UL 2596 Test Report for Elven Technologies Battery Enclosure: FireGuard Pro

Project Details

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Scope of Report

The document provides detailed analysis of the Torch and Grit test on FireGuard Light in accordance with the UL 2596 standard *Battery Enclosure Thermal Runaway Barriers*. The objective is to verify the material's ability to maintain structural integrity and limit heat/pressure transmission during extreme thermal-runaway events in lithium-ion cells.

Sample Specification

- **Sample ID: Sample B**
- **Thickness: 5 mm**
- **Density / Basis Weight: 0.62 g cm^{-3}**
- **Flexibility: no**
- **Colour: Black**

Test Procedure – BETR

.BETR Test Methodology

The BETR test evaluates how battery enclosure materials perform under thermal and mechanical stress caused by thermal runaway in lithium-ion cells. The test apparatus includes a five-sided steel test box with a fuel package of twenty-five 18650 lithium-ion cells, arranged in a 5-by-5 array (Fig. 2), charged to 100% state of charge (SOC). The cells are driven into thermal runaway using flexible film heaters.

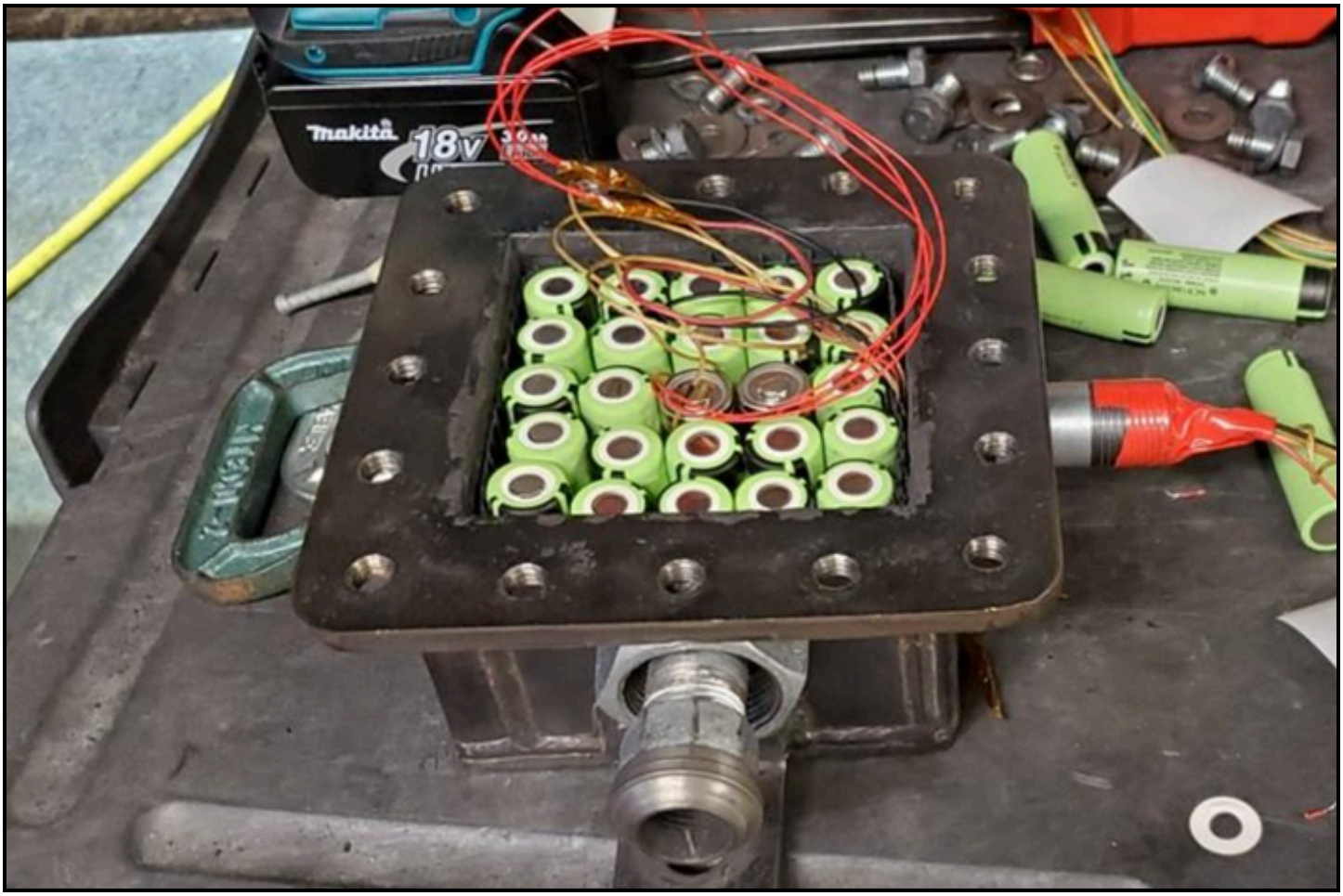

Figure 2:

Arrangement of lithium-ion

cells and test apparatus for

BETR testing.

Photo from UL website.

Test Procedure:

- Install the fuel package inside the test box.
- Secure and seal the test sample onto the open side of the test box.
- Attach a thermocouple to the test sample.
- Initiate the test by heating the film heaters at approximately 6 °C/min.
- Record temperature and pressure data during and after thermal runaway.

- Observe and document any visual changes in the test sample.

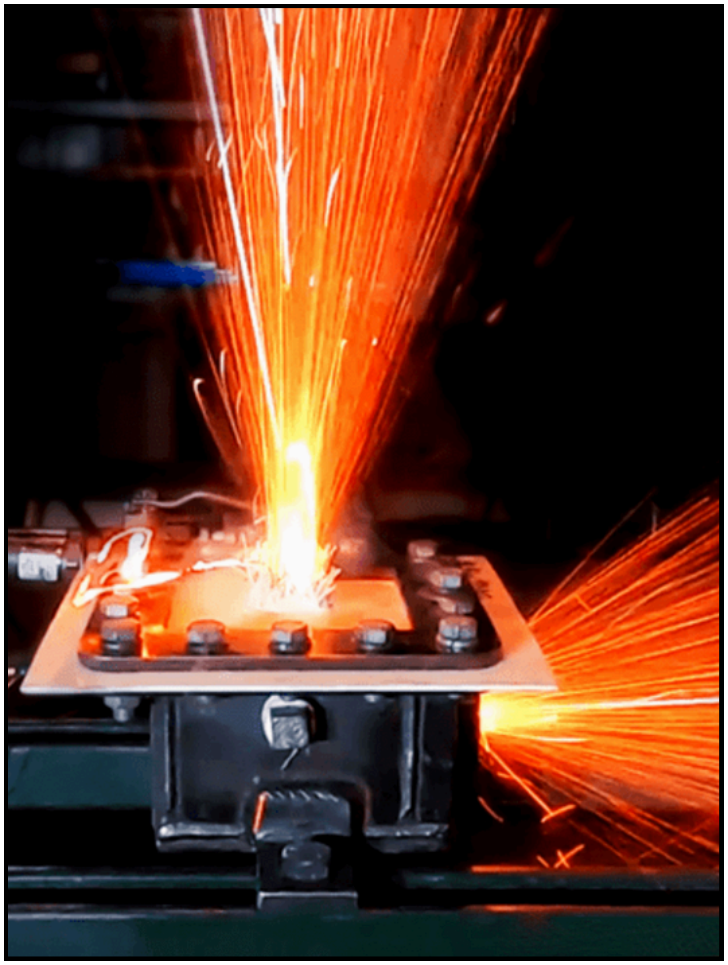

Figure 3: BETR being conducted, heated particles exiting from designated exhaust (side) and damaged test material (top). *Photo from UL website*. *Elven composite is not present in this figure.*

Test Results

The below table summarizes the test results.

Sample	Run	Vent Orifice Size (Target Pressure)	Max Internal Pressure (kPa)	Max Temperature of Battery Cell (°C)	Max Temperature Inside test Enclosure (°C)	Max Temperature Top of Sample (°C)	Observations (Note: Temperature and Pressure measurements charts and photos are included in Addendum "A")
A	1	16mm (250kPa)	233.5	1499.9*	201.4	317.1	**Did Not Breach**
A	2	16mm (250kPa)	261.9	1398.1	265.0	41.9 (TC disconnected by breach)	**Breached**
A	3	16mm	269.9	1228.3	183.4	648.7	**Breached**
B	1	16mm (250kPa)	328.8	1159.3	199.4	294.9	**Did Not Breach**
B	2	16mm (250kPa)	244.4	1499.9*	200.5	298.2	**Did Not Breach**
B	3	16mm (250kPa)	388.0	1499.9*	293.5	294.9	**Did Not Breach**

Key observations — Sample B (BETR)

- **No breaches across all runs: Withstood three BETR exposures without rupture, reaching peak internal pressures of 328.8, 244.4, and 388.0 kPa.**
- **Cool protected side: Cold-face temperatures remained tightly clustered at ≈295–298 °C, limiting the risk of secondary ignition and protecting adjacent components.**
- **Predictable, well-controlled behavior: Venting operated as intended with no side-wall blowout; any damage remained localized with no fragment ejection or sustained cold-face flaming.**
- **Severe-duty validated: Cell thermocouples hit ≈1,500 °C in two runs, confirming performance under worst-case thermal-runaway conditions while maintaining enclosure integrity.**
- **Consistent, repeatable results: Low run-to-run variance in peak pressure and surface temperature supports reliable engineering margins and scale-up.**

Conclusion

FireGuard Pro (Sample B), BETR

FireGuard Pro (Sample B) demonstrated strong BETR performance, completing three runs **without rupture** and tolerating peak internal pressures up to **388.0 kPa** while keeping the protected side near **295–298 °C**. Behavior was controlled and non-violent (no fragment ejection, no sustained cold-face flaming). Within a prudent design envelope of **≤ ~350 kPa** peak pressure, the material is **recommended** as a primary hot-face liner or wrap for battery enclosures to attenuate pressure and limit heat transfer.