National Aeronautics and Space Administration

A Li-Ion Battery Case to Enable High Power Applications (and that can Prevent Thermal Runaway)

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Program: Topic Area

Project Objective:

We are developing an Additively Manufactured (AM) Li-ion battery case that can enable rapid discharge and charge rates by using advanced thermal control features. In addition the goal is to be able to prevent the propagation of thermal runaway should a single cell catastrophically fail.

These goals are being realized by creating a battery case with a highly anisotropic effective thermal conductivity. Specifically, highly thermal conductive pathways (heat pipes) are located between each battery cell and the heat sink, while the cell-to-cell thermal conductance is kept low (see Figs. 1 & 2). The strong thermal link from each cell to the heat sink enables heat to be rapidly dissipated during high power operation, while the weak cell-to-cell thermal coupling will prevent the propagation of a thermal runaway event.

FY18/19 Results:

1. A conservative finite element thermal model of the notional battery case (Fig. 2) was made. It was shown that the heat from a thermal runaway event could be safely dissipated (Fig. 3). Boundary and Initial conditions: Base of case isothermal at 20 C; remainder of case boundaries adiabatic; battery heat load 2x the total chemical energy of an 18650 Li-ion cell dissipated over the course of 20 s. Results: During a thermal runaway event, neighboring cells do not increase more than 10 K in temperature.
2. A unit cell battery case with an embedded heat pipe was designed, fabricated and tested (Figure 4). This demonstrated that a conformal heat pipe can be successfully embedded into an Additively Manufactured (AM) battery case. To show that the heat pipe was operational, the battery case was thermally tested with the heat pipe both in a filled and empty state. When the heat pipe was filled, the thermal conductance was enhanced by approximately one order of magnitude (Fig. 5). It is expected that the conductance can be increased by another order of magnitude with optimization.
3. Other accomplishments:
   - Over 20 heat pipe wick coupons and battery cases were 3D printed out of 4 materials (AlSiMg, Ti6Al4V, 316SS, ABS). These were used to evaluate optimal designs and manufacturability.
   - A test facility was developed and used to evaluate the wick performance of the different wick coupons.
   - A 6-cell battery case design was developed (Figure 6).

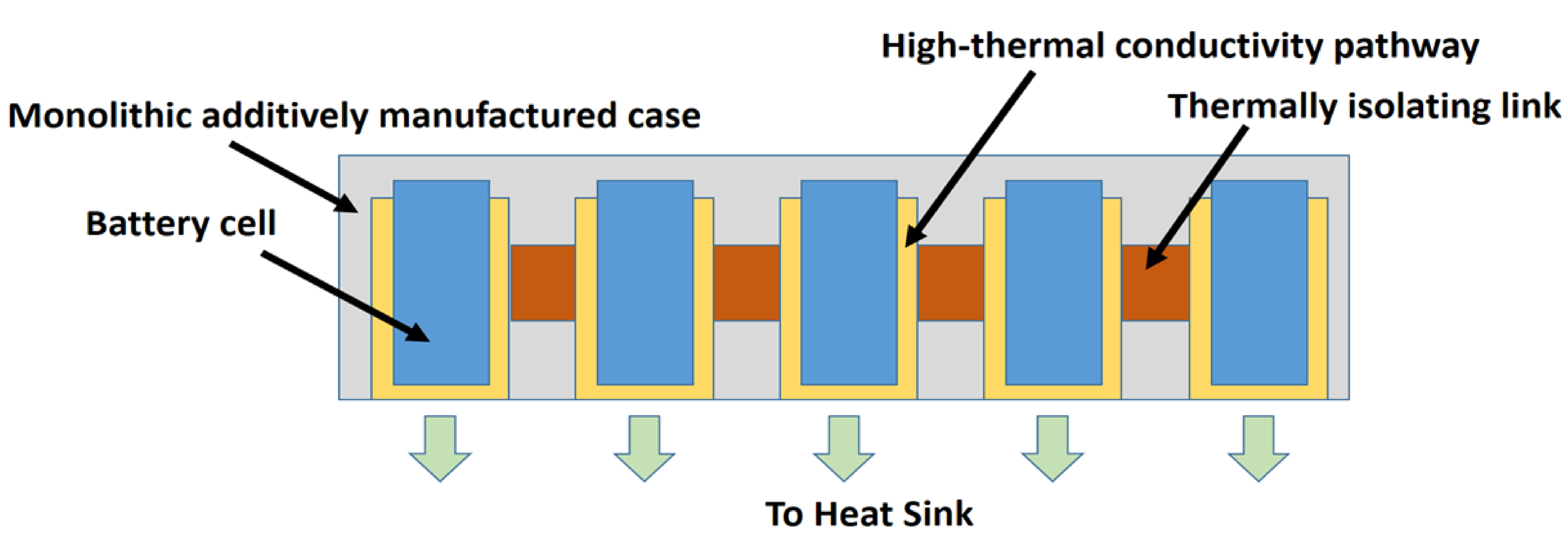

Figure 1: Schematic showing conceptual battery case design

Benefits to NASA and JPL:

A battery case that can enable high power charging and discharging of Li-ion cells could enable a multitude of high power applications such as rotorcraft, extreme robotics and high power lasers. The battery case substantially increases Li-ion battery power density.

A battery case that can prevent thermal runaway would provide an additional level of mission assurance that is currently unavailable.

The current state of the practice at NASA/JPL is to use solid aluminum battery cases. These provide zero protection from thermal runaway events, and are unable to provide the thermal control needed for high power applications.

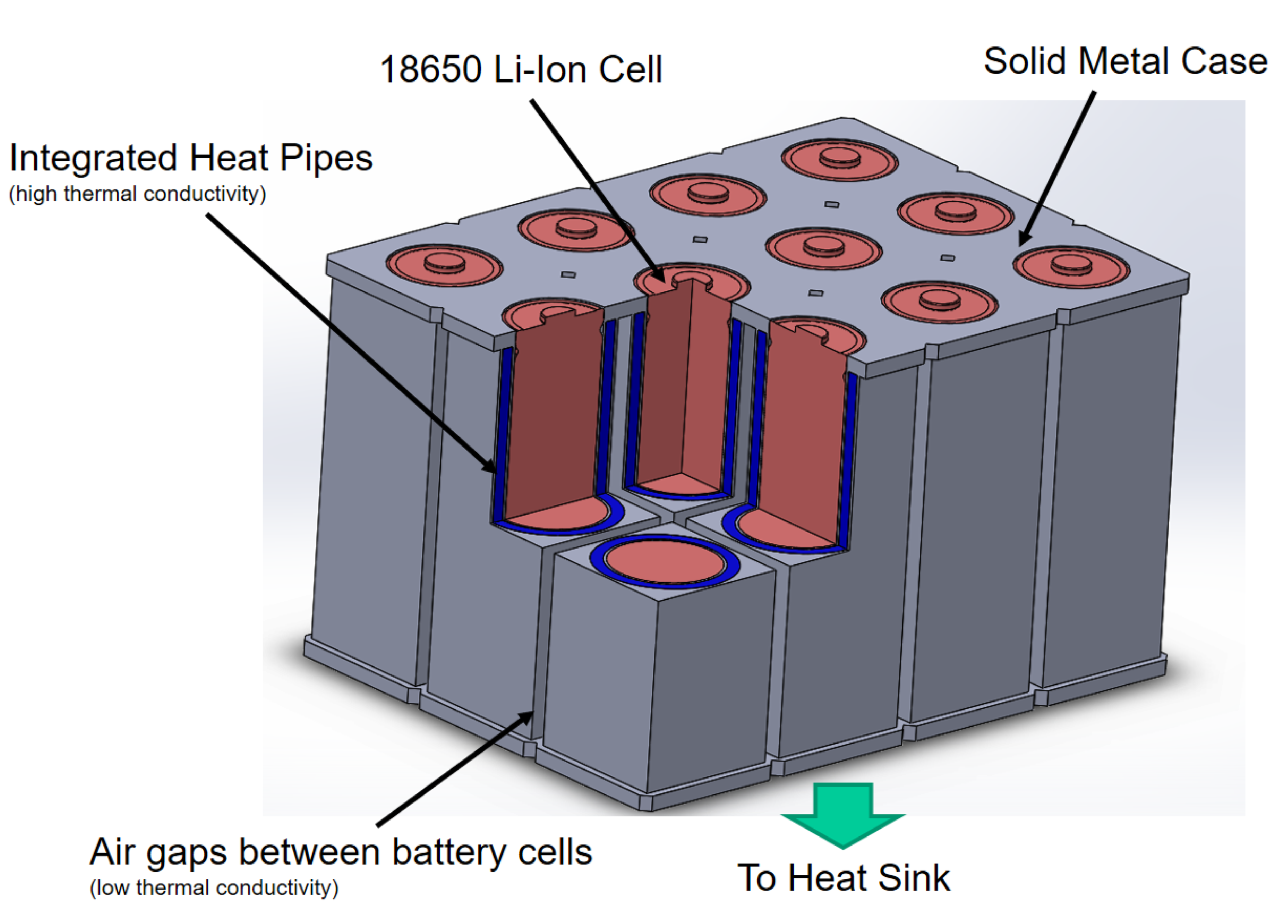

Figure 2: A notional battery case design

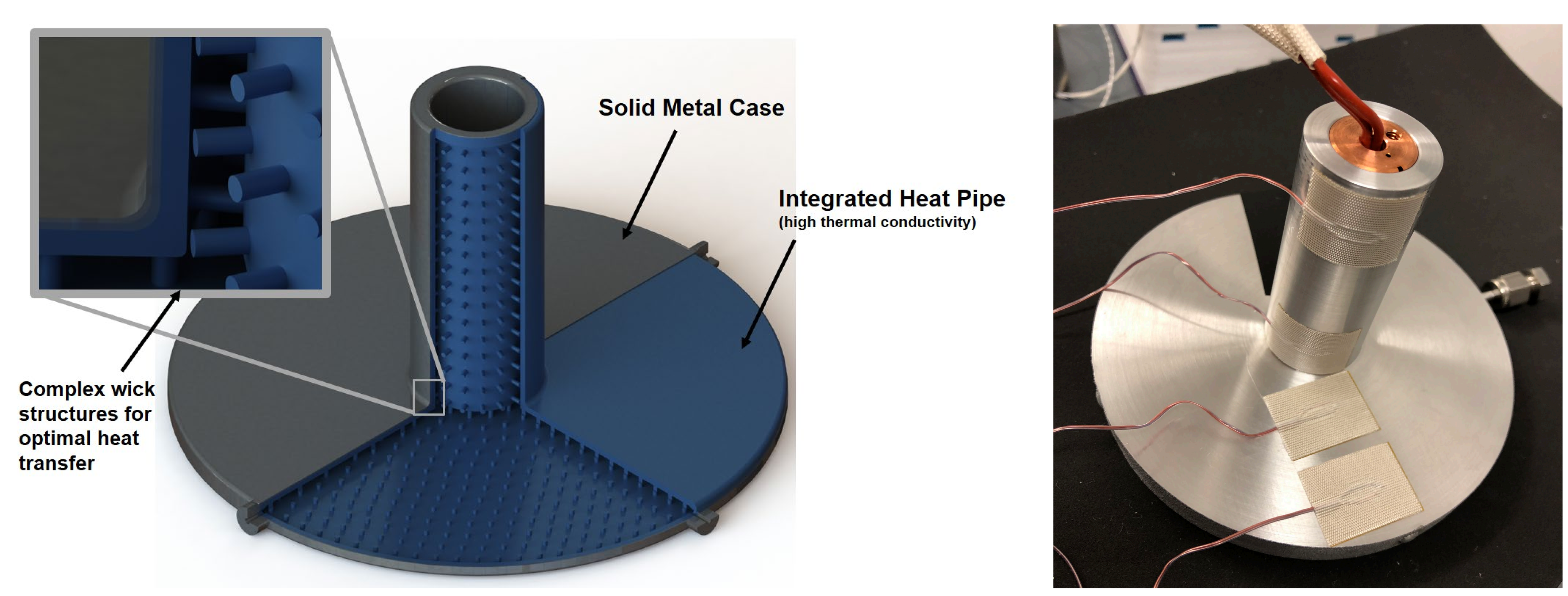

Figure 4: A unit cell battery case CAD (left) and hardware (right)

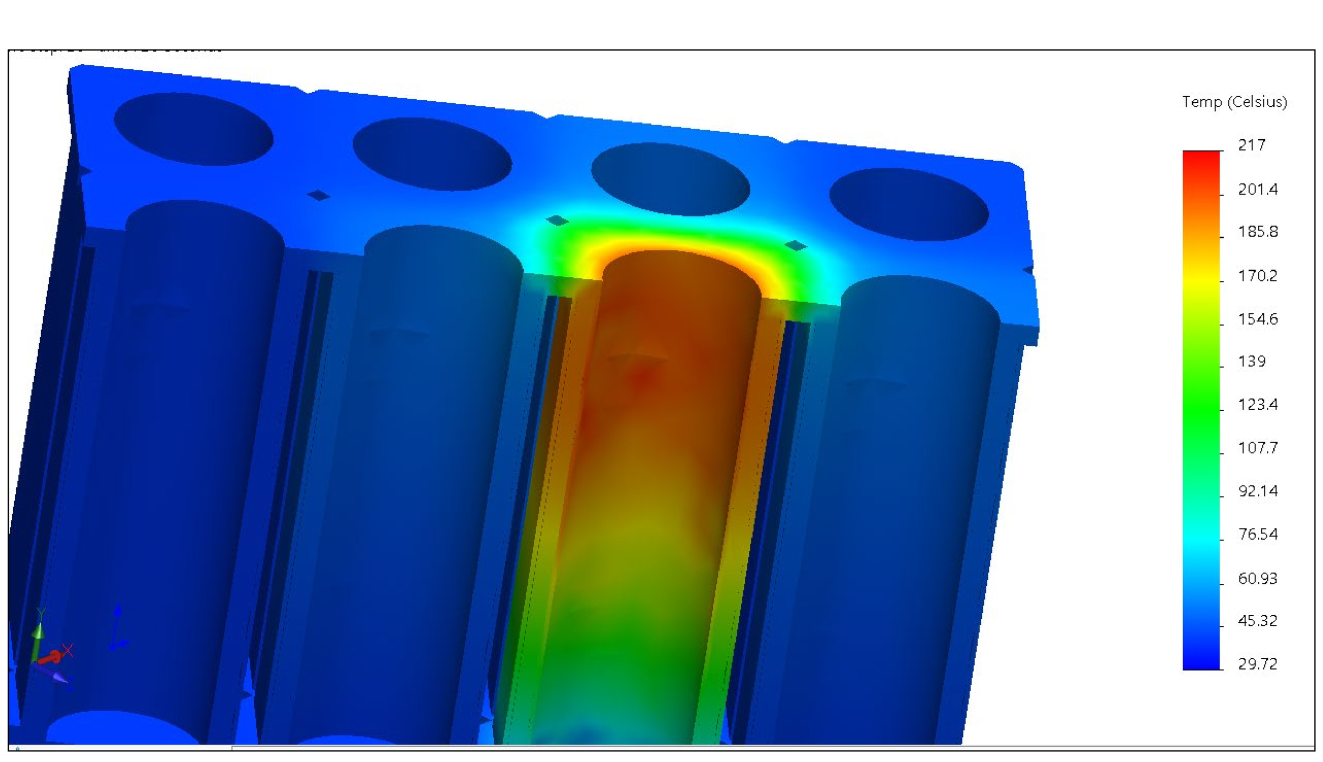

Figure 3: Thermal model of battery case during thermal runaway of a single cell. The cell is dissipating 4.9 kW for 20 s

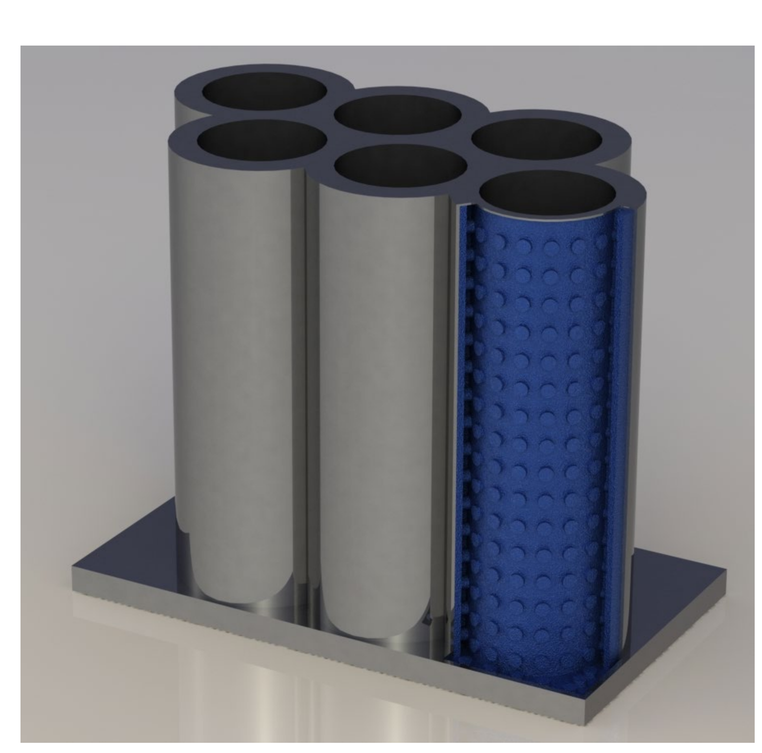

Figure 6: CAD for a partially optimized 6-cell case design

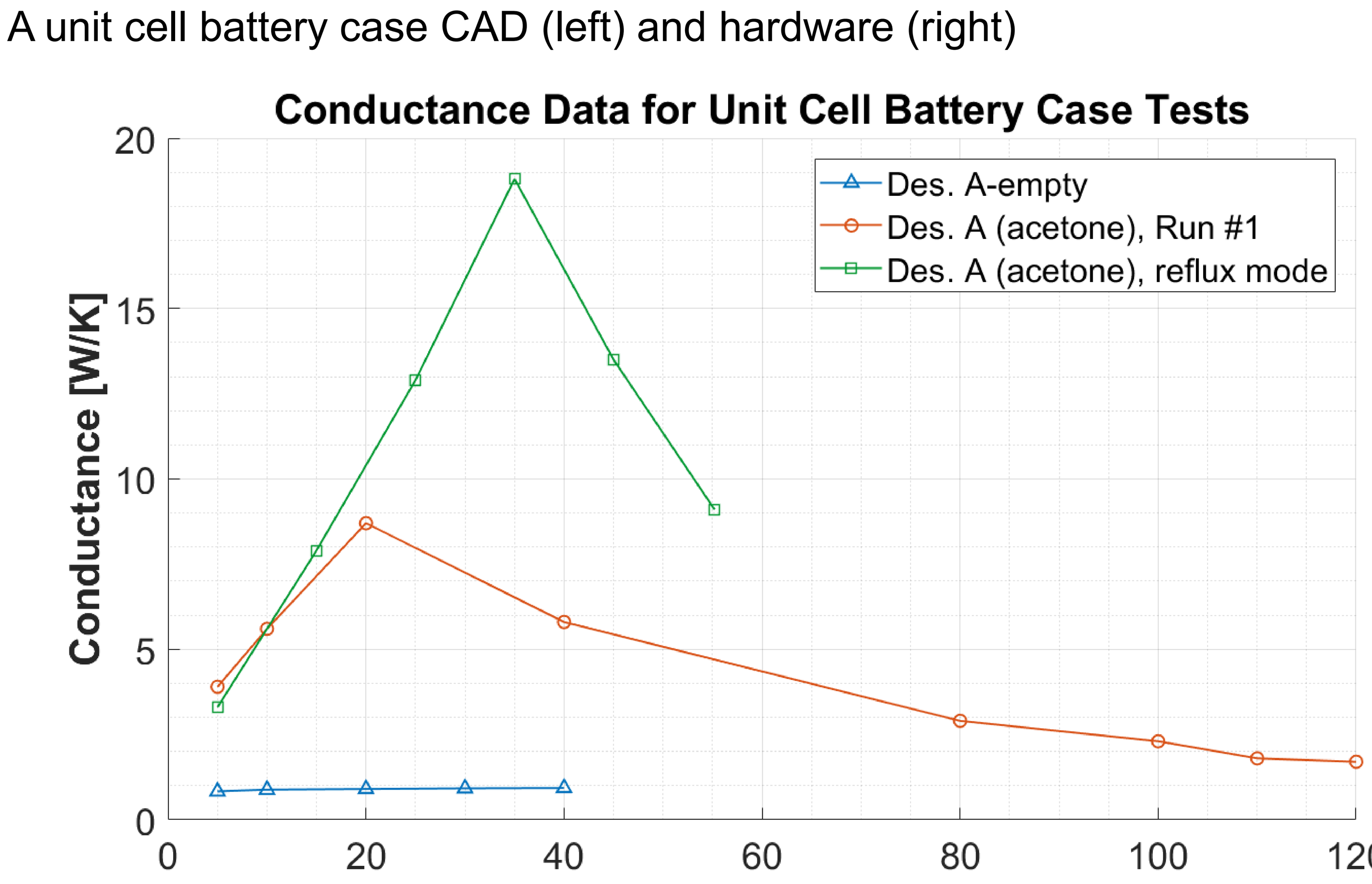

Figure 5: Thermal test results from the unit cell battery case

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Publications:

Furst, Ben, Kumar Bugga, Scott Roberts, Abhijit Shevade, Eric Sunada, Eric Darcy. An Additively-Manufactured Li-Ion Battery Case that Prevents Thermal Runaway (presentation). Interagency Advanced Power Group (IAPG) Safety Panel. September 24-26, 2019.

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