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Temperature and Shock Testing of Lithium-Organic Electrolyte Cells

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ABSTRACT

Honeywell G2655 lithium cells were tested over the temperature range -40° to +70°C and subjected to shock levels up to 17,000 g's. Output at -40°C was approximately 50 percent of that at +25°C, while at +70°C, the output was 150 percent that at +25°C. Shock had no noticeable effect on performance.

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J. E. McCreight and L. B. Brace, 2522, were responsible for programming the H. P. 3050A and building the load boxes for the discharge tests.

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TEMPERATURE AND SHOCK TESTING
OF
LITHIUM-ORGANIC ELECTROLYTE CELLS

Introduction

Sandia Laboratories is studying high-speed, earth-penetrating vehicles. Instrumentation has been designed to monitor the strains induced in these vehicles during the initial impact and subsequent penetration. A battery is needed to furnish primary power for the instrumentation package during these tests.

Battery requirements are: 34 volts maximum to 20 volts minimum, 500 ma for three hours, operating temperature range of -40° to $+70^{\circ}C$, two years' storage at room temperature, and a shock of 10,000 g's for 12 msec. Weight and volume restrictions require an energy density of approximately 15 W-hr/lb and 1.3 $W\text{-}hr/in^3$.

Based primarily on the energy density and operating temperature requirements, a lithium-organic electrolyte battery was believed to be best suited for this application. The Honeywell G2655 lithium cell was chosen (Figure 1). This cell has a lithium anode, a vanadium pentoxide (V_2O_5) cathode, and an electrolyte of lithium hexafluoroarsenate ($LiAsF_6$) plus lithium tetrafluoroborate ($LiBF_4$) in methyl formate. The cell is of a pile-type construction, which can usually withstand severe shock requirements. Its volume is 1.934 in^3 (excluding the flange) and it weighs 0.17 lb. To a 2.0 volt cutoff, it has a rated 5 amp-hr capacity.

Experimental

Twenty-five cells were procured for this test program. Five cells were tested at each of the five conditions listed below:

1. Control: Discharge $+25^{\circ}C$, 5-ohm load
2. $-40^{\circ}C$: Equilibrate 17 hours, discharge through 5-ohm load.
3. $+70^{\circ}C$: Equilibrate 17 hours, discharge through 5-ohm load.
4. Shock: 10,000 g's, 3.3 msec, discharge $+25^{\circ}C$, 5-ohm load.
5. Shock: 17,000 g's, 1.7 msec, discharge $+25^{\circ}C$, 5-ohm load.

All cells were discharged to a 2.0-volt cutoff, using a Hewlett-Packard 3050A automatic data acquisition system. The 3050A was programmed to plot each cell voltage versus time, and to compute the ampere-hour and watt-hour output of each cell.

The shock tests were conducted at Sandia's $5\frac{1}{2}$-inch air gun facility. The cells were potted with brown sugar in an aluminum canister having 0.5-inch thick walls and cover (Figure 2).

Brown sugar has been used by the Environmental testing group at Sandia as a potting material for shock testing of components over the past several years. It is an inexpensive, readily available material that is simple to use. The item to be tested is placed in an appropriate fixture which is then packed tight with moist brown sugar. The assembly is then vacuum dried at $\sim 120^{\circ}F$ overnight. Upon removal of the moisture the sugar hardens, forming a rigid potting that does not mitigate the applied shock. After testing is completed, the sugar is easily removed with water.

Voltage leads were brought out of the canister through a connector. Prior to removing the cells from the canister after the shock tests, they were allowed to sit overnight and open-circuit voltage was monitored. This was done for safety considerations, since it was thought that, if the cells should fail this test, an internal short might develop which could cause the cells to rupture violently.

The cells were removed from the canisters by dissolving the potting material with water.

Results and Discussion

Results of the five individual test conditions are given in Tables I - V. The entire test is summarized in Table VI. Energy density as a function of temperature and shock is shown graphically in Figures 3 and 4. Figures 5 - 9 are discharge curves for a typical cell under each of the five test conditions.

The Honeywell G2655 cells exceeded the system requirements at all test conditions. Over the temperature range studied, performance, as measured by the energy density, increased linearly with temperature. This is expected since the voltage increases with temperature, and life is short enough that chemical side reactions do not have enough time to cause any appreciable losses. The data show that these cells are insensitive to the shock loads applied.

Future Work

The next phase of this study will involve the design and testing of 10-cell batteries. The purpose of these tests is to demonstrate the ability of a full-sized battery to withstand the severe shock environment. Also, aging studies at various temperatures will be carried out on single cells in order to get a more complete characterization of this system.

Results of the second phase of this program will be reported upon completion.

TABLE I

Control

5-Ohm Load, 25°C

No.	S/N*	Amp-hrs	% Cap.	Watt-hrs	W-hr/lb	W-hr/in^3
1	377	3.9	78.0	11.0	64.7	5.7.
2	277	4.3	86.0	12.2	71.8	6.3
3	385	4.5	90.0	12.5	73.5	6.5
4	96	3.8	76.0	10.2	60.0	5.3
5	167	3.7	74.0	10.4	61.2	5.4
Average		4.0± 0.3	80.8±6.9	11.3±1.0	66.2±6.1	5.8±0.5

TABLE II

5-Ohm Load, -40°C

No.	S/N*	Amp-hrs	% Cap.	Watt-hrs	W-hr/lb	W-hr/in^3
1	417	2.6	52.8	6.7	39.4	3.5
2	383	2.5	50.2	6.2	36.8	3.2
3	37	1.9	37.8	4.8	28.0	2.5
4	286	2.0	39.3	4.8	28.2	2.5
5	276	1.9	38.7	4.6	27.2	2.4
Average		2.2±0.3	43.8±7.2	5.4±1.0	31.9±5.7	2.8±0.5

*Serial Number

TABLE III

5-Ohm Load, +70°C

No.	S/N	Amp-hrs	% Cap.	Watt-hrs	W-hr/lb	W-hr/in^3
1	68	6.1	121.2	16.6	97.9	8.6
2	95	5.4	108.0	14.5	85.4	7.5
3	165	5.1	102.2	13.9	81.8	7.2
4	372	6.0	119.1	16.2	95.1	8.4
5	322	5.5	110.6	15.1	88.7	7.8
Average		5.6±0.4	112.2±7.9	15.3±1.1	89.8±6.7	7.9±0.6

TABLE IV

5-Ohm Load, 25°C

10,000 g's Shock

No.	S/N	Amp-hrs	% Cap.	Watt-hrs	W-hr/lb	W-hr/in^3
1	536	4.1	82.1	11.6	68.3	6.0
2	280	4.2	84.6	12.0	70.5	6.2
3	439	4.0	79.2	11.3	66.4	5.8
4	371	3.6	72.9	10.3	60.4	5.3
5	244*	2.9	57.5	8.6	50.8	4.5
Average		3.8±0.5	75.3±10.9	10.8±1.4	63.3±7.9	5.6±0.7
Avg. #'s 1-4		4.0±0.3	79.7±5.0	11.3±0.7	66.4±4.3	5.8±0.4

*Serial number 244 was momentarily shorted while being prepared for test.

S/N's 536, 439, 371 } 10,300 g's - 3.4 msec

S/N's 280, 244 } 10,400 g's - 3.2 msec

TABLE V

5-Ohm Load, 25°C

17,000 g's Shock

No.	S/N	Amp-hrs	% Cap.	Watt-hrs	W-hr/lb	W-hr/in^3
1	250	4.1	82.2	11.8	69.4	6.1
2	182	3.7	72.9	10.5	61.8	5.4
3	105	4.1	81.7	11.2	65.9	5.8
4	282	4.1	82.9	11.9	70.0	6.2
5	194	3.9	77.5	10.9	64.1	5.6
Average		4.0±0.2	79.4±4.2	11.3±0.6	66.2±3.5	5.8±0.3

S/N's 250, 282, 194 — 17,600 g's - 1.7 msec

S/N's 182, 105 — 17,000 g's - 1.7 msec

TABLE VI

Summary of Temperature and Shock Tests

Test Condition	Amp-hrs	% Rated Cap.*	Watt-hrs	W-hr/lb	W-hr/in^3
Control, 25°C	4.0±0.3	80.8±6.9	11.3±1.0	66.2±6.1	5.8±0.5
-40°C	2.2±0.3	43.8±7.2	5.4±1.0	31.9±5.7	2.8±0.5
+70°C	5.6±0.4	112.2±7.9	15.3±1.1	89.8±6.7	7.9±0.6
10,000 g's, 25°C	4.0±0.3	79.7±5.0	11.3±0.7	66.4±4.3	5.8±0.4
17,000 g's, 25°C	4.0±0.2	79.4±4.2	11.3±0.6	66.2±3.5	5.8±0.3

*Calculated before rounding off amp. hrs. to 2 significant figures.

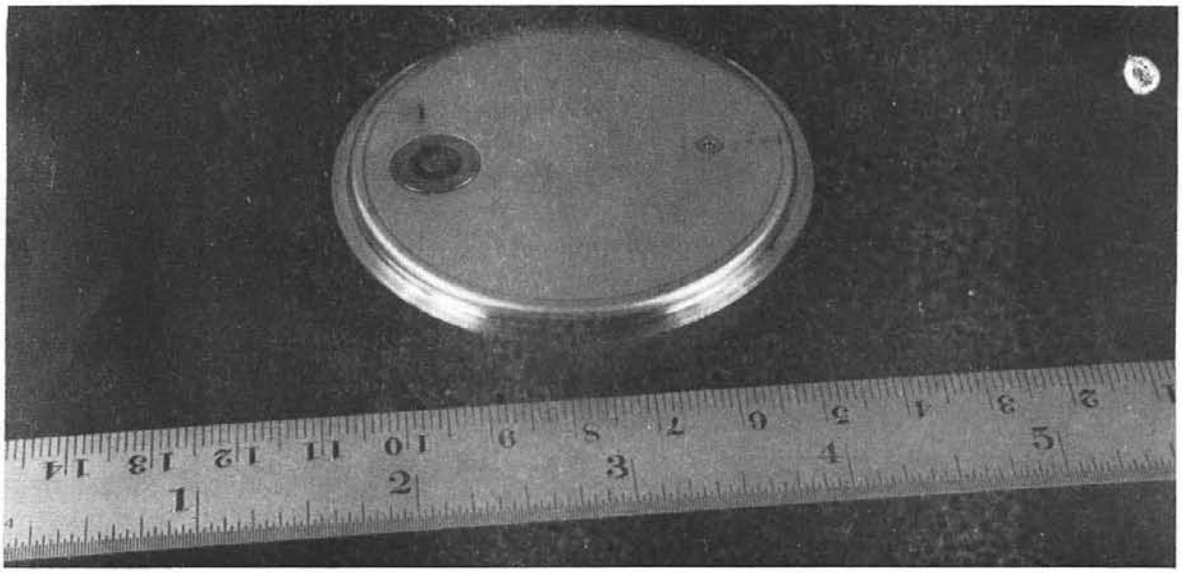

Figure 1. Honeywell G2655 Lithium-Organic Electrolyte Cell

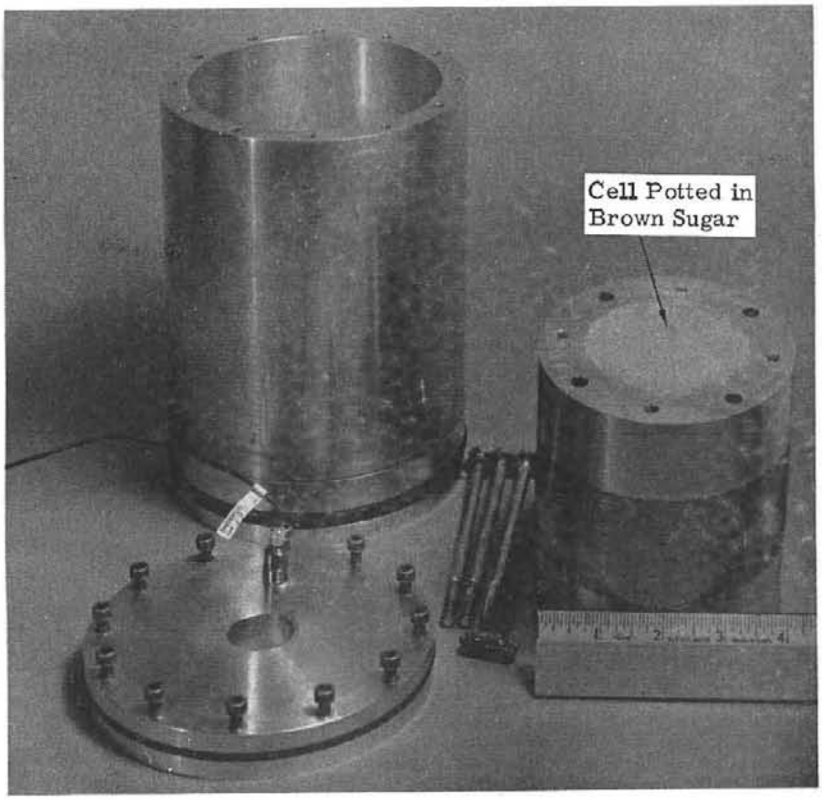

Figure 2. Aluminum Canister used for Brown-Sugar Potted Cells

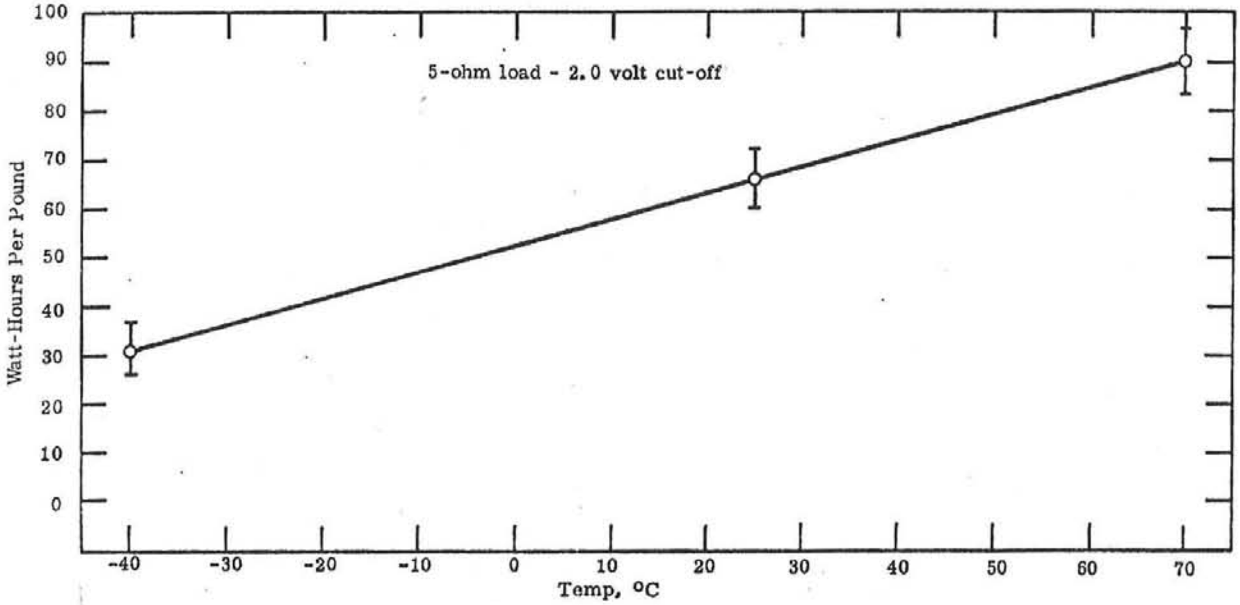

Figure 3. Energy Density for Honeywell Lithium Cell G2655, versus Temperature

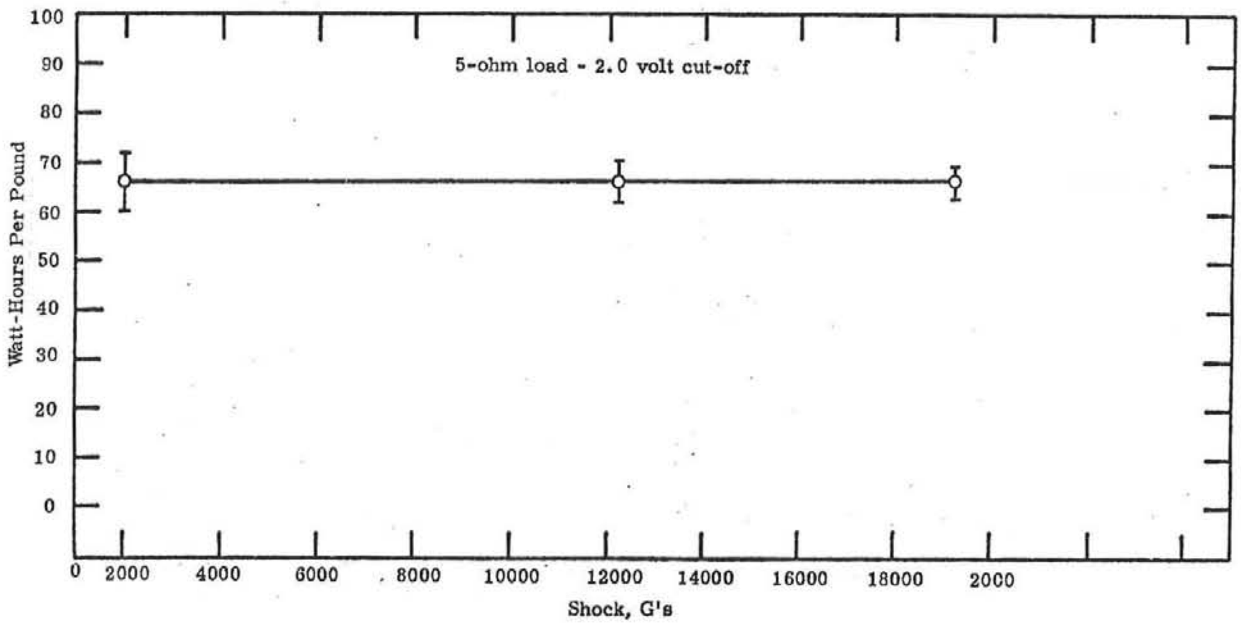

Figure 4. Energy Density for Honeywell Lithium Cell G2655, versus Shock, Temperature 25°C

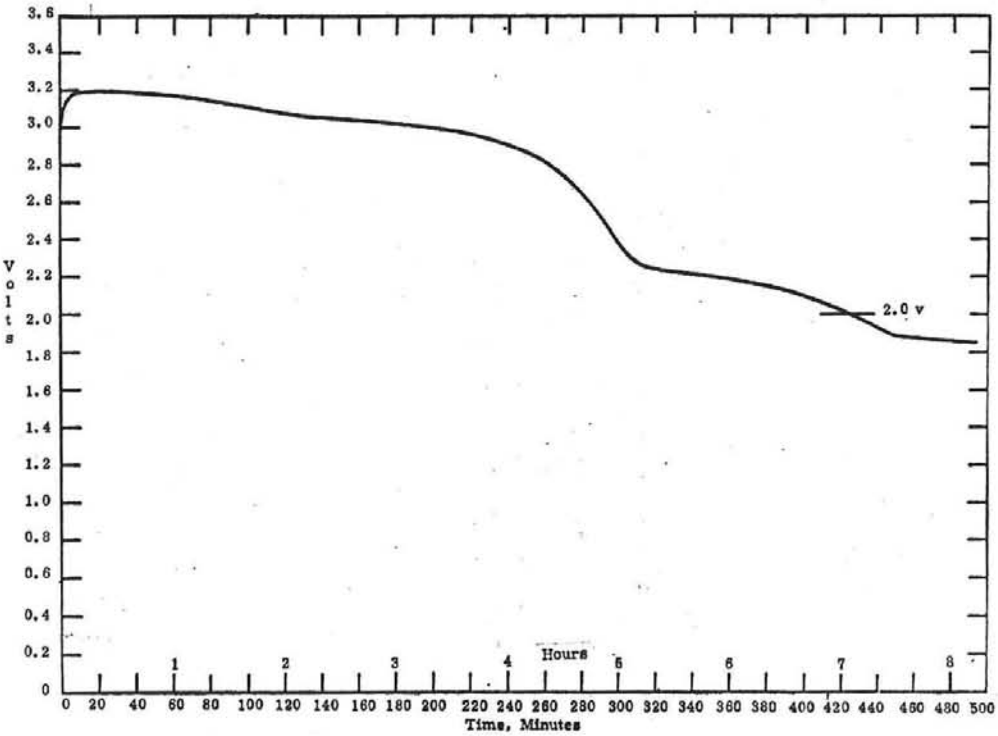

Figure 5. Discharge Curve for Honeywell Lithium Cell G2655, SN 377, 5-Ohm Load, 25°C

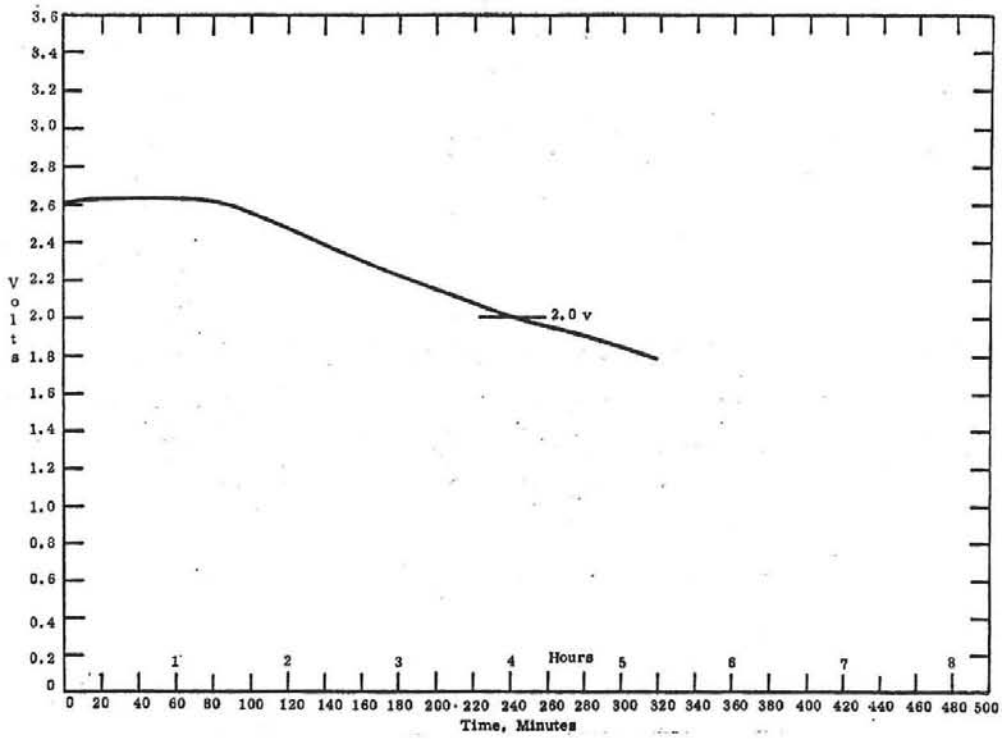

Figure 6. Discharge Curve for Honeywell Lithium Cell G2655, SN 286, 5-Ohm Load, -40°C

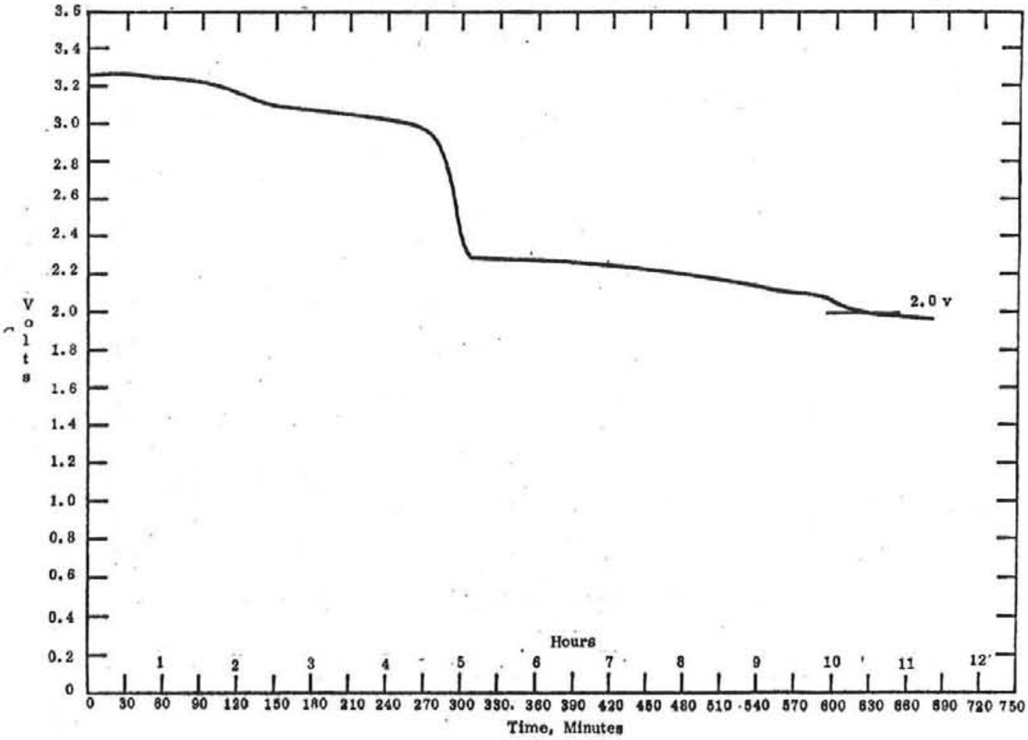

Figure 7. Discharge Curve for Honeywell Lithium Cell G2655, SN 322, 5-Ohm Load, +70°C

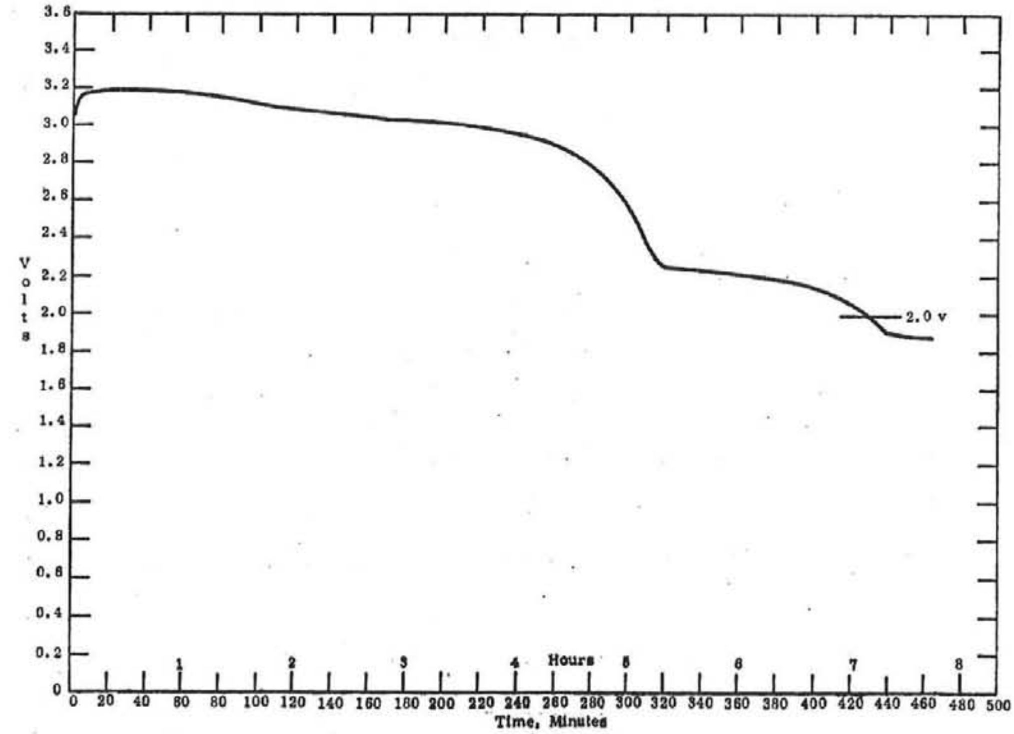

Figure 8. Discharge Curve for Honeywell Lithium Cell G2655, SN 439, 5-Ohm Load, 25°C, Shocked 10,300 g's, 3.4 ms

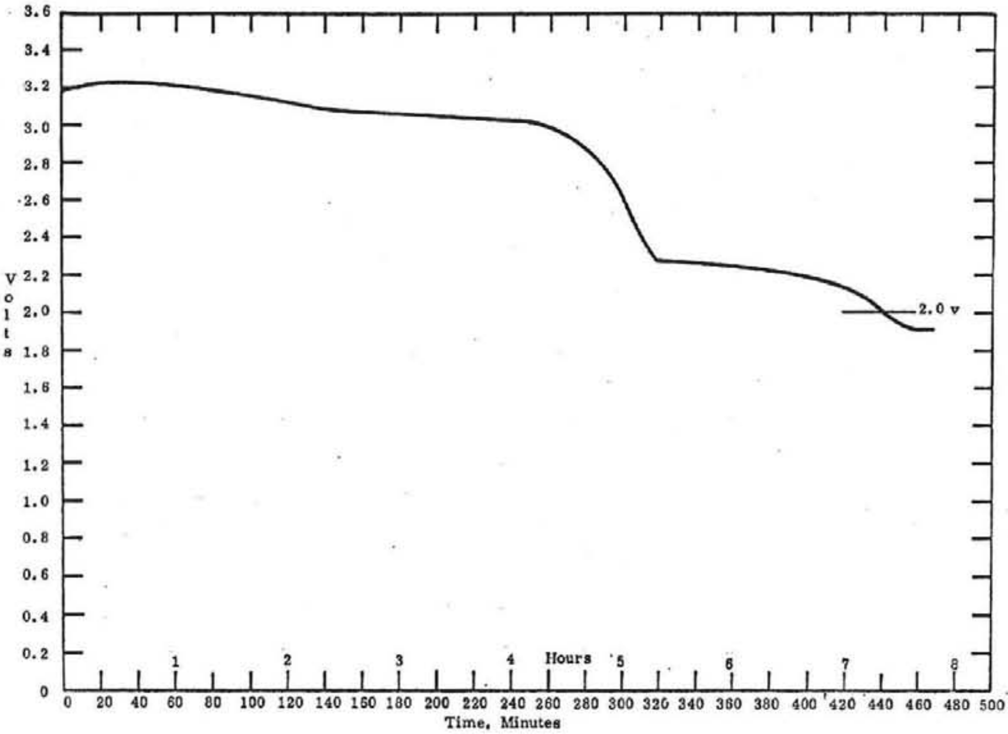

Figure 9. Discharge Curve for Honeywell Lithium Cell G2655, SN 250, 5-Ohm Load, 25°C, Shocked 17,000 g's, 1.7 ms

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