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High-g Shock Test Results of Tadiran TLM-1530MP Cells

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Abstract

In April of 2009, testing was done of a high-g instrumentation device that utilized Tadiran TLM-1530MP cells as a power source. As a result of that testing, it was determined that those cells exhibit failure more often when shocked in the axial direction. No failures over many tests where found when the cells were shocked laterally. Moreover, when shocked laterally, the cells exhibited no observable degradation in performance. We looked at the failed cells via non-destructive x-ray analysis to determine what internal structures failed.

ACKNOWLEDGMENTS

We would like to acknowledge our partners in the testing that led to the results found herein. However, doing so may cause this document to become official use only. So we acknowledge the assistance we received and we wish we could say who it was who helped us but we can’t.

We would like to acknowledge the assistance of two Sandia departments, 1522 and 1715, for their assistance with the x-ray analysis.

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TABLES

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1. TEST SETUP

1.1 Mechanical Setup of the Cells

The TLM-1530MP cells were tested inside a larger assembly. We cannot show the larger assembly but Figure 1 shows the housing for the TLM-1530MP cells. The cells are held in this housing with Dow Corning 3145 RTV. Two compression pads made of a relatively compliant material are then installed at the top and bottom of the housing to allow the housing to be compressed into the larger assembly. The larger assembly fully encloses the battery housing.

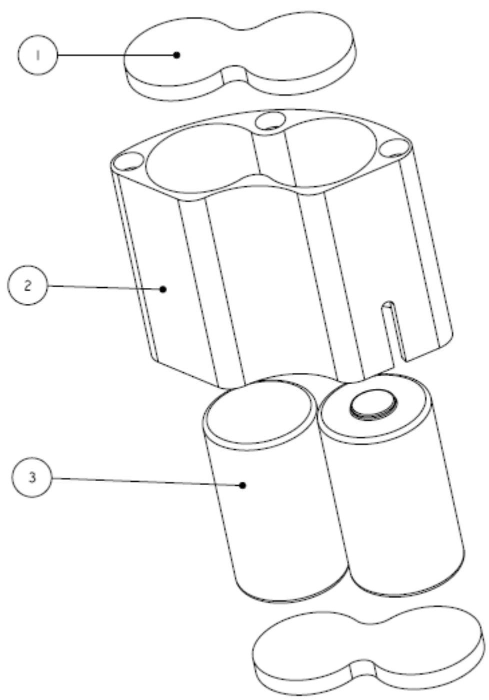

Figure 1: Housing for TLM-1530MP cells

The cells are both placed into the larger assembly in the axial direction. That is, the cells are mounted with their long axis in the direction of what is known as the axial (or *X*) direction of the larger assembly. One of the cells is placed with the anode towards +X, the other with it placed towards –X.

It should be noted that the compression pads and RTV may not hold the cells rigidly during shock. They could move axially under shock conditions. We could not determine from post-test analysis whether the cells had moved axially or not. The RTV was still intact and the cells appeared to be held just as well after the testing as before but we couldn't confirm that they hadn't moved.

1.2 Electrical Setup of the Cells

The pair of cells are wired in series. They then supply power to a larger system which uses linear voltage regulation to power its circuits. The typical current consumption of the larger system is 100+/-2mA. Because the voltage regulation is linear, the larger assembly can be simulated by a constant current load.

1.3 Shock Test Setup

The shocks were generated by a machine which could generate very high-g impulses: from 2,000 g_n to >40000g_n. The duration of the pulses can range from hundreds of microseconds to less than 100us, depending on the setup of the machine. The machine creates the shocks by subjecting the test article – which is initially at rest – to an oncoming piston.

2. TEST RESULTS

2.1 Cell Survivability

Failure of the cells was expected and did happen. During testing, we destroyed three TLM-1530MP battery cells when testing in the axial direction. Testing in the lateral directions did not lead to any battery losses. In fact, one set of batteries lasted 11 lateral shots. (Lateral is defined as 90degrees from the long axis. Since there is no zero degree marking on the cylinder of the cell, we cannot say exactly what lateral angle was impacted.)

The cell failures exhibited as a dramatic loss of battery voltage: from above 7V for a good pair to approximately 4.3V when a cell failed. The other cell in the pack would remain alive and the failed cell would seem to supply some small voltage. The cell that failed was always the cell that was mounted with the cathode (negative terminal) towards the oncoming piston. After disconnecting the cells and measuring each failed cell individually, they measured effectively zero volts. Some of the cells seemed to be self-heating after the tests, indicating a possible internal short.

The cells that failed during axial impacts failed under the conditions given in the following table.

Table 1: Test history of failed cells

	Peak g level (nom)	Duration(nom)	Result
Cell #1	2000	400us	Cell survived
	6000	250us	Cell survived
	10000	160us	Cell failed
Cell #2	13500	2ms	Cell failed
Cell #3	14000	110us	Cell survived
	21000	75us	Cell failed

X-rays of two of the failed cells were taken to determine the internal damage that led to the failures.

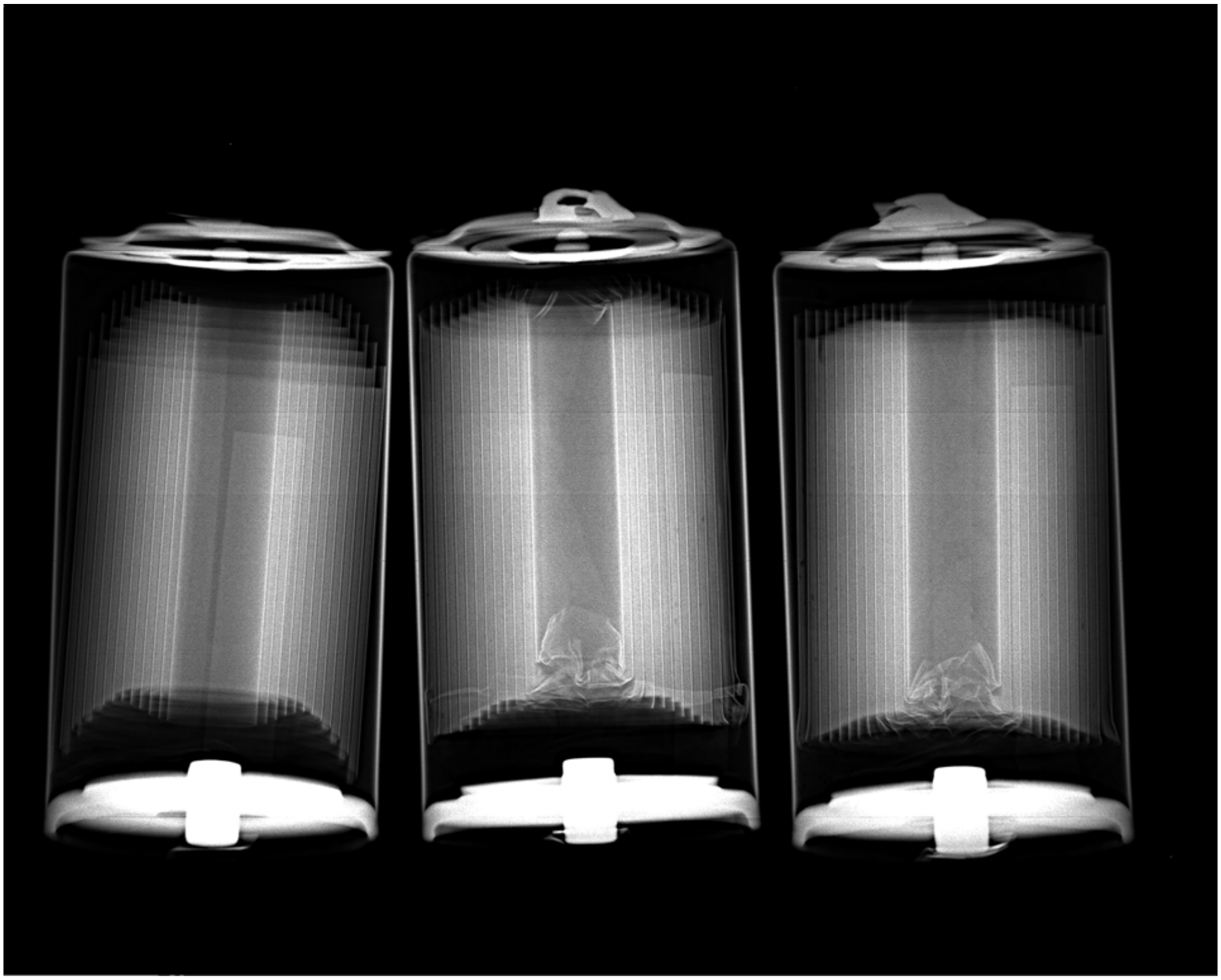

Figure 2: X-rays of a good cell (left) and two failed cells

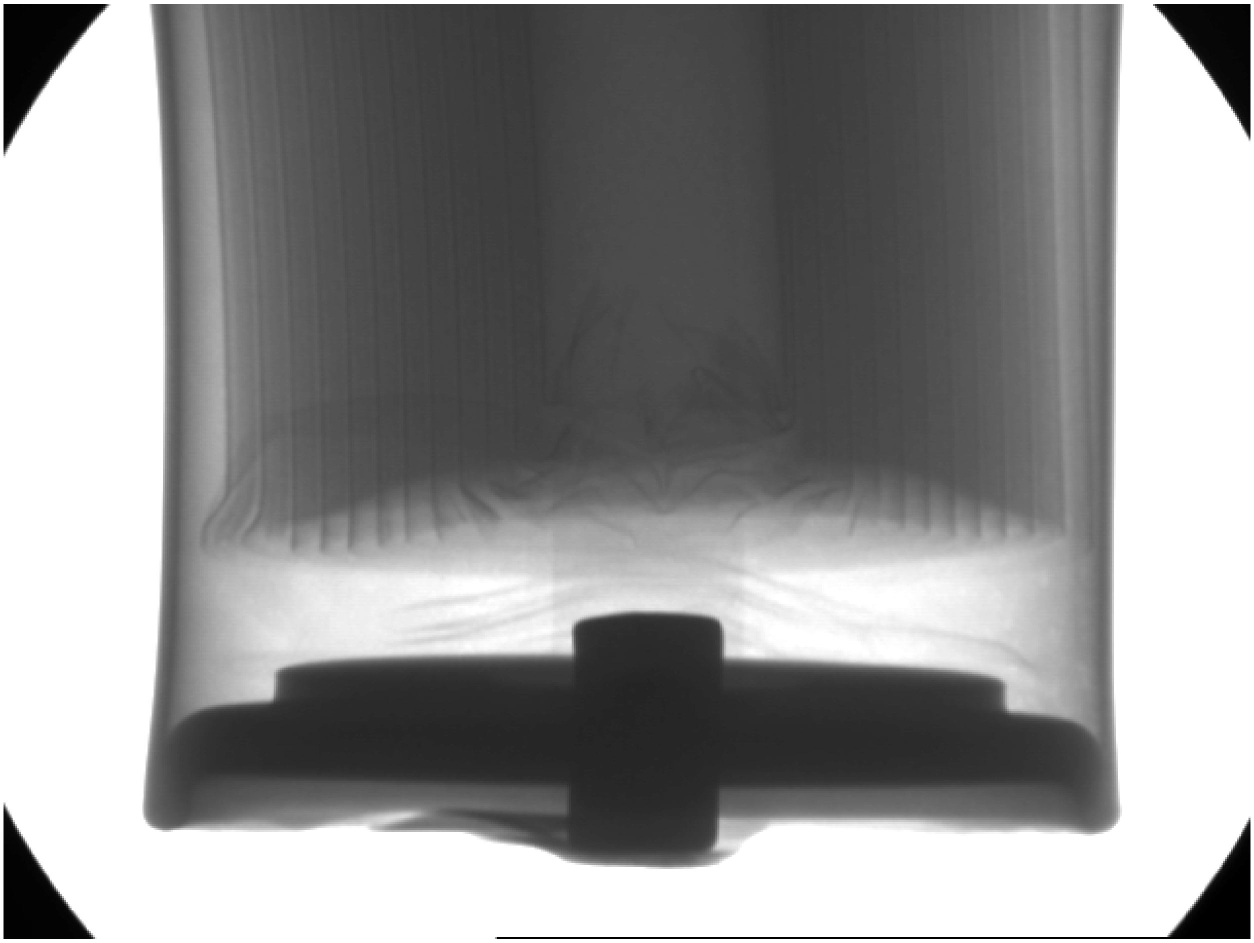

Figure 3: Close-up of the anode of a failed cell

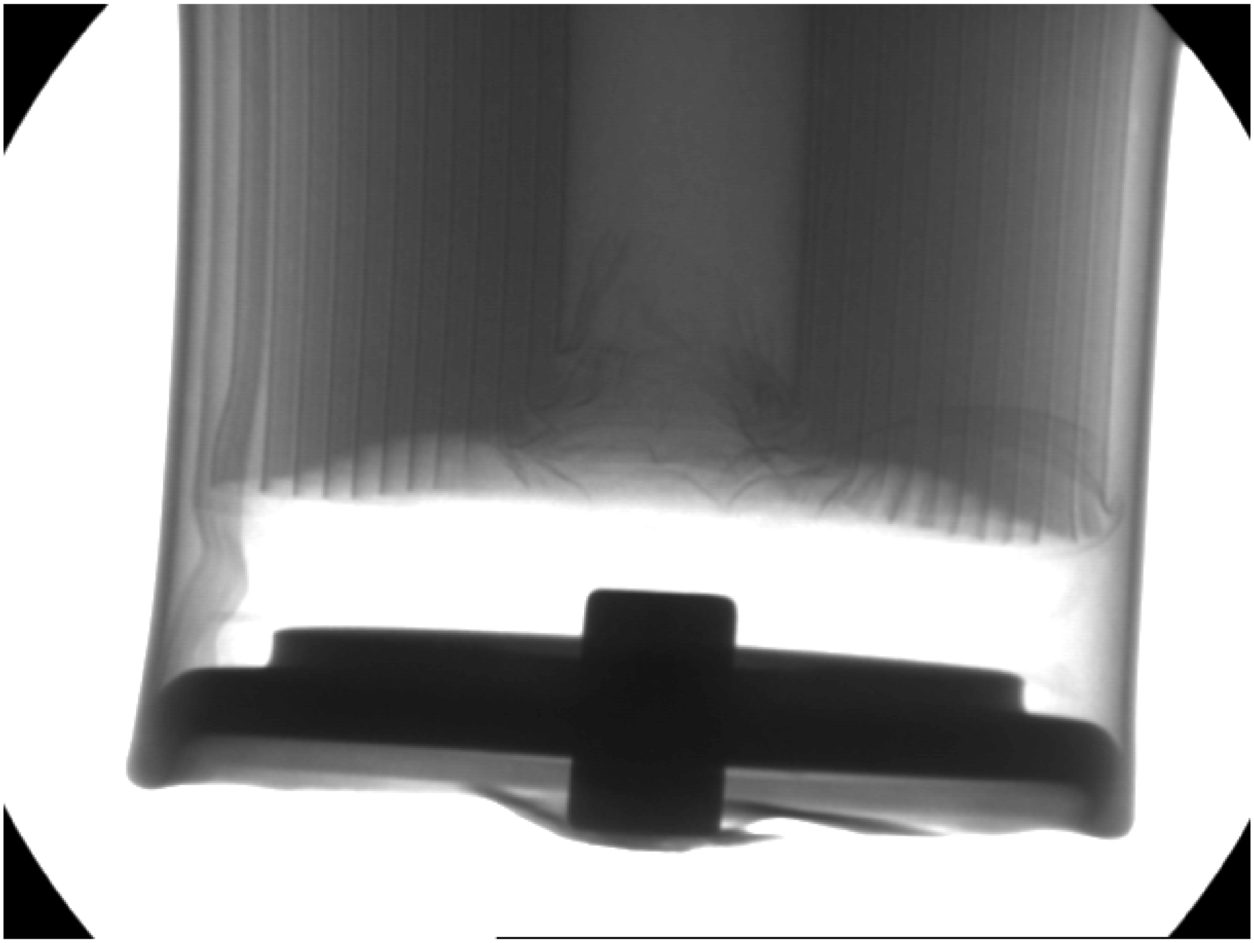

Figure 4: Close-up x-ray of the anode of the second failed cell

The x-rays shows that the wound core of the cell mechanically yielded (crushed). The damage is most noticeable at the anode but the cathode end of the core shows a “flattening” in shape. This damage is typical of a body that experiences a setback or setforward acceleration relative to another body. Put another way, the core has moved relative to the case of the cell.

The case of the cells showed no noticeable mechanical damage other than the wrapper being torn off – probably as a result of trying to remove the cells from the RTV. There was no mechanical crushing or other noticeable damage. The x-rays of the cells confirm the lack of noticeable outer damage.

2.2 Cell Performance

When used in a lateral configuration, a set of cells was able to survive eleven high-g shots. Using the data collected during that test series, we can evaluate the battery discharge against previously-collected discharge data taken with a 100mA constant current load that simulates the load of the unit. For this exercise, we assume that we run the unit for 5 minutes per test. This is an educated guess based on recorded data. (It is a very good estimate.) The table below lists all of the tests that the cells experienced.

Table 2 : Lateral shock test parameters

Test #	Nom g	Nom Duration
1	2000	400
2	6000	250
3	10000	160
4	2000	400
5	6000	250
6	10000	160
7	7000	140
8	14000	110
9	21000	75
10	7000	140
11	14000	110

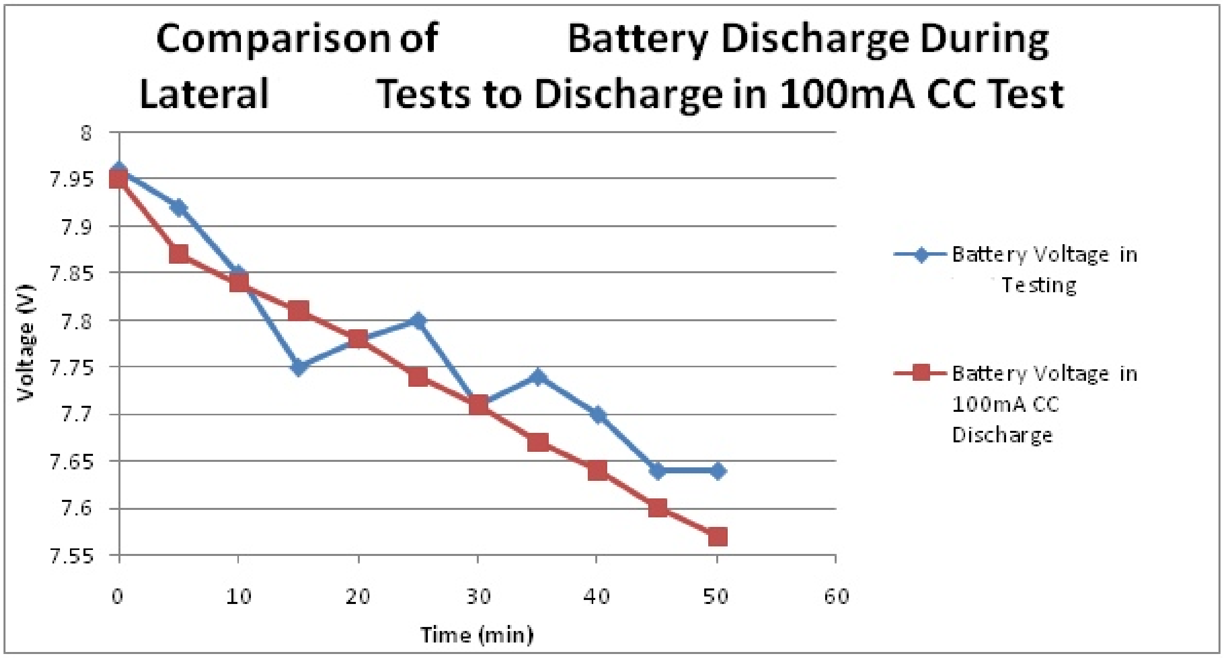

Figure 5: Comparison of battery voltage during high-g testing to ideal discharge curve

From the chart we can see that the batteries in the high-g testing discharged relatively in-line with what is expected from the lab testing of the batteries under a 100mA constant current load. ***From this we conclude that in the lateral direction, shock impact has little effect on the capacity or output voltage of the batteries.*** Of course, the caveat is that this is based on high-g testing of one pair of cells over eleven experiments. There is no data to say that the batteries wouldn't undergo catastrophic failure on the 12th test or that some other type of shock other than that delivered by this testing machine wouldn't produce a loss of capacity due to some damage mechanism.

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3. CONCLUSIONS

From this testing, we concluded that in the axial orientation – the long axis of the cells in the direction of the acceleration or deceleration – these cells have a “preferred” orientation. That is, they survive better in one orientation than the other. However, we found that the axial direction is probably the weakest orientation when compared to lateral orientations. The x-rays of the cells showed that the cell core moved relative to the cell housing which led to the core being crushed and, as a result, the cell failed.

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