Characterization of the Thermal Conductivity of Materials in Energy and Thermal Management Applications

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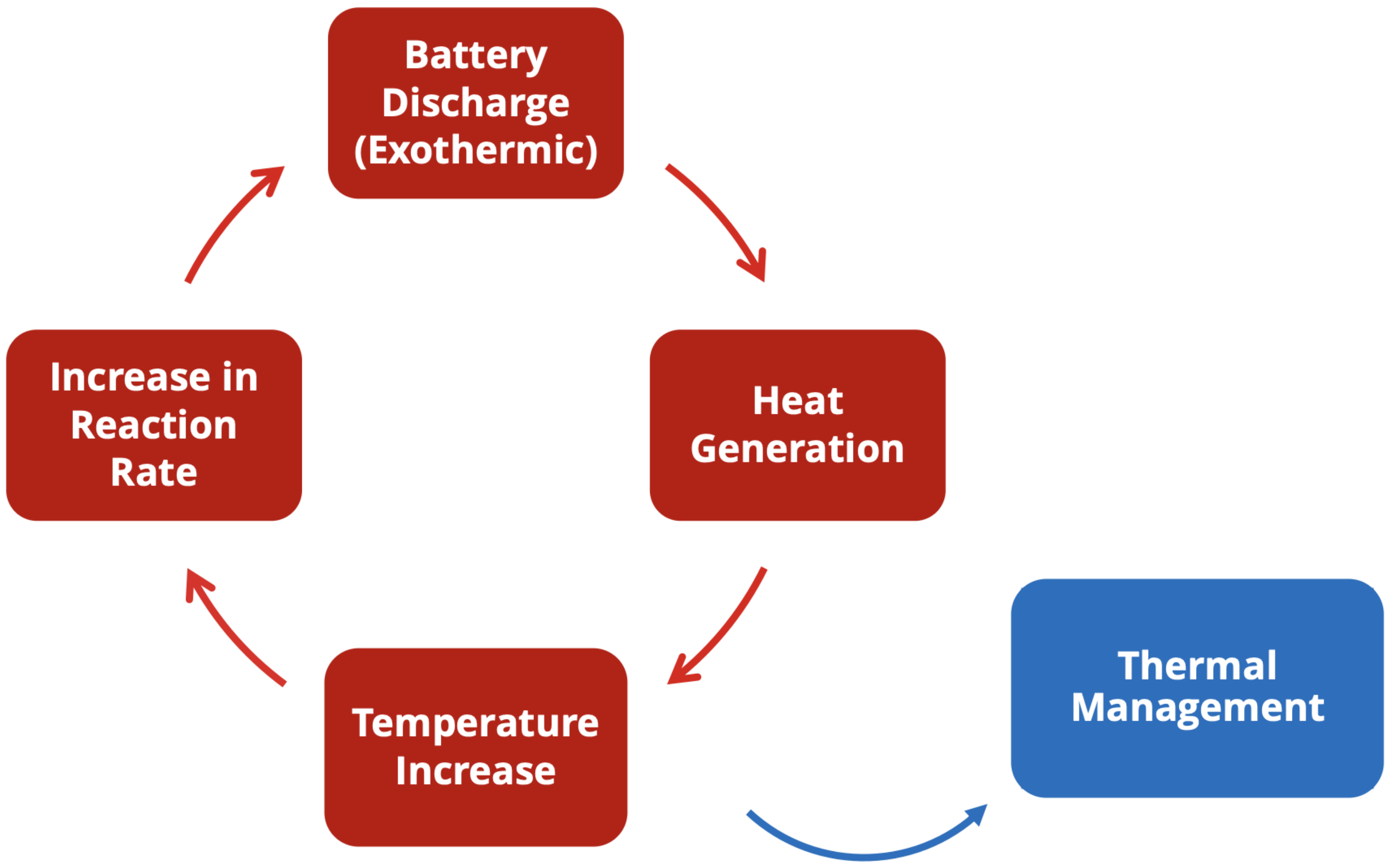
Battery Thermal Runaway: Basic Mechanism



Thermophysical Properties Dictating Thermal Behaviours

k/λ

- Thermal Conductivity:
  - Ability to transfer (conduct) heat
  - Units (W/m·K)

C_p

- Specific Heat Capacity:
  - Ratio of heat input versus temperature change
  - Units (J/kg · K)

α

- Thermal Diffusivity:
  - How quickly (speed) heat diffuses
  - Units (m^2/s)

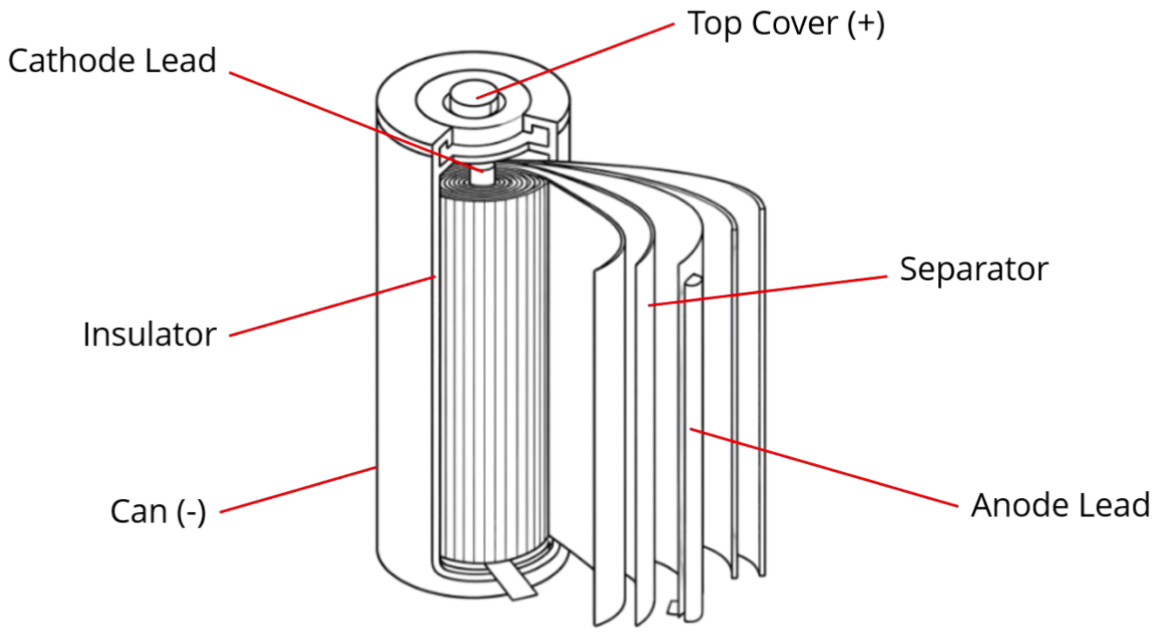
Relationship Between Properties

$$\alpha = \frac{k}{\rho C_p}$$

Where:

ρ = density, C_p = specific heat capacity

Battery Cells – Individual vs Bulk Considerations



A battery is a multicomponent system:

- Separators
- Insulators
- Current collectors
- Cell Can
- End Caps/Terminals

The Trident Instrument

Multi-method system for thermal property characterization

TRIDENT

1 instrument, 4 methods for

Thermal Conductivity (k)

(It's better to have options.)

AVAILABLE METHODS

- **MTPS** GUARD RING TECHNOLOGY
- **FLEX** TRANSIENT PLANE SOURCE
- **NEEDLE** TRANSIENT LINE SOURCE
- **THW** TRANSIENT HOT WIRE

TPS Utilities Overview

TPS adapts to material geometry through specialized utilities.

Anisotropy

- Battery anisotropic separations

Slab

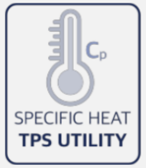
- Current collectors
- Outer can
- Busbars

Thin Films

- Insulators
- Separator Films

Single-Sided

- Bulk battery



Cp

- Battery heat capacity

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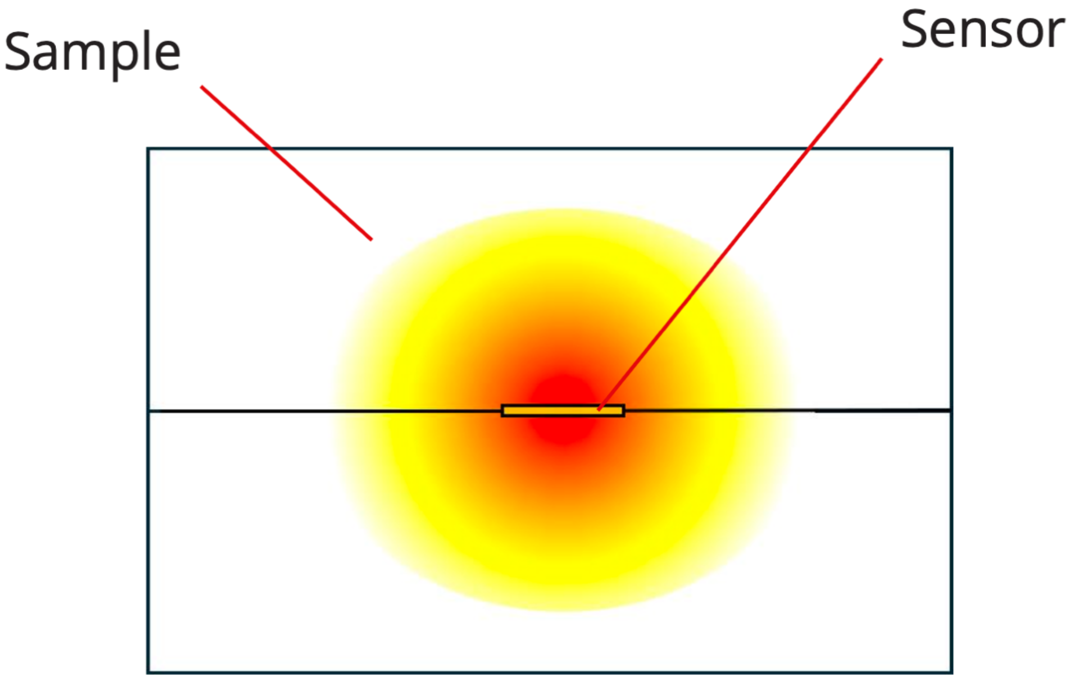
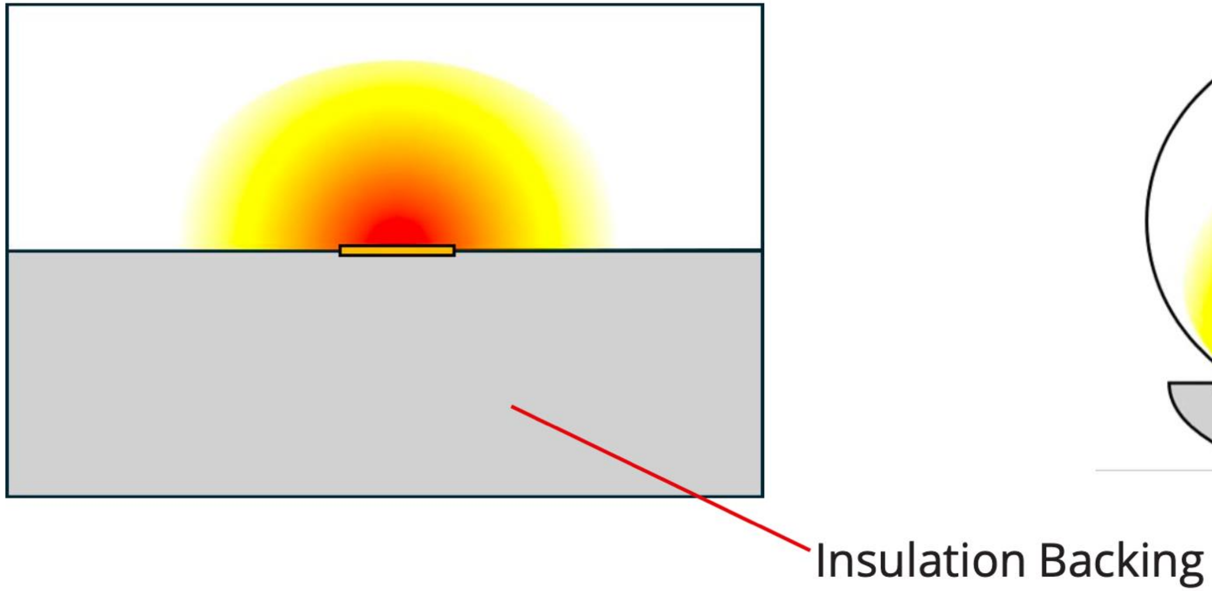
TPS General Principles – Conventional Setup

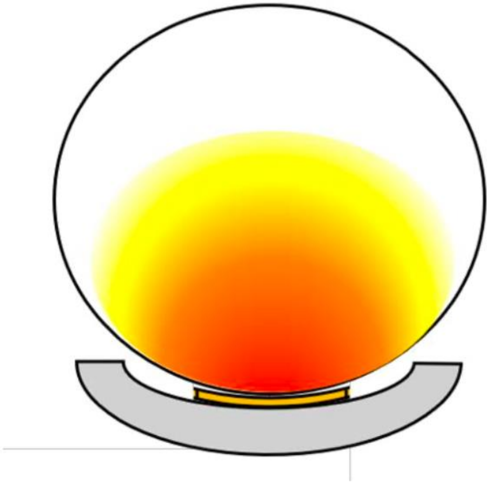
- The sensor doubles as an ohmic heat source and resistance thermometer.
- Temperature-time data fit into a mathematical model to derive thermal properties.
- Anisotropic separation is possible if heat capacity is known.



$$\Delta T(\tau) = \frac{P_0}{\pi^{\frac{3}{2}} r \cdot k} \cdot D(\tau)$$

Single-Sided Configuration for TPS



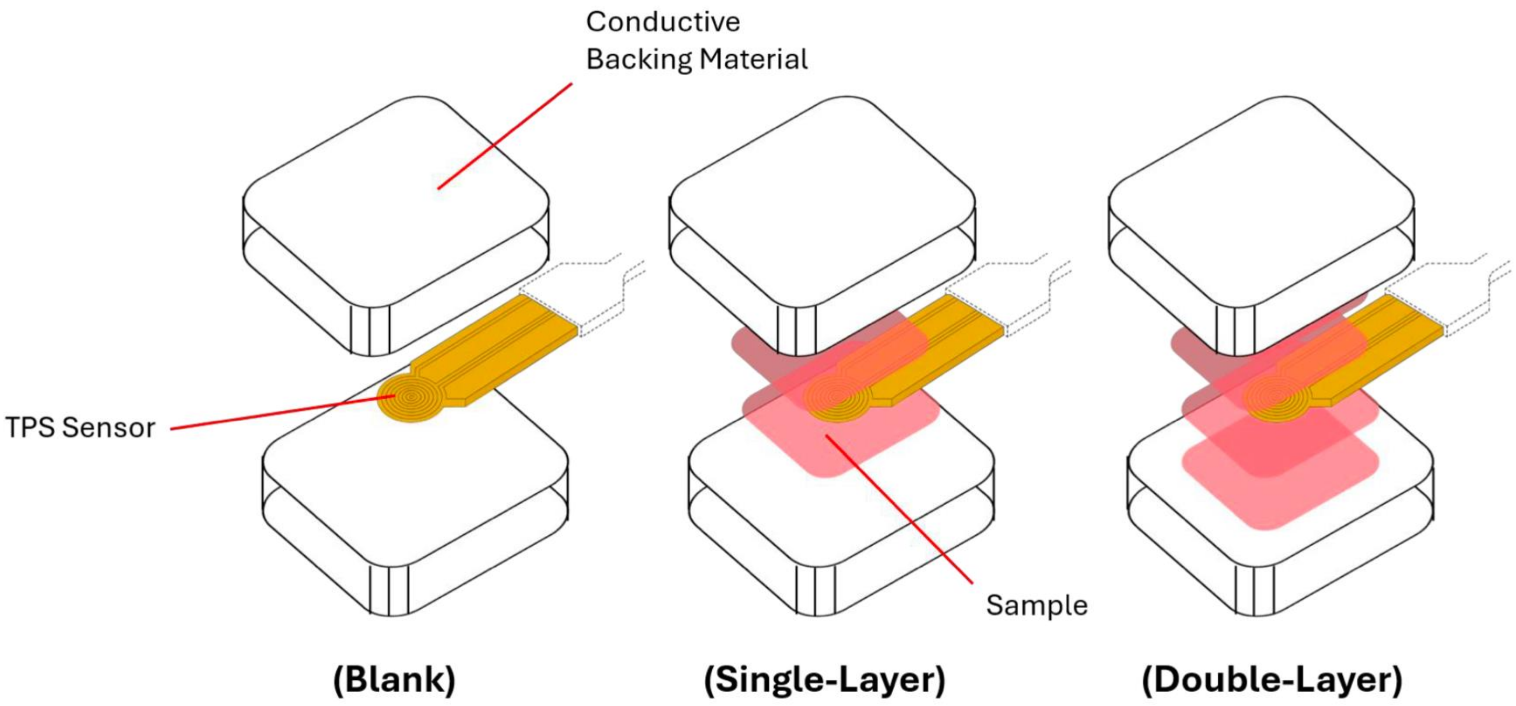


- Asymmetry is rectified through the introduction of the correction factor S:

$$\Delta T(\tau) = \frac{S \cdot P_0}{\pi^{\frac{3}{2}} r \cdot k} \cdot D(\tau)$$

TPS Thin Films – General Principles

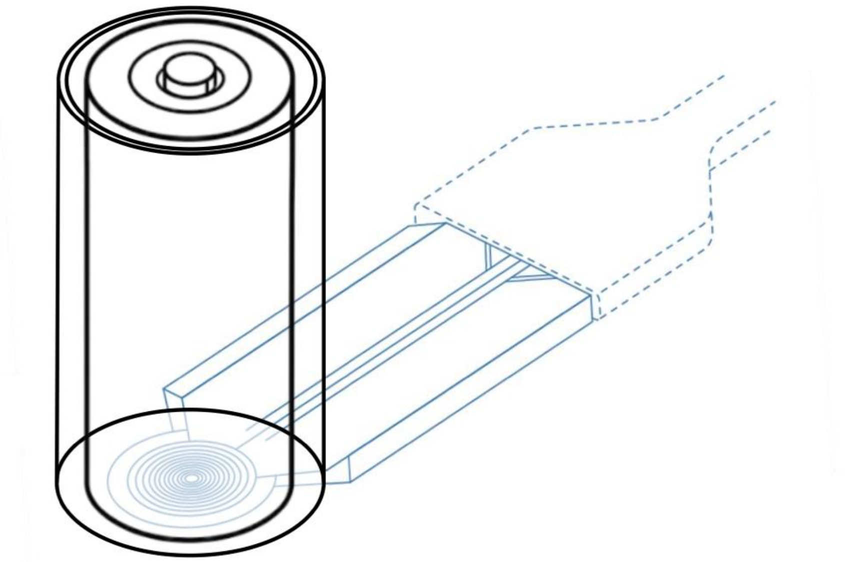
- Layering approach used to account for thermal contact resistance.
- Through-plane k derived from measured thermal resistance.



$$q = 2k \cdot (\frac{\Delta T_{eff}}{\delta})$$

TPS C_p Utility – General Principles

- Sample contained within the aluminum cell enclosure.
- Cell-sample assembly enclosed within insulating material to simulate adiabatic conditions.
- Heat capacity derived through temperature-time data.



$$P_{in} = mC_p \frac{dT}{dt} + f\left(\frac{dT}{dt}\right)$$

Application Highlights

Let’s see Trident in action.

Battery Cell Specific Heat, TPS Cp Utility

Non-destructive Cp measurement of intact lithium-ion pouch and cylindrical cells

Why It Matters

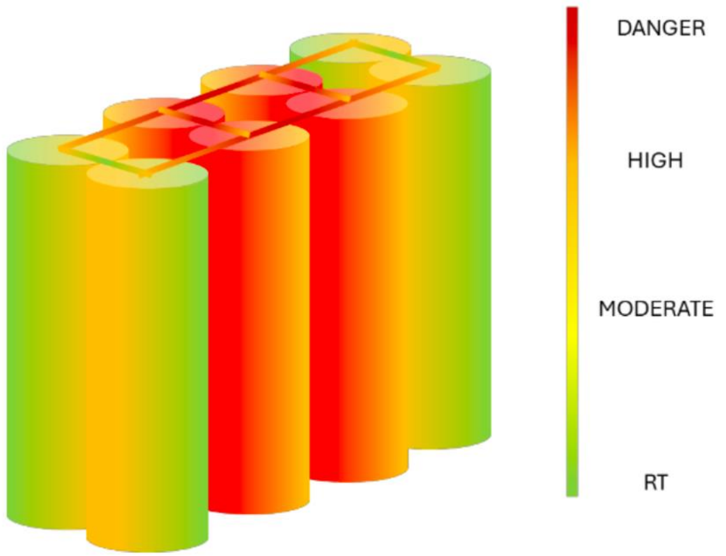
Cp sets the thermal buffer during fast charge and discharge. Higher Cp lets a cell absorb more heat before critical thresholds.

The Challenge

A full cell cannot go in a DSC, so it must be disassembled or approximated by surrogate materials, slow and non-representative.

Why TPS

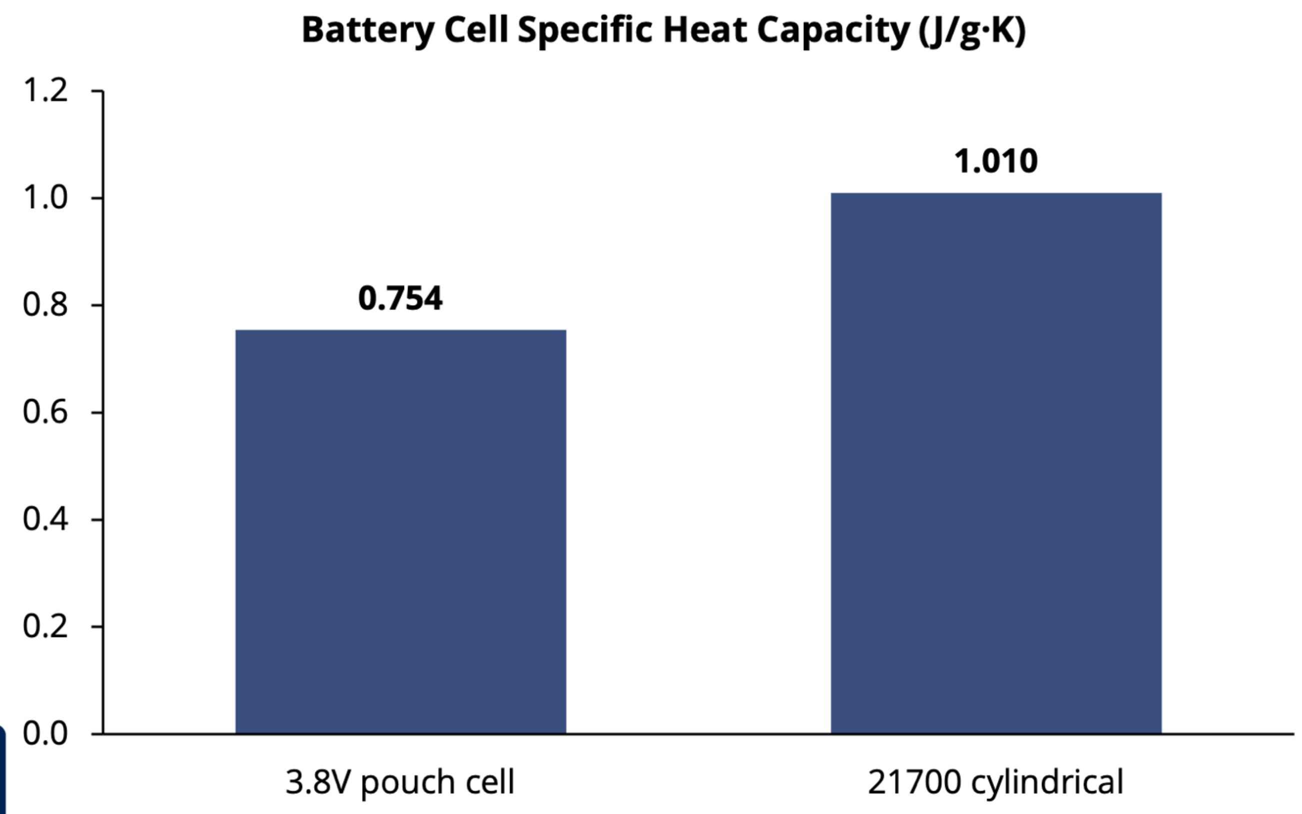
The TPS Cp Utility measures assembled cells as-received, capturing the integrated Cp of the whole cell without disassembly.



Check out the full application and more at ctherm.com

Whole-Cell Cp, No Disassembly

TPS Cp Utility · Specific Heat Capacity · Lithium-Ion Cells



0.754 J/g·K POUCH

The 3.8 V Li-ion pouch cell measured 0.754 J/g·K, within its 0.7 to 0.9 J/g·K expected range.

1.01 J/g·K CYLINDRICAL

The 21700 cylindrical cell measured 1.01 J/g·K, within its 0.8 to 1.1 J/g·K expected range.

Intact AS-RECEIVED

The Cp Utility measures assembled cells as-received, capturing integrated Cp without disassembly or surrogate samples.

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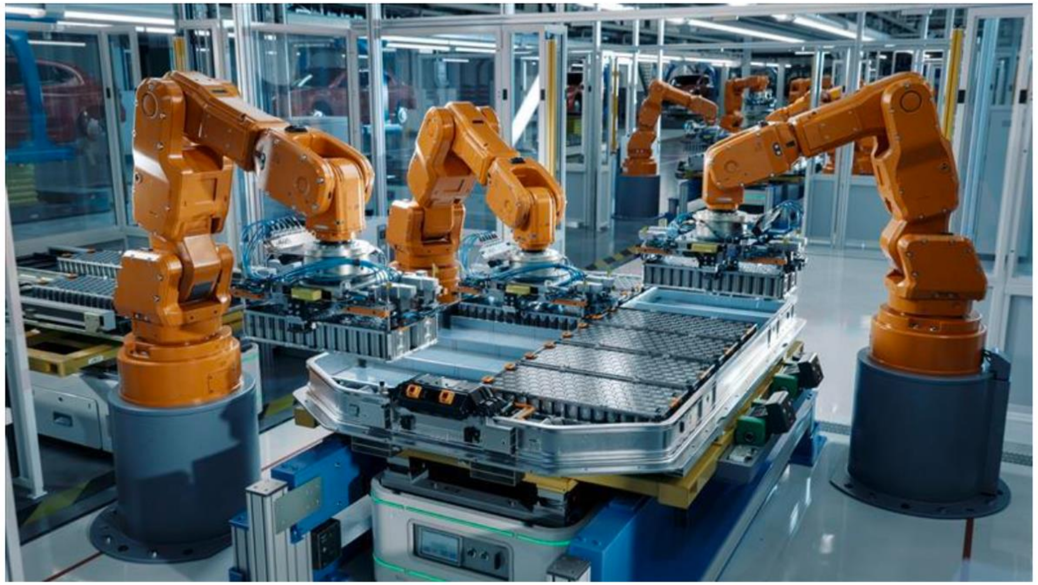
Anisotropic Conductivity of Cylindrical Cells

Single-Sided TPS with the Anisotropy Utility, in-plane and through-plane

Why It Matters

Battery cells generate heat on discharge, and poor thermal management drives capacity loss, aging, and even thermal runaway.



The Challenge

A cell’s conductivity is directional: heat moves far more easily along the layers than across them, by orders of magnitude.

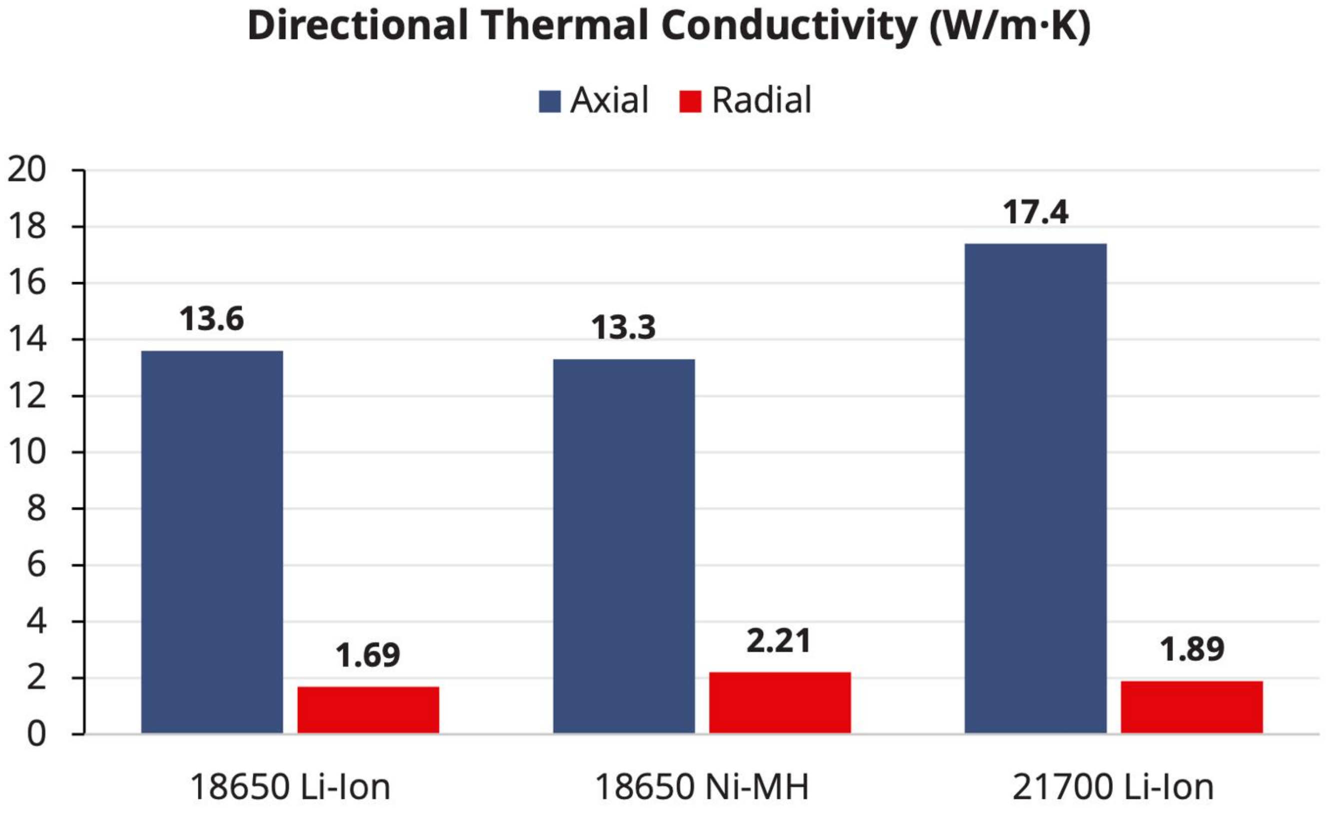
Why TPS

Single-Sided TPS with the Anisotropy Utility separates in-plane and through-plane conductivity on an intact cell.

Check out the full application and more at ctherm.com

Axial Conduction Outruns Radial by 8x

Single-Sided TPS with Anisotropy Utility · Thermal Conductivity · Three Cell Formats



8x AXIAL VS RADIAL, 18650

The 18650 Li-Ion returned 13.6 W/m·K axially against 1.69 radially. Collectors carry heat; separators block it.

17.4 HIGHEST AXIAL, 21700

The 21700 Li-Ion led axially at 17.4 W/m·K with ρCp of 2.81 MJ/m³·K, pointing to a different internal architecture.

≤ 3% RSD ON EVERY VALUE

Same-size 18650 Li-Ion and Ni-MH cells split on radial k, 1.69 against 2.21 W/m·K, resolved well inside repeatability.

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Thin-Film Adhesives in EV Battery Modules

TPS Thin Films Utility · Thermal Conductivity · EV Battery Adhesives

Why It Matters

Adhesive films bond battery pouch cells and shape how heat moves through the module, directly affecting pack heat distribution, cell longevity, and safety.

The Challenge

Thin adhesives are hard to measure. Steady-state methods are unreliable at low thickness, and stacking layers to add thickness introduces defects that skew results.

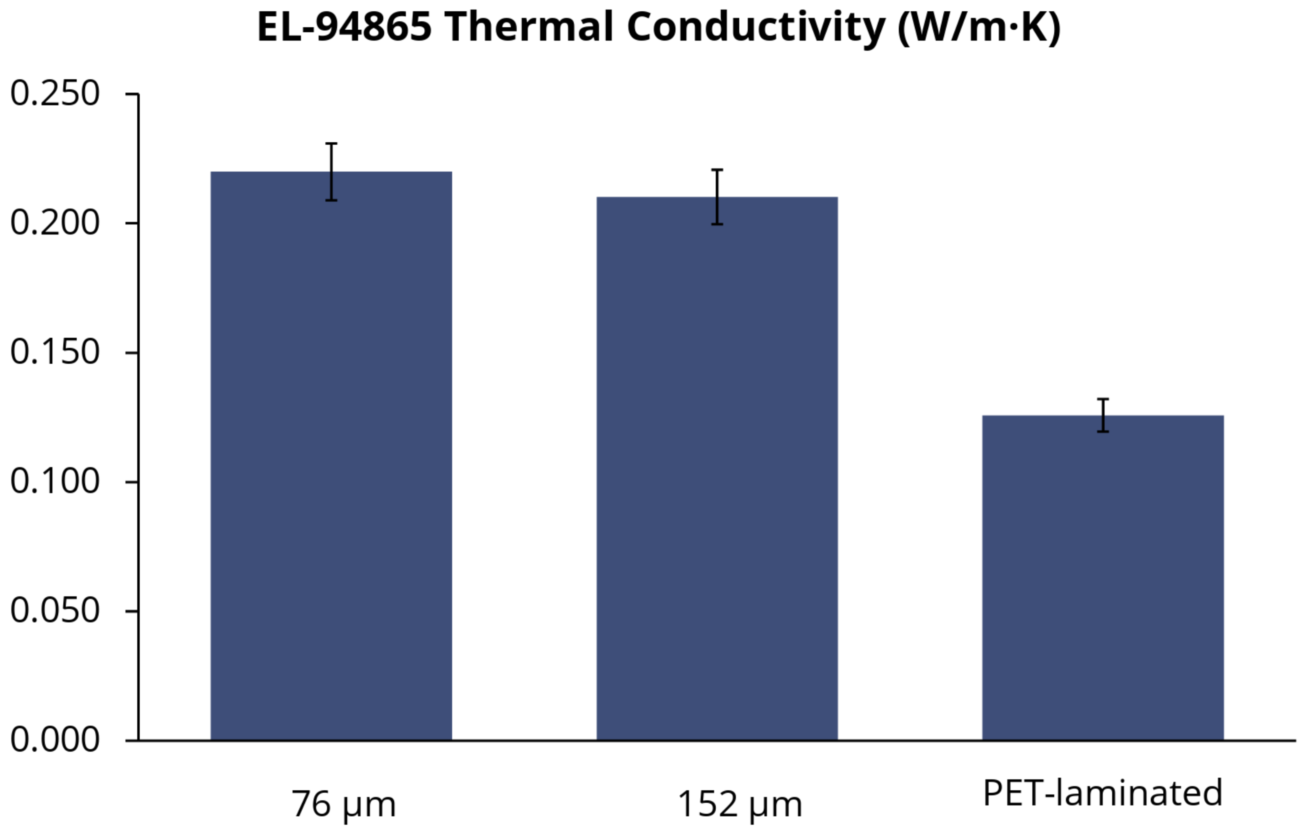
Why TPS Thin Films

The Transient Plane Source Thin Films Utility measures micron-scale films, capturing intrinsic thermal conductivity fast, per ISO 22007-2.

Check out the full application and more at ctherm.com

Thin-Film Adhesive Conductivity

TPS Thin Films Utility · Thermal Conductivity · ISO 22007-2



≈ Equal ACROSS THICKNESSES

76 µm and 152 µm EL-94865 gave nearly identical k. Well-controlled layering with no measurable interfacial resistance.

Lower WITH PET INTERLAYER

Laminating to a flame-retardant PET layer clearly drops conductivity, enhancing thermal-barrier performance.

µm-scale DIRECT MEASUREMENT

Thin films measured per ISO 22007-2, capturing intrinsic properties.

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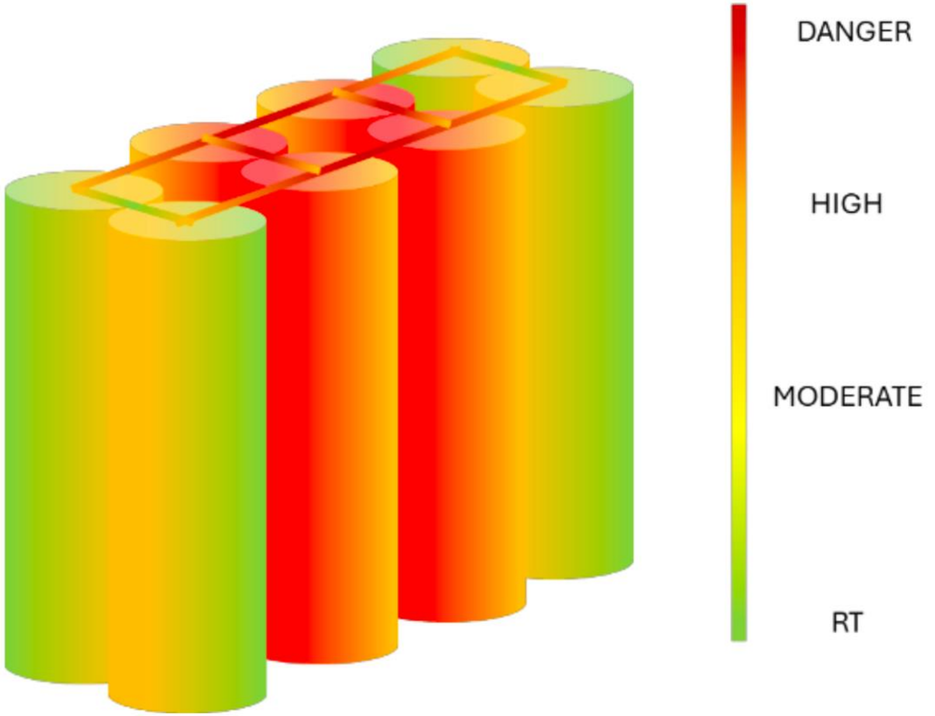
Key Takeaways

- Thermal management is key to safe implementation of battery technology.
- Apart from individual battery components, bulk thermal properties must also be considered.
- Trident's TPS system allows for comprehensive characterization of batteries.



Thank you for your attention !