized Shawingan Acetylene Block (SAB) carbon, comprising 10% PTFE on an Exmet current collector. There were no known additives. The cathode thicknesses varied between 20 and 27 mils depending on the program stage.

The assembly process included developing a technique for handling the electrode pack including separator. The lithium anode consisted of two layers of lithium film mechanically pressed on opposite sides of nickel screen. The separator is a Meade fiberglass material. The cathode, anode, and separator pack were rolled on a mandrel and placed in the stainless steel case. After welding the cover containing a single glass for metal seal, the cell was vacuum-filled with electrolyte to ($LiAlCl_4$ in $SOCl_2$).

The results of testing these first generation cells is given in figure 1. The surprising results showed that at the 0.2 and 1 amp rate the 300 Wh/Kg (10.7 Ah) was achievable. At the 5 amp discharge rate, this goal was not quite met. The V-I power characteristic curves presented at last year's workshop are given in figure 2. The ability of producing 50 watts at full charge and 30 watts at 90% discharge was also impressive.

The goal of this past year's effort was to optimize the design for a high rate application (see figure 3). This included characterization of the carbons and the electrodes, evaluation of electrolyte concentration, anode/cathode ratio, effect of reversal, inside/outside carbon, among others.

The second generation design is given in figure 4 (1). Note that the lithium electrode capacity is minimized. The reason for this is that at the high rate the carbon electrode will limit the capacity so it is unnecessary to add the additional lithium. There is an important point to be made here. In order to design a safe cell to meet a specific application, the anode, cathode, and electrolyte balance must be designed with the applications in mind; a high rate design will result in different performance than a low rate design.

From a safety standpoint, it has been shown (2) that a $SOCl_2$-limited cell can lead to safety hazards. Thus, its capacity must be maximized so that there is adequate electrolyte to provide conductivity throughout and at the end of discharge.

The work on the cathode characterization has led to some interesting results. The work performed on this subject included determining particle size, surface area, and structure of several carbons (SAB, Ketjen Black, Vulcan, and Black Pearls) and the surface area and pore-size distribution (PSD) of the carbons as electrodes measured using the BET and mercury porosimetry methods (3). Although no definitive statement can be made at this time, some of these characteristics appear to more relevant than others. For example, the mercury porosimetry provided some insight into the PSD of the cathode. An example is shown in figure 5 in which the SAB electrode characteristic is compared before and after discharge. More work is continuing in this area to better understand the controlling physical processes.

Experimental work on the safety of Li-$SOCl_2$ during reversal (4) especially the carbon-limited cells of interest for this application. This work indicates that during carbon-limited reversal lithium forms on the carbon. However, if there is adequate electrolyte, the lithium will quickly dissolve removing the potential for dendrite formation - a condition that has been reported on hazards. The innovative experimental setup of his work is given in figure 6. The results given in figure 7 indicate that there is plating of lithium on carbon during reversal as can be seen by the potential of the reference carbon (C2) versus the reversed carbon (C1). The 3.5 volts is typical of the Li-$SOCl_2$ cell potential. The reversal lasted for 200 mah. However, after a 1-hour stand, only 24 mah of lithium capacity was available indicating there was a reaction between the Li and the $SOCl_2$ solution.

The test results all done at ambient temperatures are given in the next few figures (5). The 1 amp discharge is given in figure 8. The voltage was level at 3.3V. The temperature increased only slightly in the forced air circulation chamber until close to failure. The capacity to 2 volts was greater than 12 Ah (340 Wh/Kg). At 2 amp in figure 9, the results were similar with a minor difference in capacity of 11.2 Ah (318 Wh/Kg). The 5 amp discharge resulted in higher temperature (162°F) - less than the 212°F predicted and required for safe operation. The capacity of 11.1 Ah at 3.3 (316 Wh/Kg) was surprisingly high and exceeded beyond the 300 Wh/Kg goal.

The design considerations described earlier were evaluated and the results given in figure 11. Three cells of each type were included in the evaluation. The results are the average of the three. There was not much difference in the placement of the carbon or in the electrolyte concentration. However, the 1.8 mah electrolyte has greater conductivity and the need to maximize the carbon electrode by placing it on the outside makes the selection of design more appropriate.

Additional tests were conducted in which the cells were reversed for 2 hours at 5 amps. There were no incidents reported during this revised test. Summarizing the work on the JPL design cells. A goal of 300 Wh/Kg at the ship rate has been exceeded. And thus, design of the cell appears to be adequate to meet the requirements. The thermal analysis discussed by Cho(6) at this conference further verifies that the cells are capable of meeting the mission goal.

REFERENCES

1. V. Ang, Internal Memorandum of October 1985

2. S. Subbarao, G. Halpert, and I. Stein, "Safety Considerations of Lithium Thionyl Chloride Cells" (JPL Document soon to be released)

3. S. Dawson, Fall Meeting, Electrochemical Society, Las Vegas, Nevada, October 1985

4. S. Subbarao, Fall Meeting, Electrochemical Society, Las Vegas, Nevada, October 1985

5. F. Deligiannis, Paper to be presented at the IECEC Meeting in San Diego, California, August 1986

6. Y. Cho, The 1985 NASA/GSFC Battery Workshop

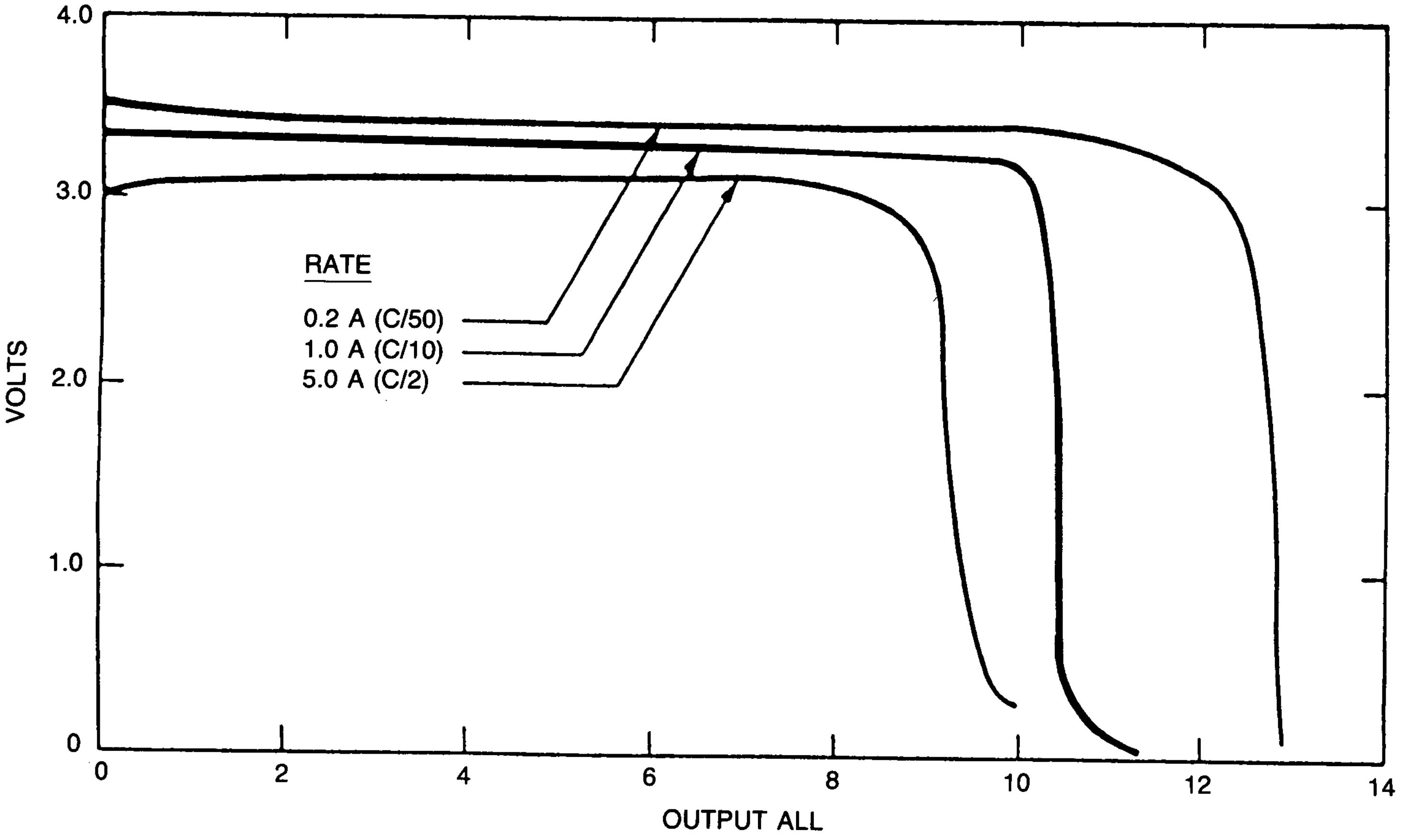


Figure 1. EFFECT OF DISCHARGE RATE ON $Li\text{-}SOCl_2$ CELL PERFORMANCE

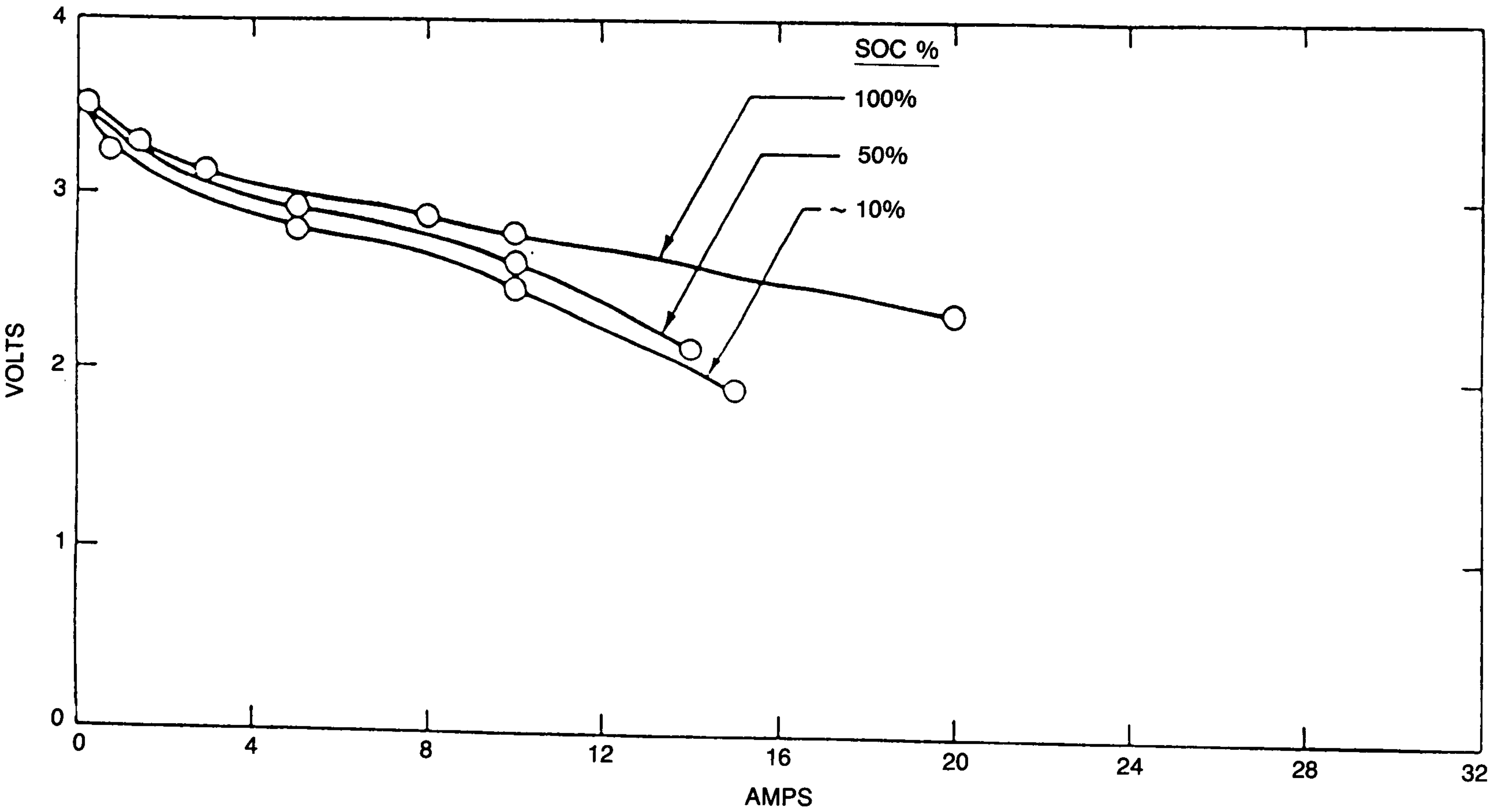


Figure 2. EFFECT OF STATE OF CHARGE ON VOLTAGE—CURRENT CHARACTERISTICS

OPTIONS	1ST GEN	2ND GEN
POS/NEG LIMITED	X	
CASE +/ CASE –	X	
ELECTROLYTE CONC		X
ELECTRODE CONFIGURATION		X
ELECTRODE CAP RATIO		X
INSIDE/OUTSIDE CARBON		X
TAB DESIGN		X
LINER MATERIALS		X

Figure 3. CELL DESIGN CONSIDERATIONS

Li	14.8 ± 0.2 Ah
$SOCl_2$	18.5 ± 0.5 Ah
CARBON (LIMITING)	13 ± 1 Ah
ELECTROLYTE	1.8 M $LiAlCl_4$ TN $SOCl_2$
SEPARATOR	MEAD 934-S FIBERGLASS SEPARATOR
CASE	304L STAINLESS STEEL CYLINDRICAL 1.36″ DIAM × 2.60″ TALL
COVER/SEAL	FUZITE
CELL WEIGHT	116 ± 1 GM

Figure 4. THE SECOND GENERATION CELL DESIGN

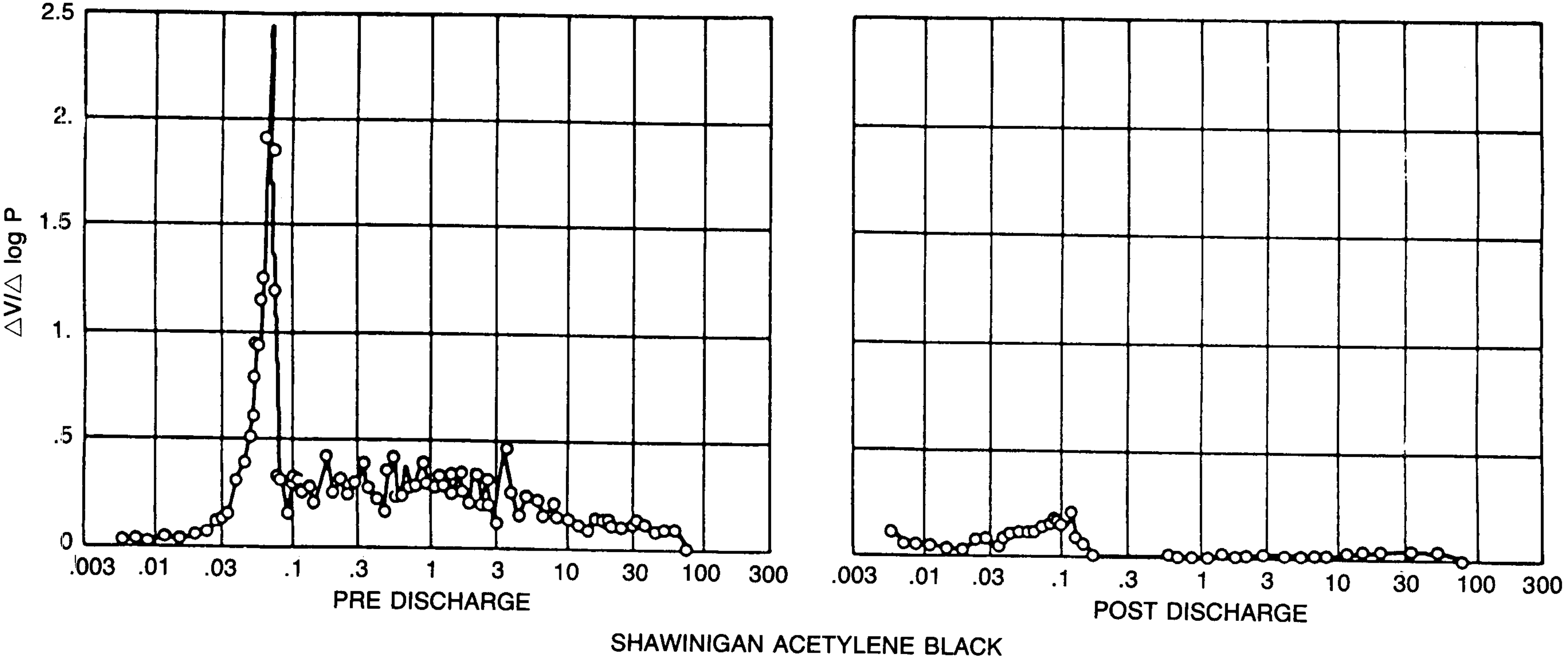
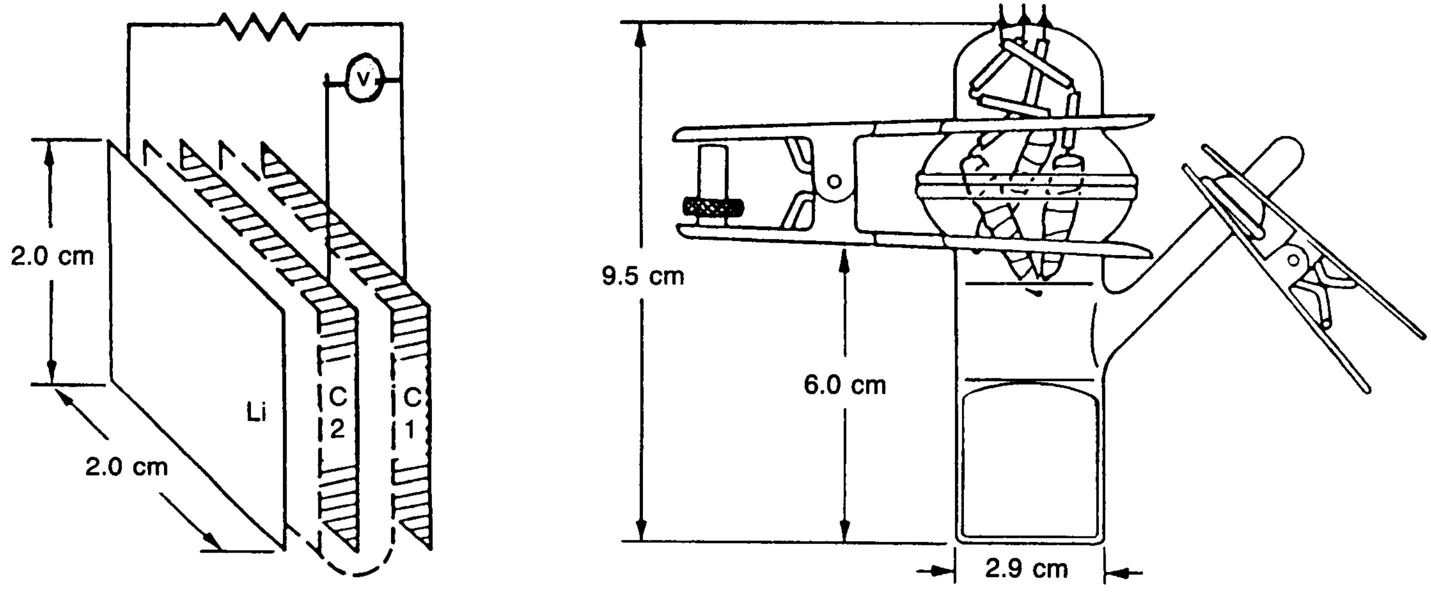


Figure 5. PORE DISTRIBUTION VS PORE DIAMETER PRE/POST LABORATORY CELL DISCHARGE



CELL DETAILS

ELECTROLYTE COMPOSITION	1.5 M $LiA\ell C\ell_4/SOC\ell_2$ ELECTROLYTE
ELECTROLYTE QUANTITY	3CC (FLOODED)
CARBON ELECTRODE CAPACITY (10 mA/cm^2)	~ 0.12 AH
LITHIUM ELECTRODE CAPACITY	~ 1.5 AH

Figure 6. EXPERIMENTAL CELL FOR CATHODE REVERSAL STUDIES

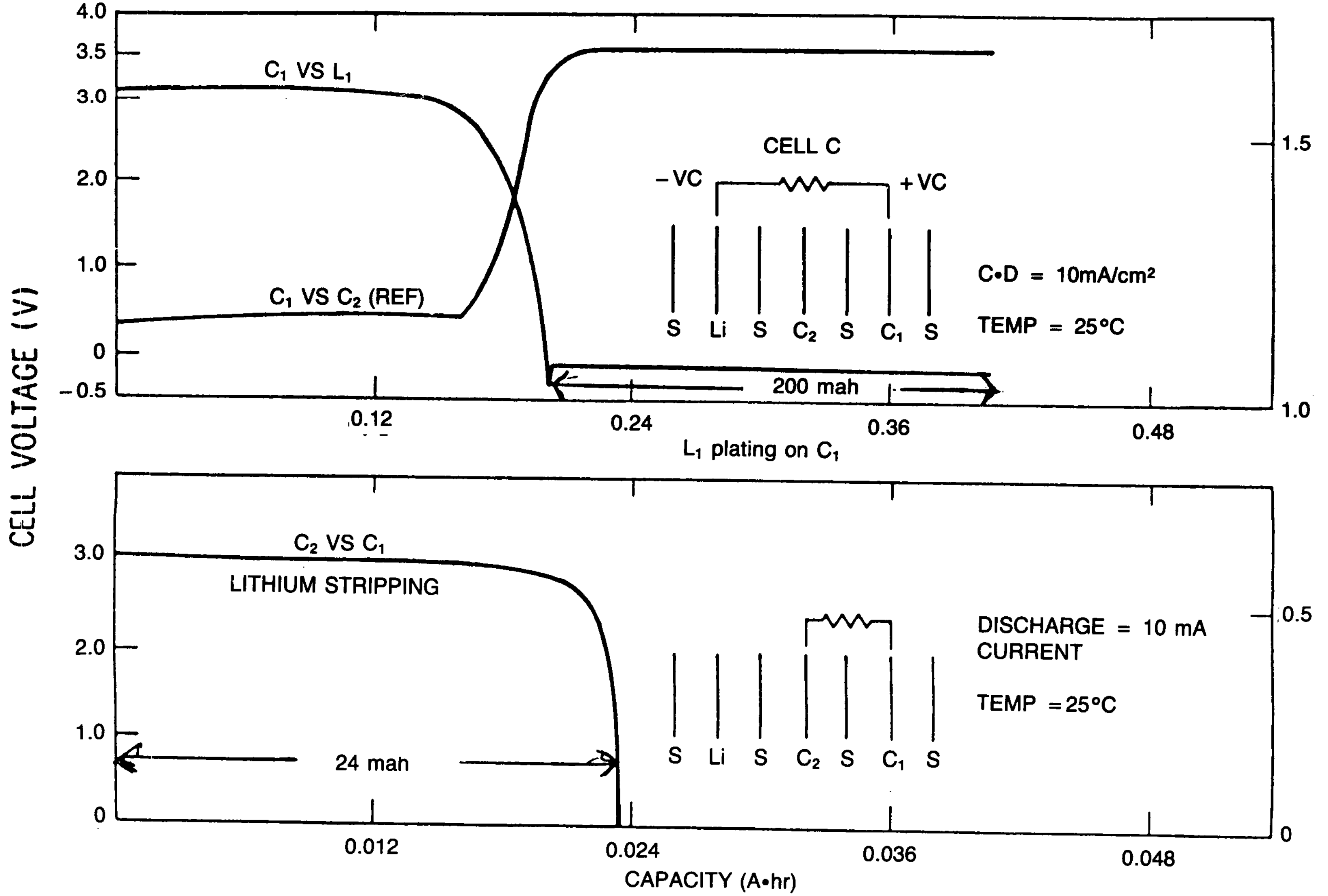


Figure 7. DISCHARGE CHARACTERISTICS OF SPECIAL CELLS

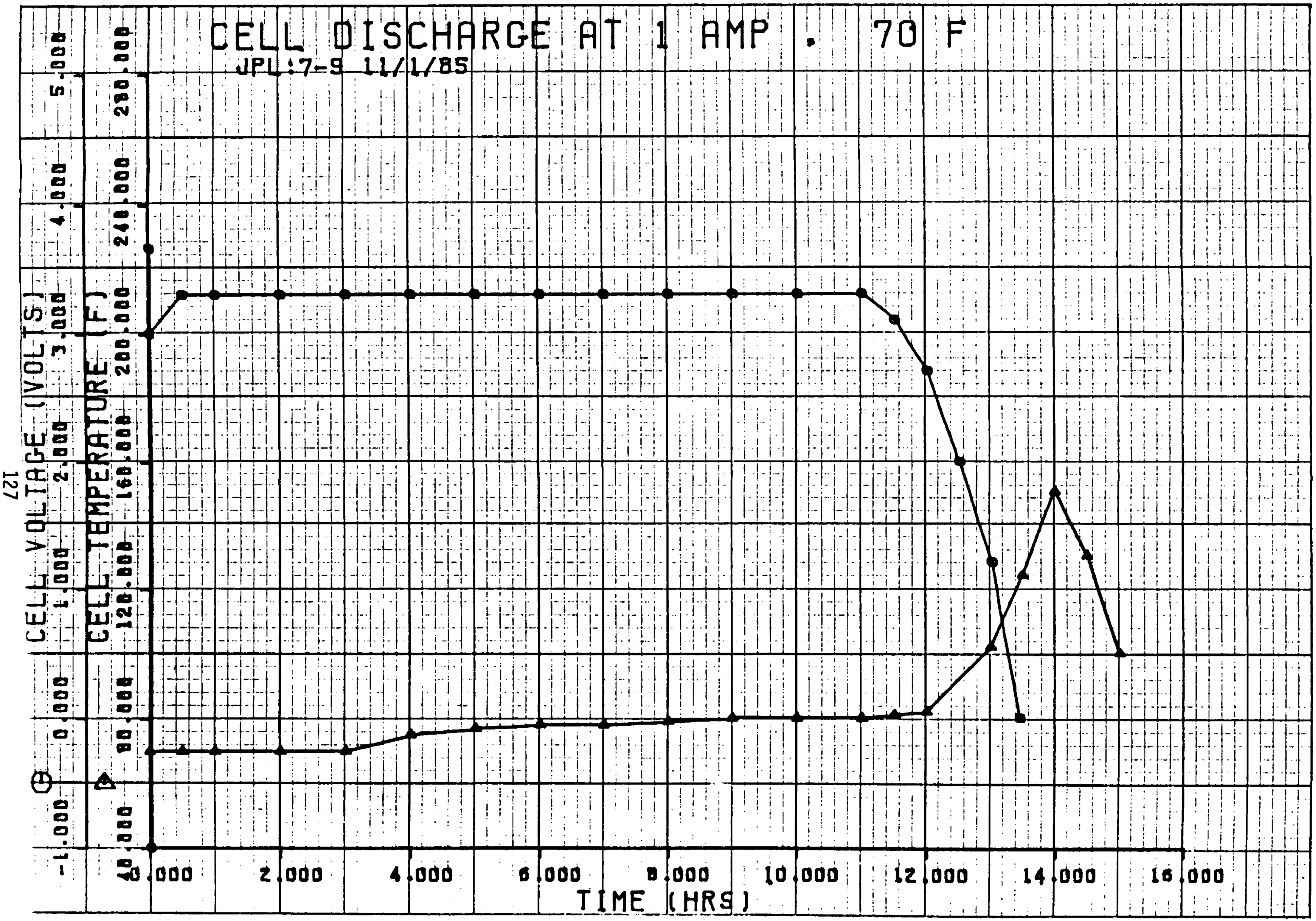


Figure 8. DISCHARGE OF JPL Li-$SOC1_2$ CELL AT 1 AMP

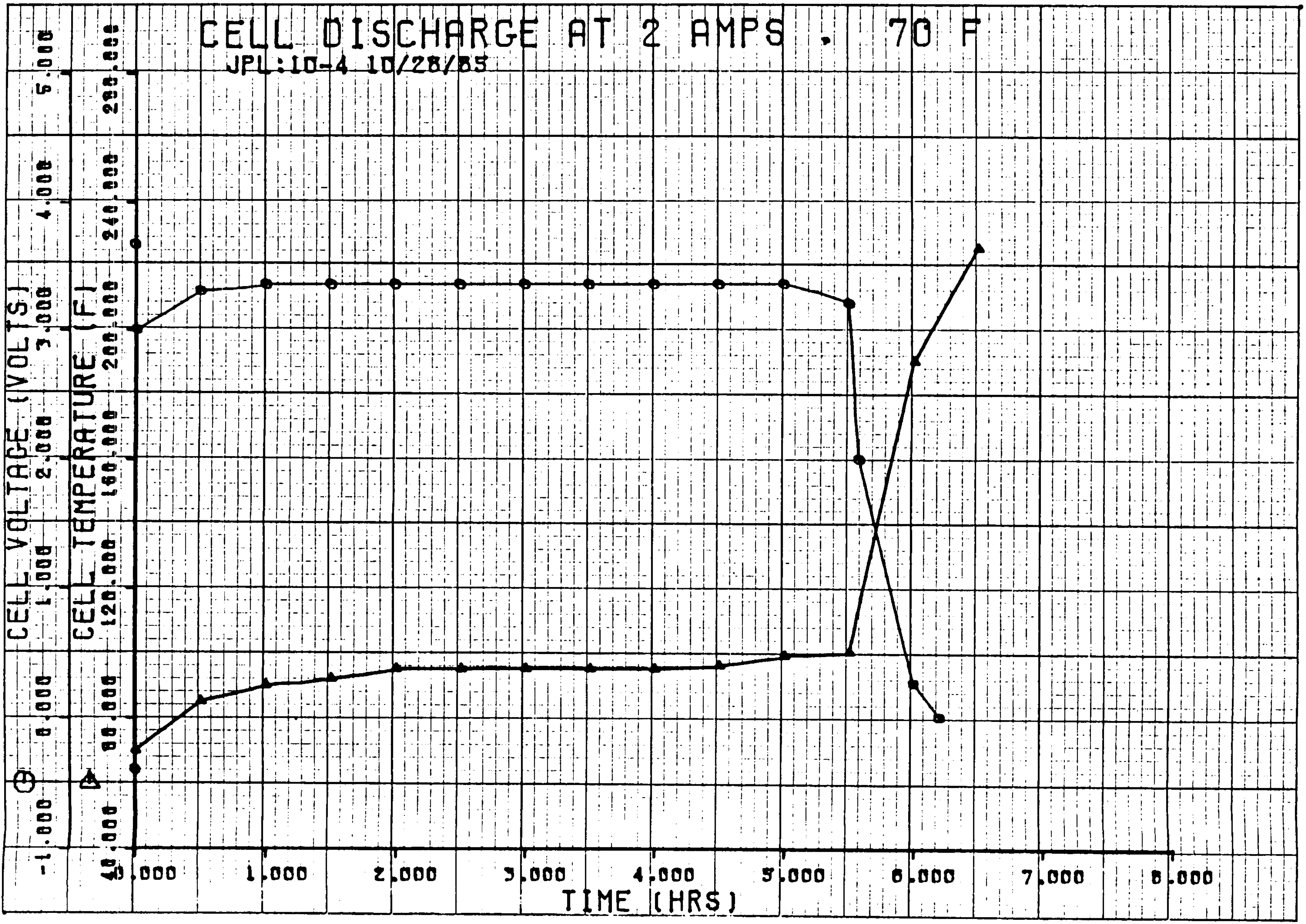


Figure 9. DISCHARGE OF JPL Li-SOCl$_2$ CELL AT 2 AMPS

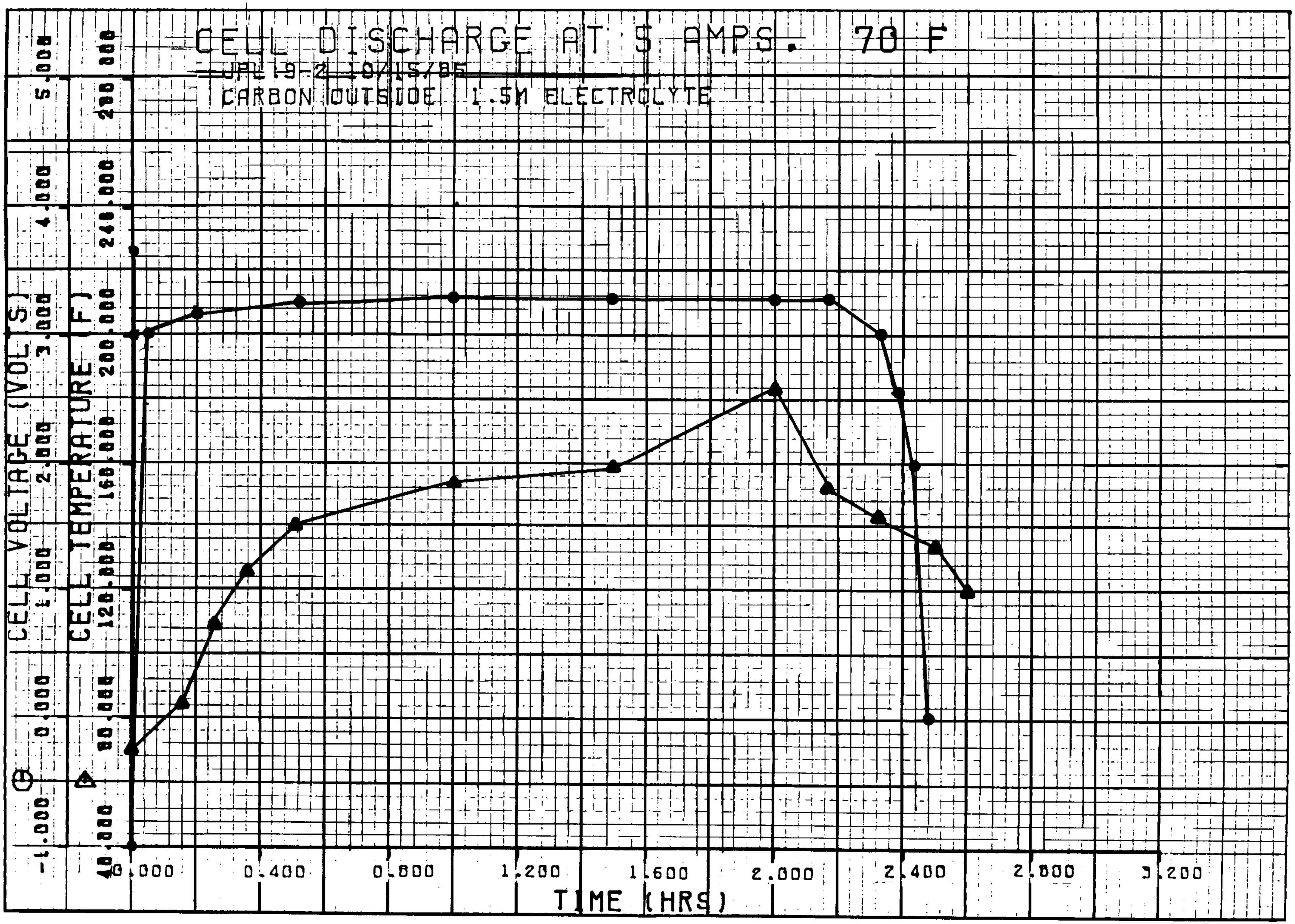


Figure 10. DISCHARGE OF JPL Li-SOCl$_2$ CELLS AT 5 AMPS

JPL CELL TEST DATA

DESIGN	PARAMETER	CAPACITY		$E_{1/2}$	$T_{1/2}$	$T_{2.0}$
NO		AH	TO 2.0V		.F	F
6	LITHIUM	5A	10.7	3.10	150	200
	OUTSIDE					
	1.8M	2A	11.5	3.15	90	135
	ELECTROLYTE	1A	11.8	3.40	82	95
7	CARBON	5A	12.1	---	150	210
	OUTSIDE					
	1.8M	2A	11.7	3.25	90	125
	ELECTROLYTE	1A	12.5	3.35	78	95
8	CARBON	5A	10.0	3.20	160	180
	OUTSIDE					
	1.0M	2A	11.4	3.20	90	125
	ELECTROLYTE	1A	12.4	3.35	78	105
9	CARBON	5A	11.7	3.20	155	205
	OUTSIDE					
	1.5M	2A	12.0	3.25	95	142
	ELECTROLYTE	1A	12.5	3.37	78	100
10	CARBON	5A	11.6	3.20	160	240
	OUTSIDE					
	1.8M	2A	11.1	3.28	95	150
	ELECTROLYTE	1A	12.0	3.35	78	100

Figure 11. SUMMARY OF DISCHARGE DATA OF JPL Li-$SOCl_2$ "D" CELLS