

78th Lithium Battery Technical/Safety Group Meeting

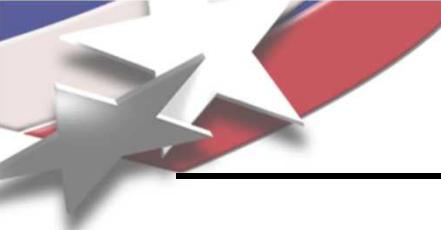
Performance and Abuse Testing of Tadiran TLM-1550 Series Cells/Batteries

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- Requirements Overview
- Battery Design
 - Tadiran TLM-1550 Series Specs
- Electrical Testing Results
- Abuse/Safety Testing Results
- Shock and Vibration Testing Results
- Summary
- Future Plans



Mechanical & Environmental Requirements

- **Package Size**
 - No larger than:
 - 3.00" Long by 3.75" Wide by 2.25" Deep
 - Dimensions of entire package including batteries
 - Package also contains ancillary circuitry
 - Space for cells is approximately 2.5" X 3.5" X 2"
- **Mechanical Shock/Vibration**
 - Capable of withstanding transportation type loads
- **Temperature**
 - **Operating Environment**
 - High: 60 °C
 - Low: -10 °C
 - **Non-Operating Environment**
 - High: 60 °C
 - Low: -25 °C
- **Safety**
 - Present no safety hazards to operating personnel

Electrical Requirements

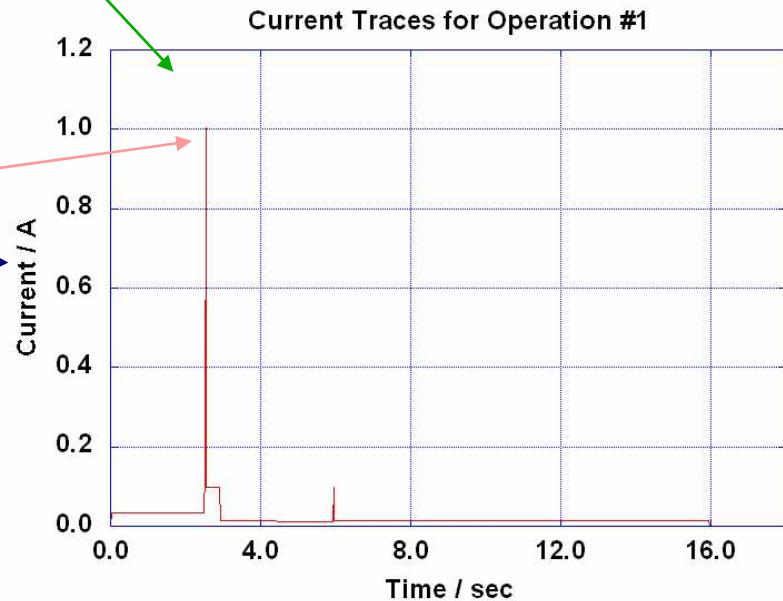
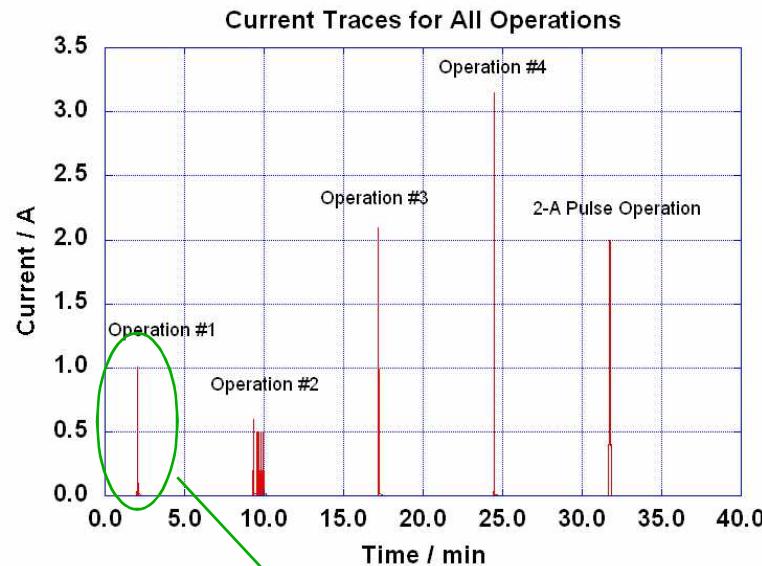
Load Profiles of Operations

- Voltage requirements at open circuit and under load
 - Upper: 32.5 V
 - Lower: 24.7 V
- Five load profiles

Operation #1	
Duration	Load
2.5 s	1066 mW
2 ms	143 mA
34 ms	30 Ω
366 ms	98 mA
3 s	373 mW
12 ms	30 Ω
23 ms	98 mA
10 s	426 mW



Peak Load



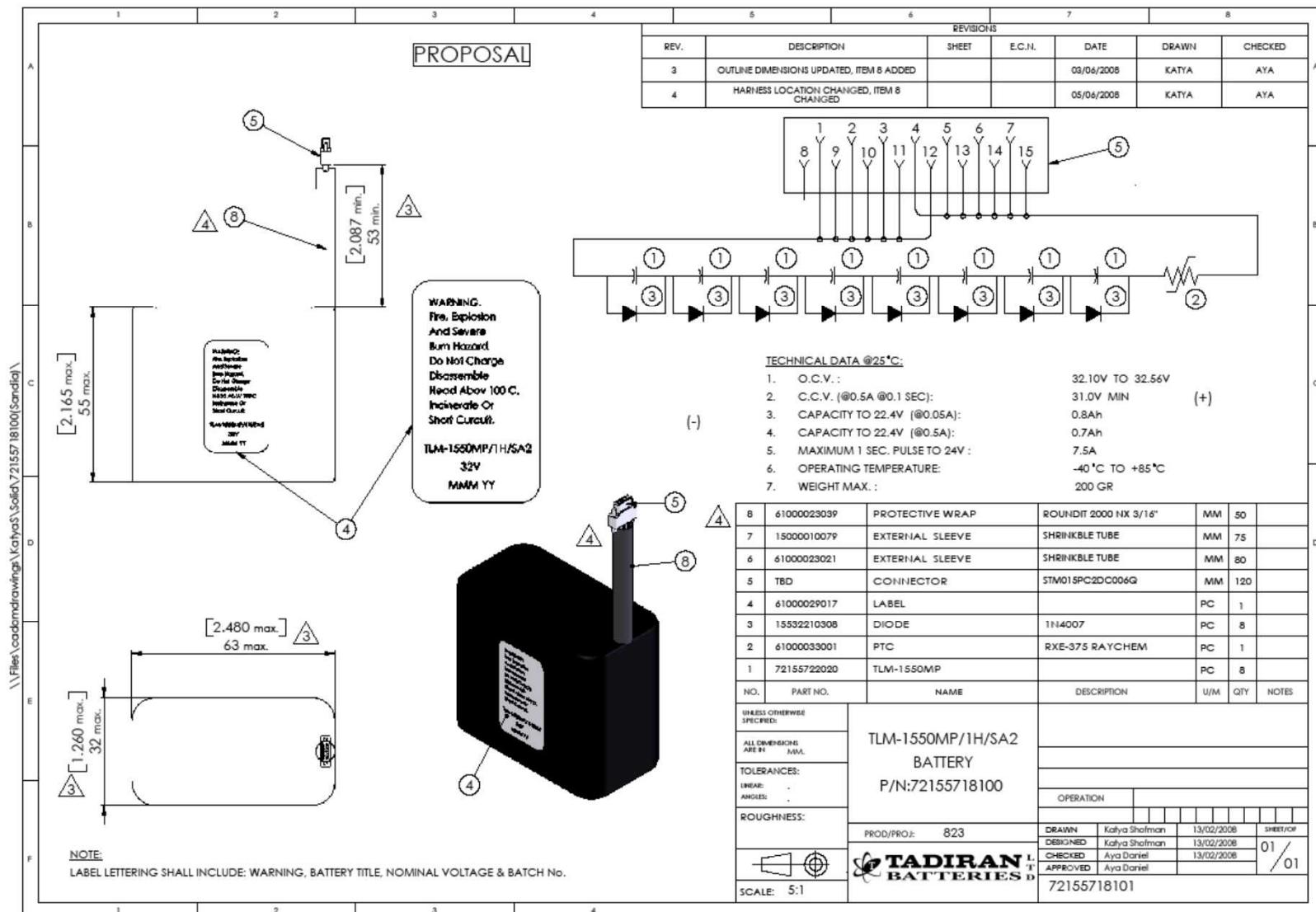
- **Baseline Cell**

- **Tadiran TLM-1550 (AA size cell)**
 - **High Power (HP)**
 - **Medium Power (MP)**
- **Li-CoNiO₂ primary cells**

- **Baseline Battery Design**

- **1x8 Series Configuration**
 - **32 V**
- **Size of 1X8 Series Configuration**
 - **2.17" Long by 2.48" Wide by 1.26" Deep**

Tadiran Manufacturing



Tadiran TLM-1550 Specs

- **Physical Characteristics - AA-size**

- Length: 51 +0/-1 mm
- Diameter: 14.8 ± 0.3 mm
- Weight: 20 g max



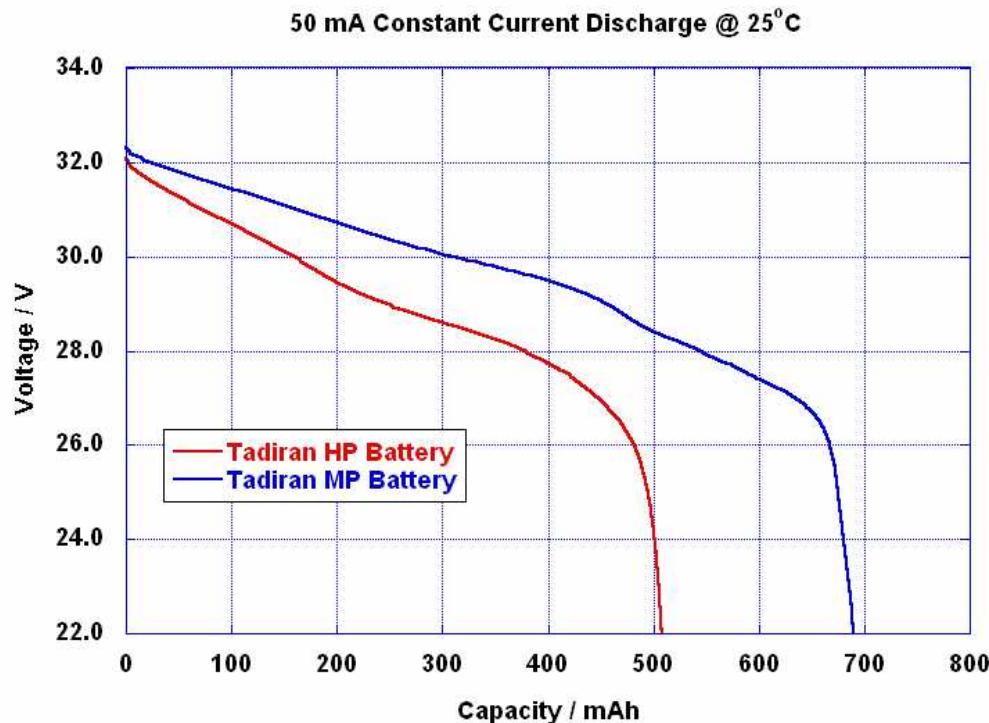
- **Electrical Characteristics**

- OCV of 3.95 - 4.07 V
- Operating voltage of 4.00 - 2.80 V
- Max discharge current
 - Continuous: 5 A
 - Pulse: 15 A
- Nominal Discharge Capacity at 50 mA @ RT to 2.8 V
 - HP Series: 550 mAh
 - MP Series: 800 mAh

- **Safety Characteristics**

- Internal shutdown separator
- External PTC on MP series cells

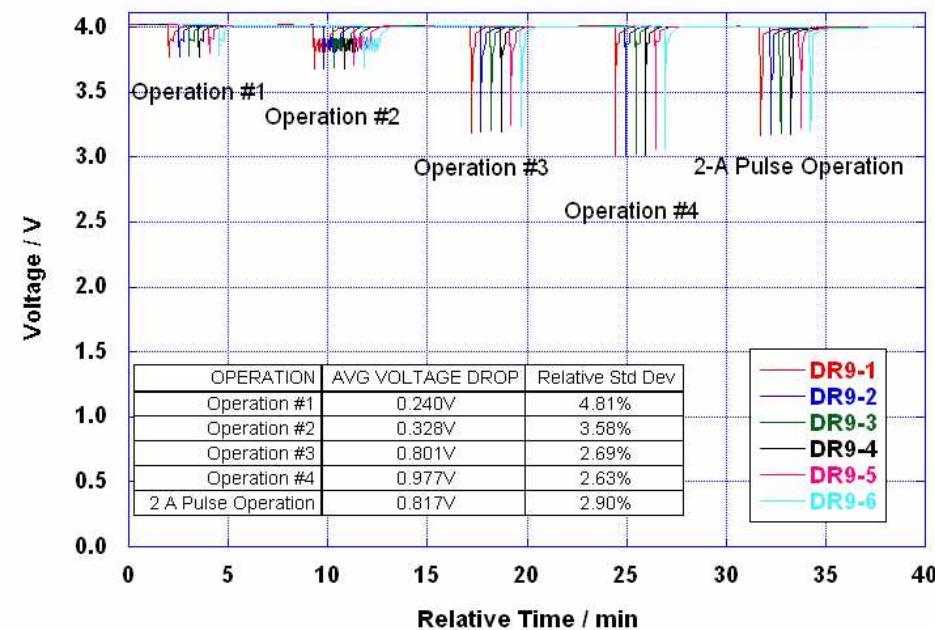
- **Operating Temperature of -40 °C - 85 °C**



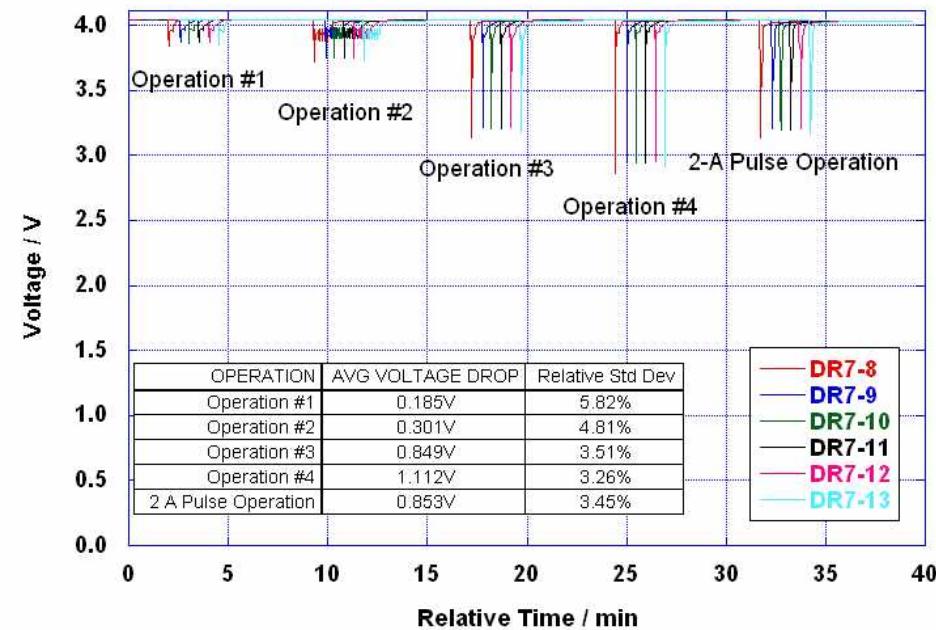
Reproducibility of Tadiran Cells

Tadiran TLM-1550-MP/HP Cells

Tadiran TLM-1550-HP Cell -10°C



Tadiran TLM-1550-MP Cell -10°C
PTC Included in Measurement - Spot Welded

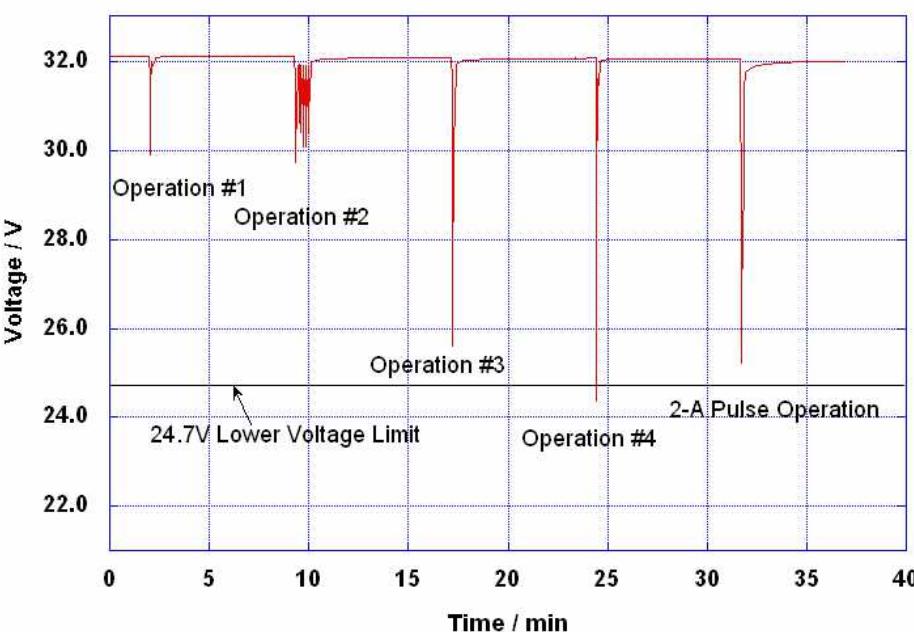


- Evaluation of six cells @ -10 °C
 - All five operations were conducted
 - Allows for assessment of battery voltage drop
- Small relative standard deviation

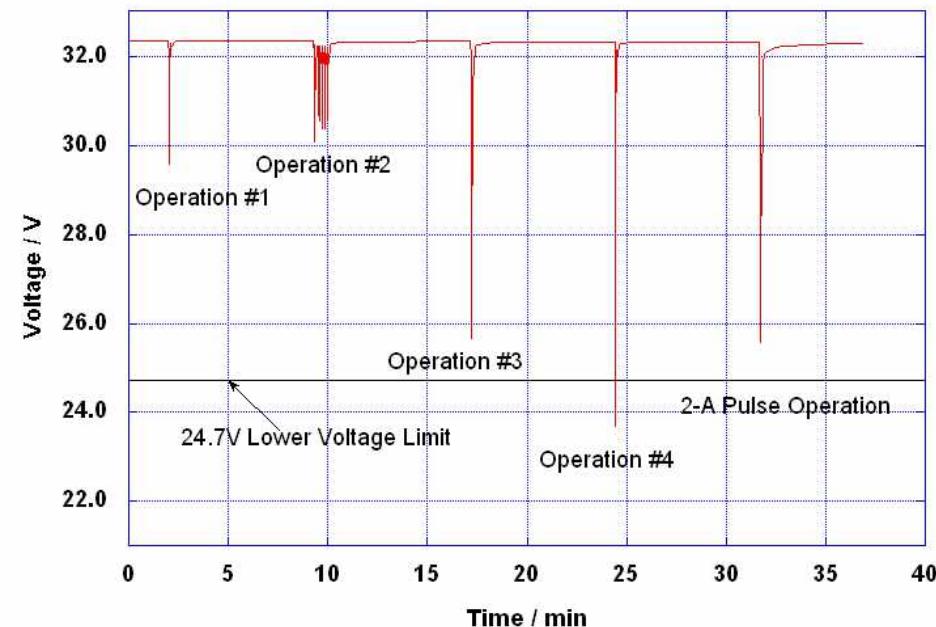
Behavior of Tadiran Battery Packs

Tadiran TLM-1550-MP/HP Batteries

Tadiran TLM-1550-HP Battery @ -10°C



Tadiran TLM-1550-MP Battery w/PTC @ -10°C

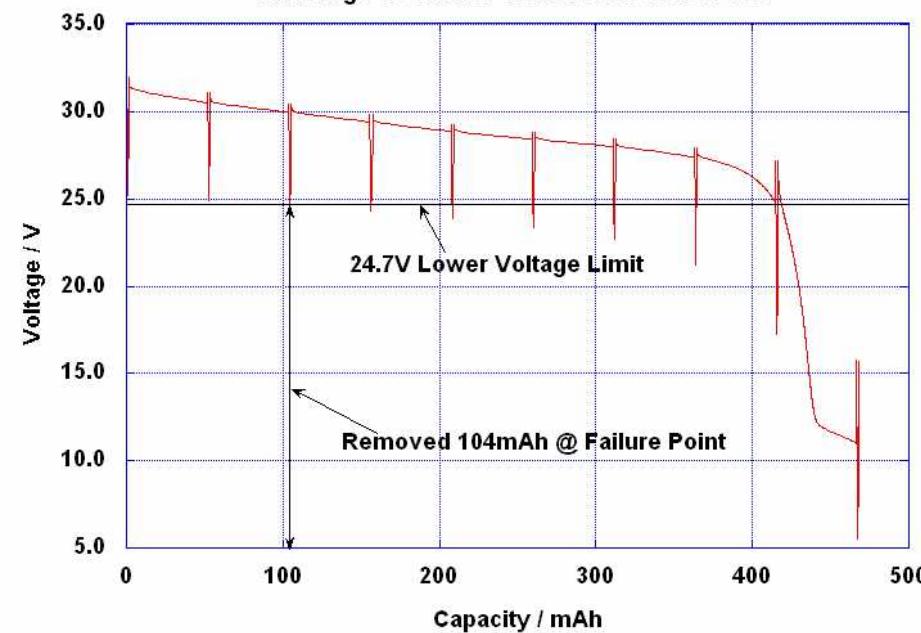


- Evaluation of two battery packs @ -10 °C
 - Battery packs consist of 8 MP or HP type cells in series
 - MP Battery packs incorporate an individual PTC on each cell
 - All five operations were conducted

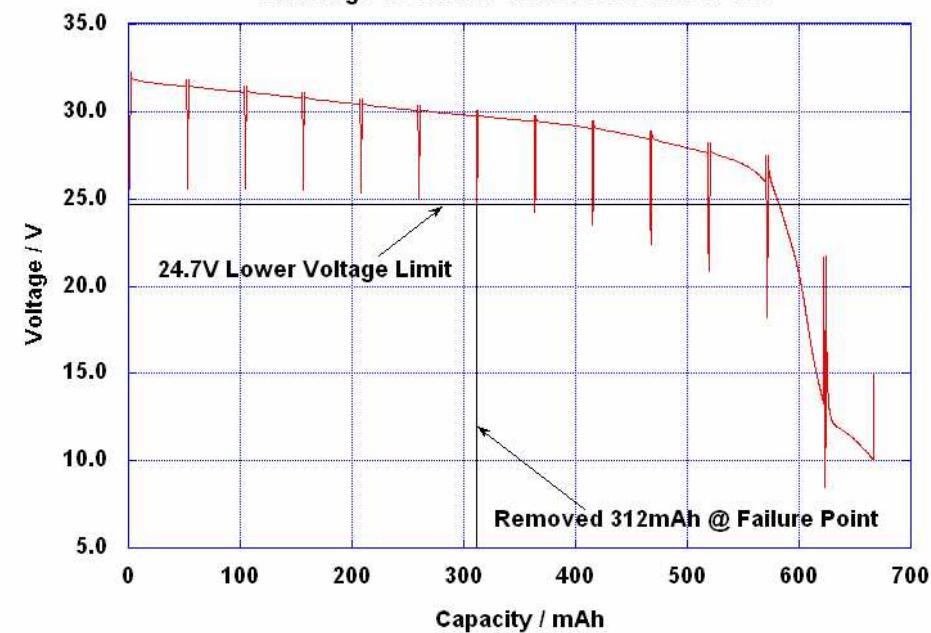
Behavior of Tadiran Battery Packs

Tadiran TLM-1550 HP & MP Batteries

Tadiran TLM-1550-HP Battery @ -10°C
Discharge Test with Periodic 2-A Pulse Profile



Tadiran TLM-1550-MP Battery w/PTC @ -10°C
Discharge Test with Periodic 2-A Pulse Profile

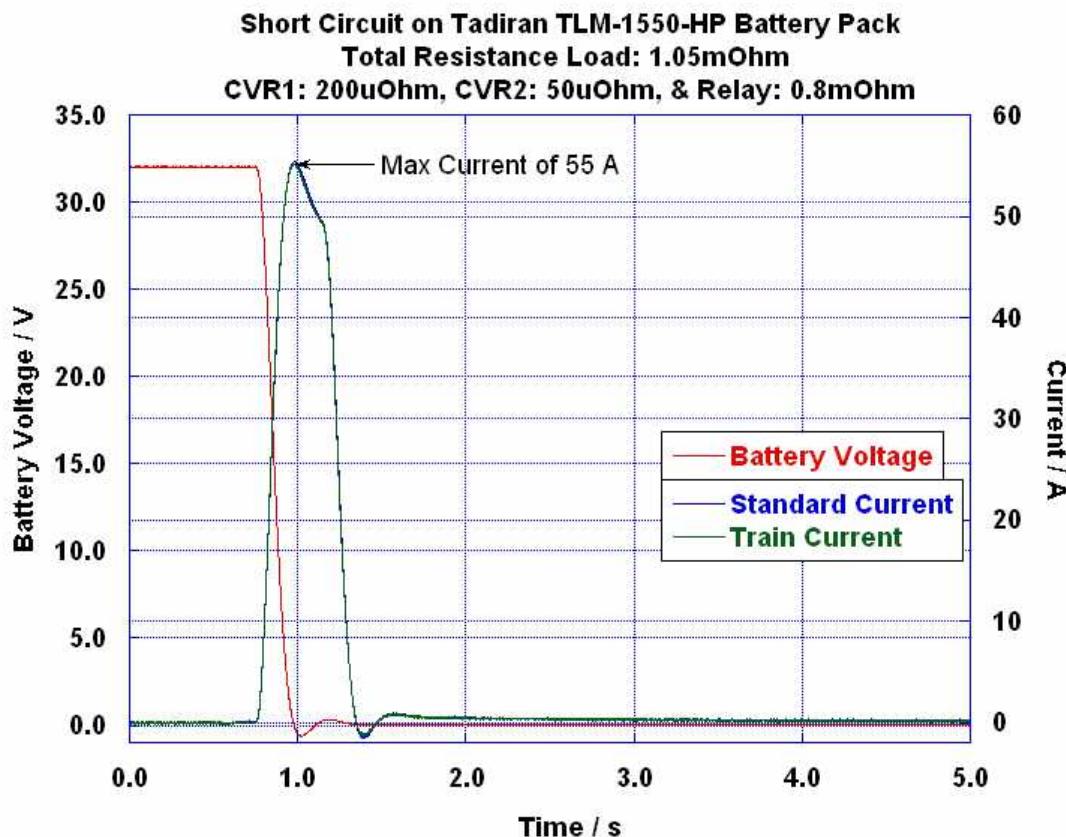


- 50 mA constant current discharge with periodic 2-A Pulse Operation @ -10 °C
- Allows for assessment of max number of operations

Short Circuit Testing

Tadiran HP Battery

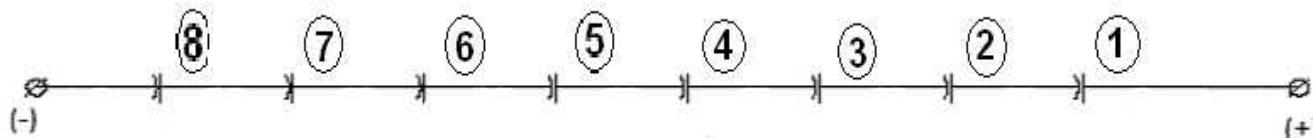
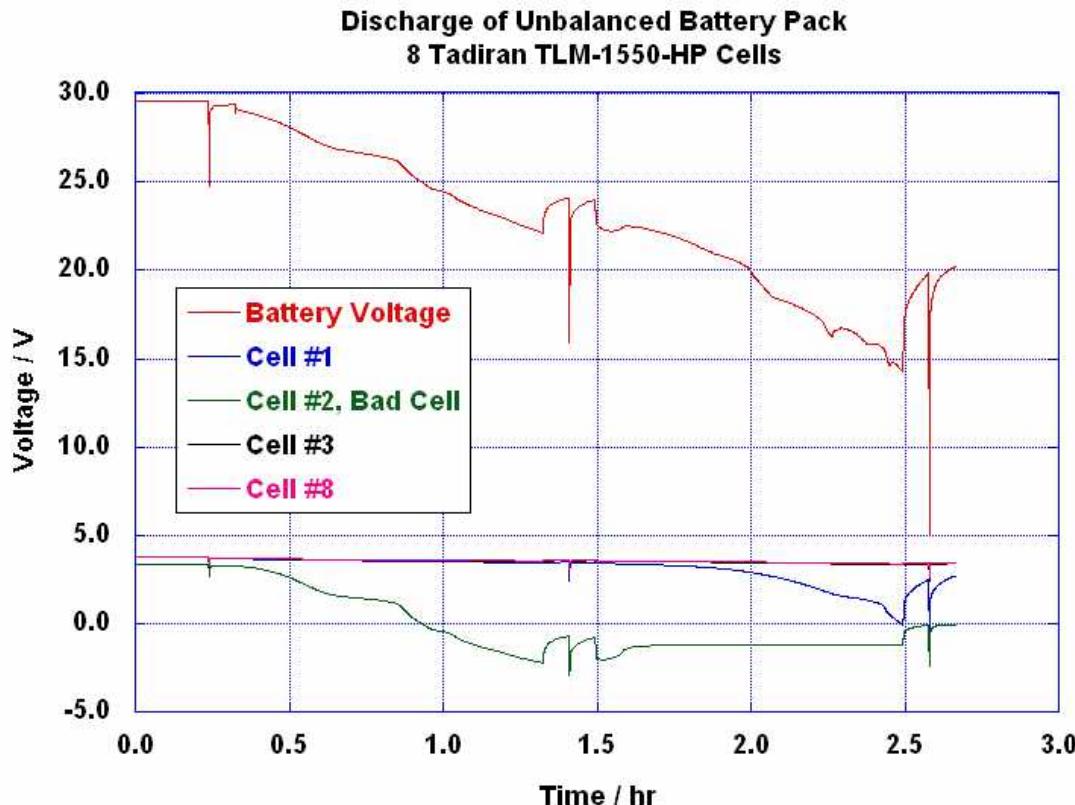
- Short Circuit Test on Tadiran HP Battery Pack
 - Total res. load of 1.05 mOhm
 - Peak current of 55 A
 - One cell Vented and Sparked
 - *No* fire or explosion
 - Battery Voltage Recovered to ~30 V after removal of load
 - Signs of internal safety device
- Second Test was Performed on New Battery
 - Produced equivalent results
 - No cells vented or sparked



Discharge of Unbalanced String

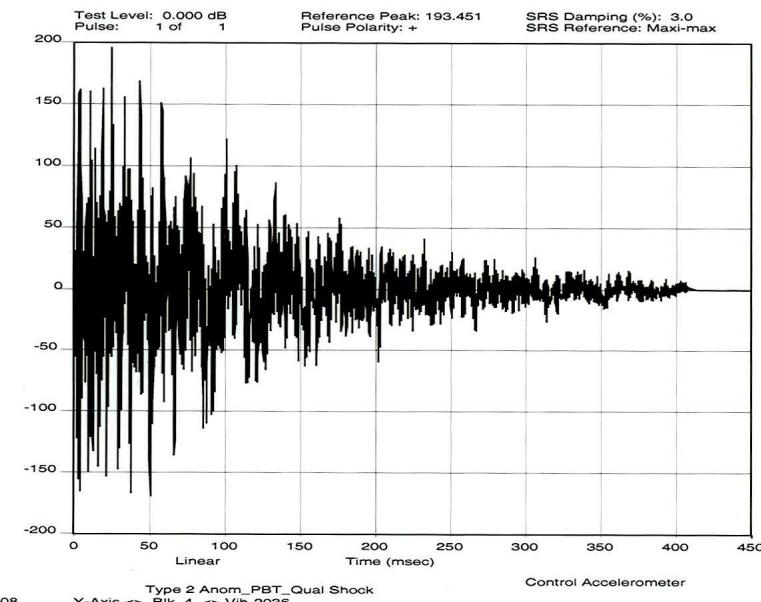
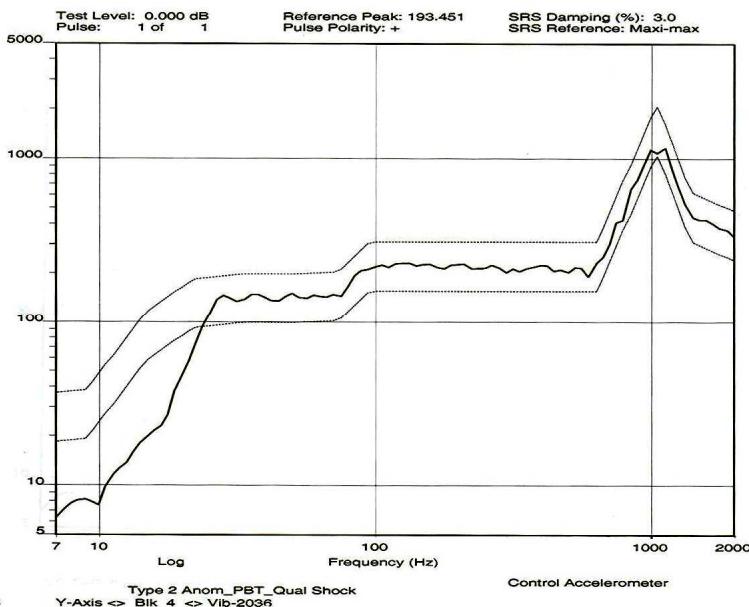
Tadiran HP Battery

- Discharge of Unbalanced Battery String
 - 50 mA discharge with periodic 2-A Pulse Operation
 - 2nd Cell was ~ 90 % discharged
 - Remaining 7 cells were ~ 10 % discharged
- 2nd cell went into reversal
 - -2.9 V
- Battery pack showed no signs of venting



Vibration Testing

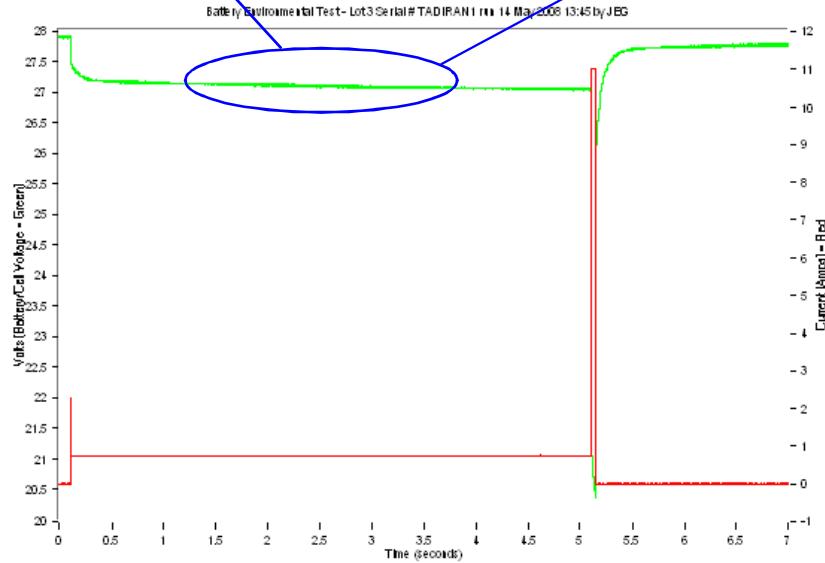
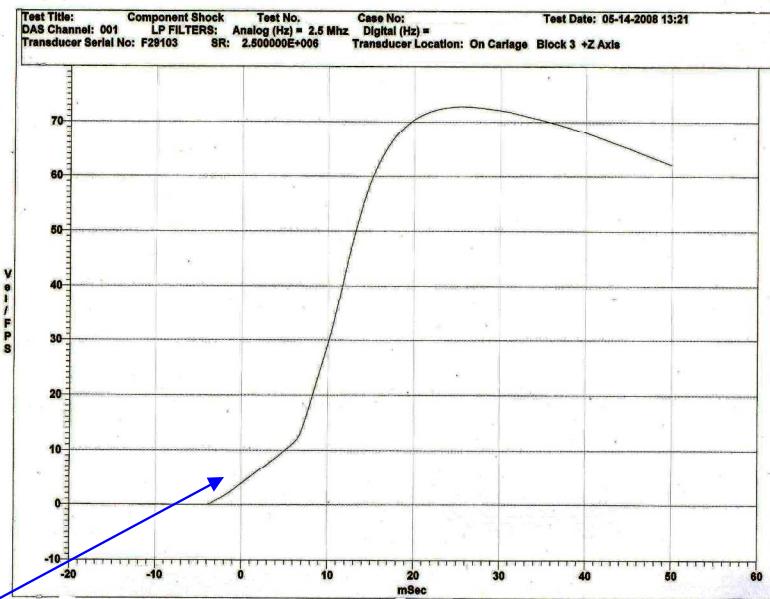
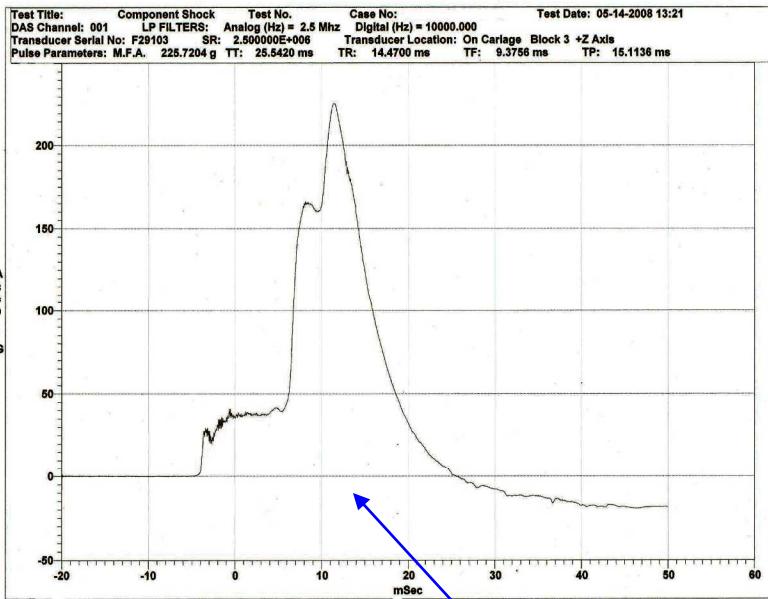
Tadiran HP Battery



- Peak Vibration: 1161 G
- Performed electrical testing after vibration
 - Battery performed as expected

Shock Testing

Tadiran HP Battery



- Amplitude of Shock: 225.7 G
- Duration of Shock: 25.5 ms
- Max Velocity: 72.5 FPS



- Behavioral Characteristics of Tadiran TLM-1550 Cells
 - Both types of Tadiran cells show characteristics of high reproducibility
 - Relative standard Deviation of TLM-1550 HP cells
 - 4.8 % at -10 °C
 - 2.3 % at 25 °C
 - Relative standard Deviation of TLM-1550 MP cells with PTC
 - 5.8 % at -10 °C
 - 2.2 % at 25 °C
- Both types of Tadiran cells/batteries are capable of supporting the three required operations at all temperatures
 - Operations #1, #2, and #3
- Useable Discharge Capacity @ -10 °C
 - ~105 mAh for HP Battery
 - ~310 mAh for MP Battery

- Tadiran cells/batteries showed excellent safety characteristics during abuse testing
 - The shutdown separator was the major influencing factor in the short circuit tests
 - No cells vented while in reversal
- Tadiran cells/batteries were capable of supporting the shock and vibration loads at transportation levels
 - No signs of voltage dropouts

- Continue testing at higher temperature
- Expand abuse/safety tests
 - Over discharge
 - Impact
- Evaluate electrical performance of battery packs built by Tadiran
 - Perform abuse/safety tests on these battery packs