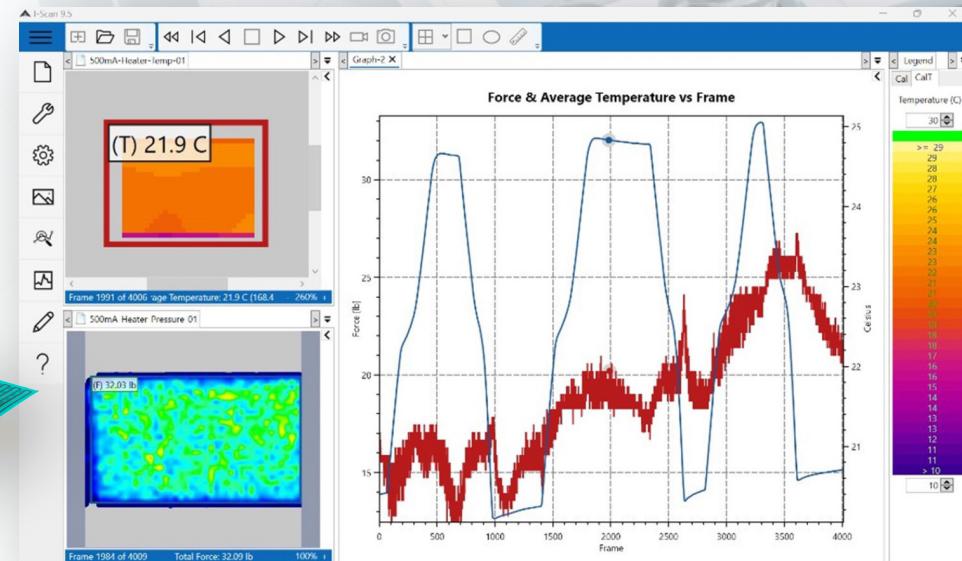
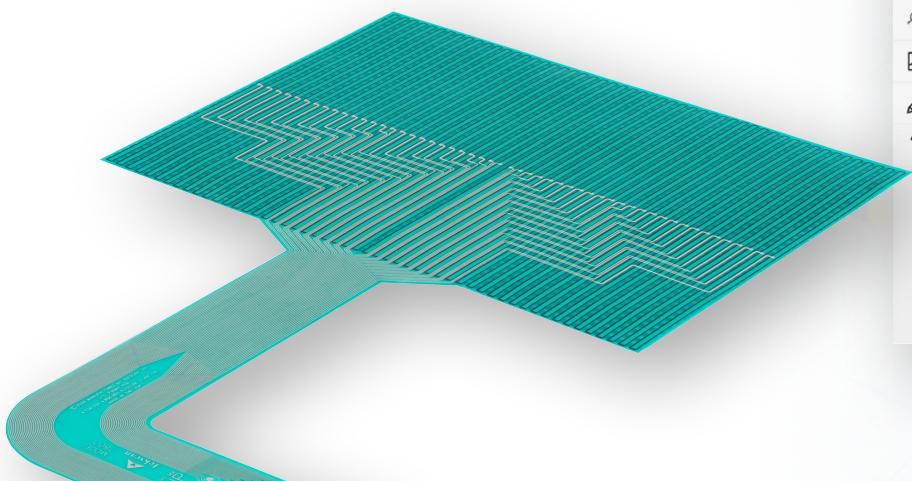


# Engineering Safer, Longer-Lasting Batteries with Pressure and Temperature Mapping

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## Application Spotlight



# Battery Swelling: Causes, Consequences, and Design Implications

Today's battery manufacturers face a puzzle: they must deliver more energy in smaller, lighter packages—while meeting the highest standards of safety and reliability. As production ramps up and chemistries evolve, understanding how pressure and temperature impact battery behavior is no longer optional. This guide explores how surface sensing technologies reveal critical insights to engineer safer, longer-lasting batteries.

Prismatic lithium-ion batteries are vulnerable to mechanical swelling during charging and discharging cycles - a challenge well known to battery engineers. These cycles trigger changes in temperature, electrochemistry, and internal mechanics, which in turn influence internal pressure within the battery. Over time, elevated or uneven pressures and heat buildup can significantly degrade the battery's performance, shorten its lifespan, and compromise safety.

When selecting materials and designing battery construction, evaluating the pressure dynamics is essential to maintaining material spacings, controlling gassing, and preventing excessive swelling. Understanding and managing these factors are key to optimizing battery design for both performance and safety.

## Engineer Tip

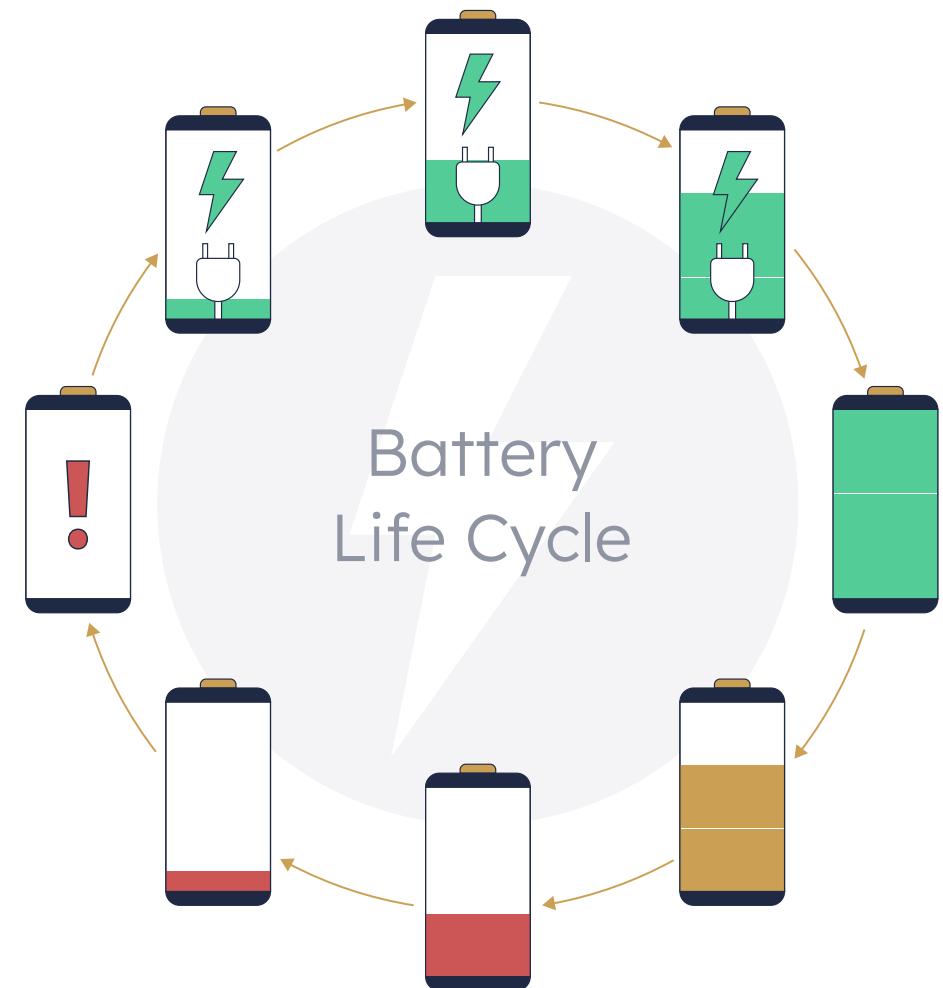
By making invisible forces visible, pressure and temperature mapping equip design engineers with the data needed to optimize performance, prevent failures, and reduce production costs.

## Performance vs. Safety Tradeoffs

As manufacturers pursue smaller, lighter batteries with faster charge times, they must also meet growing safety expectations and tighter tolerances. However, these performance targets often introduce conflicting mechanical and thermal demands. While silicon anodes can dramatically improve energy density, they can expand up to 4x during charging, exerting pressure on internal components and risking delamination or structural failure—especially if paired with uneven heating.

## The Role of Pressure & Temperature Mapping

To address these conflicting demands, engineers need reliable methods to visualize and quantify how pressure and heat evolve inside a cell - insights that traditional tools often can't provide. That's where pressure and temperature mapping technologies come in. To optimize battery construction and material selection, engineers must evaluate both mechanical pressure distribution and thermal uniformity. Tekscan's I-Scan™ Pressure Mapping System provides real-time insight into pressure dynamics, with new Temperature Mapping capabilities, which detect heat buildup and thermal propagation - revealing vulnerabilities that would otherwise be invisible.



## Did You Know?

**Silicon anode materials can expand up to 4x during charging.** This makes pressure and thermal stress analysis essential for safe, high-performance cell design.

# What is Pressure Mapping?

Even between relatively flat surfaces, the interface pressure distribution is often not uniform, with localized areas of peak pressure. Pressure mapping technology provides insight into areas that may impact design and quality.

Pressure mapping systems consist of 3 components – **sensors, scanning electronics and software** – to deliver real-time, actionable data, in ways other methods cannot.

1. The sensor transforms compressive pressure loads to a change in resistance.
2. The scanning electronics collect analog data from the sensor and convert the data to a digital signal.
3. The software displays real-time activity of the sensor area, allowing the user to see force, pressure, contact area, and timing data.

Now Available:

## Temperature Mapping

Tekscan now offers a thin-film temperature mapping solution that integrates with I-Scan, enabling users to collect thermal data, and in some cases, thermal and pressure data simultaneously.

[Explore the Possibilities](#)



## Components of a Tekscan Surface Sensing System



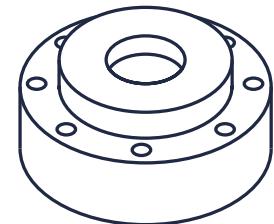
# Technology Comparison

Below are technologies to consider when trying to measure force or interface pressures. While there is some overlap with the information each sensing technology provides, they each present a unique value in the problem-solving process.

## Pressure Mapping

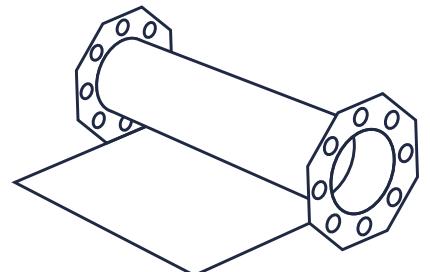
### Load Cell

Reliable, but bulky and offers no data on pressure distribution



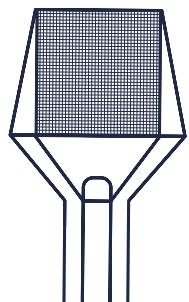
### Pressure Sensitive Film

Flexible, but single use and can only measure peak pressure



### Tactile Pressure Sensor

Thin, flexible, reusable sensor capturing static and dynamic pressures across a surface



## Temperature Mapping

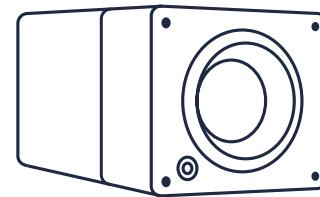
### Thermocouples

Simple and widely used way to get point-specific data and requires complex wiring for multi-point or distributed sensing



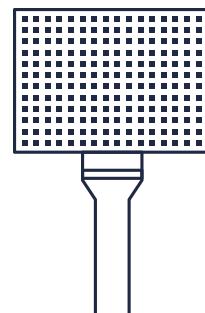
### Infrared/Thermal Cameras

Non-contact, provides wide area thermal measurements quickly. Require line-of-sight, are affected by emissivity and can't measure between surfaces



### Temperature Mapping Sensor

Measures distributed surface temperature between contacting surfaces with no emissivity adjustments needed. Currently available in select configurations.



# What You Don't Know About Stack Pressure Can Lead to Failure

Improper or uneven stack pressure—often missed during production and QA—can result in capacity fade, delamination, and internal structural damage. Traditional load cell fixtures offer only a partial view, while pressure mapping reveals full pressure distribution across the surface, enabling more informed, reliability-driven decisions.

While many manufacturers go to great lengths to maintain consistent stack construction, stack pressure validation is still often overlooked during production and quality assurance. Equally important but less frequently quantified: the mechanical and thermal stresses that develop inside the stack during charging and discharging cycles.

## What's at Stake?

A Princeton Study<sup>1</sup> confirmed that improper stack pressure—whether too high or too low—can lead to capacity fade, delamination, and internal structural damage. This highlights the need for precise, balanced mechanical loading in battery design. [See infographic for study results.]

The key challenge is identifying the optimal housing pressure that stabilizes internal components without introducing excess stress. Traditionally, engineers have relied on load cell fixtures to characterize average pressure during charge/discharge testing. While useful, these methods offer a limited view—capturing only bulk force data and missing localized variations. Understanding and controlling these variations is critical because even small imbalances can lead to mechanical failure, capacity fade, and safety risks over time.

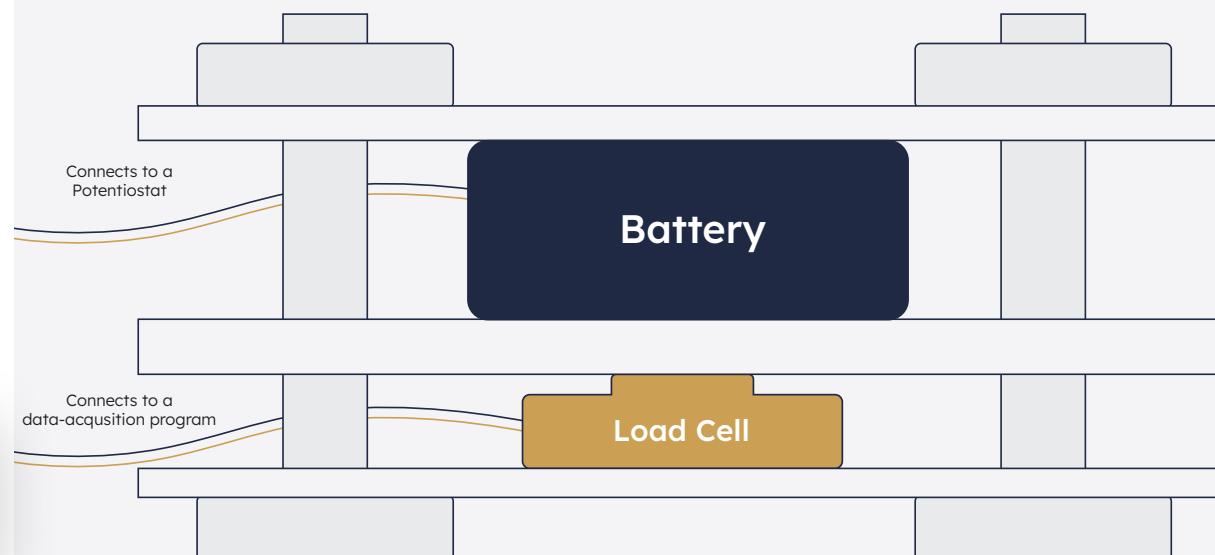
**Pressure mapping technology reveals a more complete picture**, identifying pressure distribution across the full surface of the cell or stack. This granular data helps engineers spot pressure imbalances, edge effects, or misalignment—leading to more informed decisions and improved mechanical reliability.

NEW

Pairing pressure mapping with temperature mapping offers even deeper insights. Detecting thermal hotspots and correlating them with mechanical pressure zones helps identify risks like material expansion, delamination, or uneven electrode contact—before they affect performance or safety.

## One Method to Measure Compressive Stack Stress

This fixture diagram depicts one way to measure pressure changes during the charge/discharge cycle of a prismatic cell battery. This is a similar setup to the one used in the 2013 Princeton study<sup>1</sup>, where a load cell positioned below the battery was used to capture pressure changes.



## Results

**Higher stack pressures** led to higher rates of capacity fade. Significant internal pressures may also cause plastic deformation, delamination, and internal impedance increases when the cathode separates.



**Lower stack pressures** allow for too much movement from thermal expansion within the housing, which can also lead to plastic delamination.

<sup>(1)</sup> Summarized from: Cannarella, J., Arnold, C., "Stress Evolution and Capacity Fade in Constrained Lithium-Ion Pouch Cells" Journal of Power Sources. 245 (2014) 745-75 <https://doi.org/10.1016/j.jpowsour.2013.06.165>

# Pressure Mapping in Battery Testing and Material Evaluation

Pressure mapping has been used in multimonth studies evaluating force distribution over thousands of charge/discharge cycles. Characterizing swell profiles is critical when evaluating stack materials, pouch designs, and thermal management strategies.

## Mapping Pressure – And Now, Temperature

Thin and flexible sensors can measure pressure between nearly any two surfaces. As shown at right, a 0.01 mm thick sensor can be wrapped around a battery to capture **360° pressure profiles** during testing. Now, with temperature mapping sensors as an additional capability, it's possible to visualize both thermal and mechanical stresses simultaneously—identifying points of excessive pressure or heat buildup, and how they might degrade performance.

## Solid-State & Silicon Challenges

These methods are just as important for solid-state batteries, where rigid electrolytes cause non-uniform pressure distribution, leading to cracking and reduced performance. Batteries with silicon/carbon materials face similar challenges due to extreme volume expansion. Controlled pressure can help mitigate delamination, but pairing it with **temperature data** gives engineers even more insight into how expansion and heat affect long-term reliability.

## Backed by Research

A 2019 study in the Journal of the Electrochemical Society<sup>2</sup> used Tekscan pressure sensors to identify pressure hot spots over time—flagging potential manufacturing defects. This data-driven approach helps optimize both battery design and production methods. |

(NOTE: Temperature mapping was not included in the original study. This recreated test setup by Tekscan Application Engineers adds thermal sensing to provide enhanced analysis of pressure and heat dynamics.)

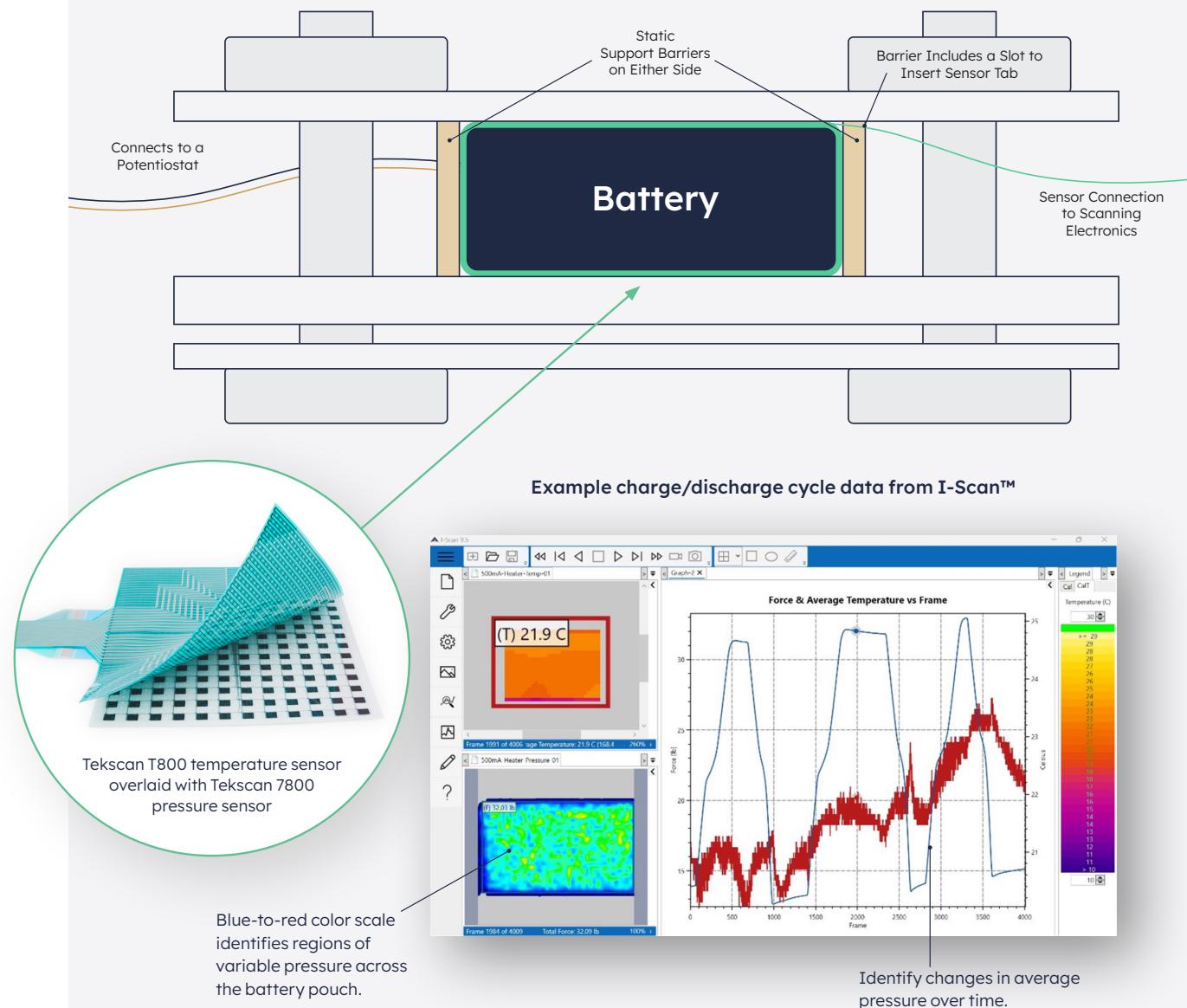
## From Laboratory to Industry – Now with Thermal Insight

What started as a research tool is now a powerful production asset. Manufacturers are using pressure mapping to validate quality and ensure consistency at scale.

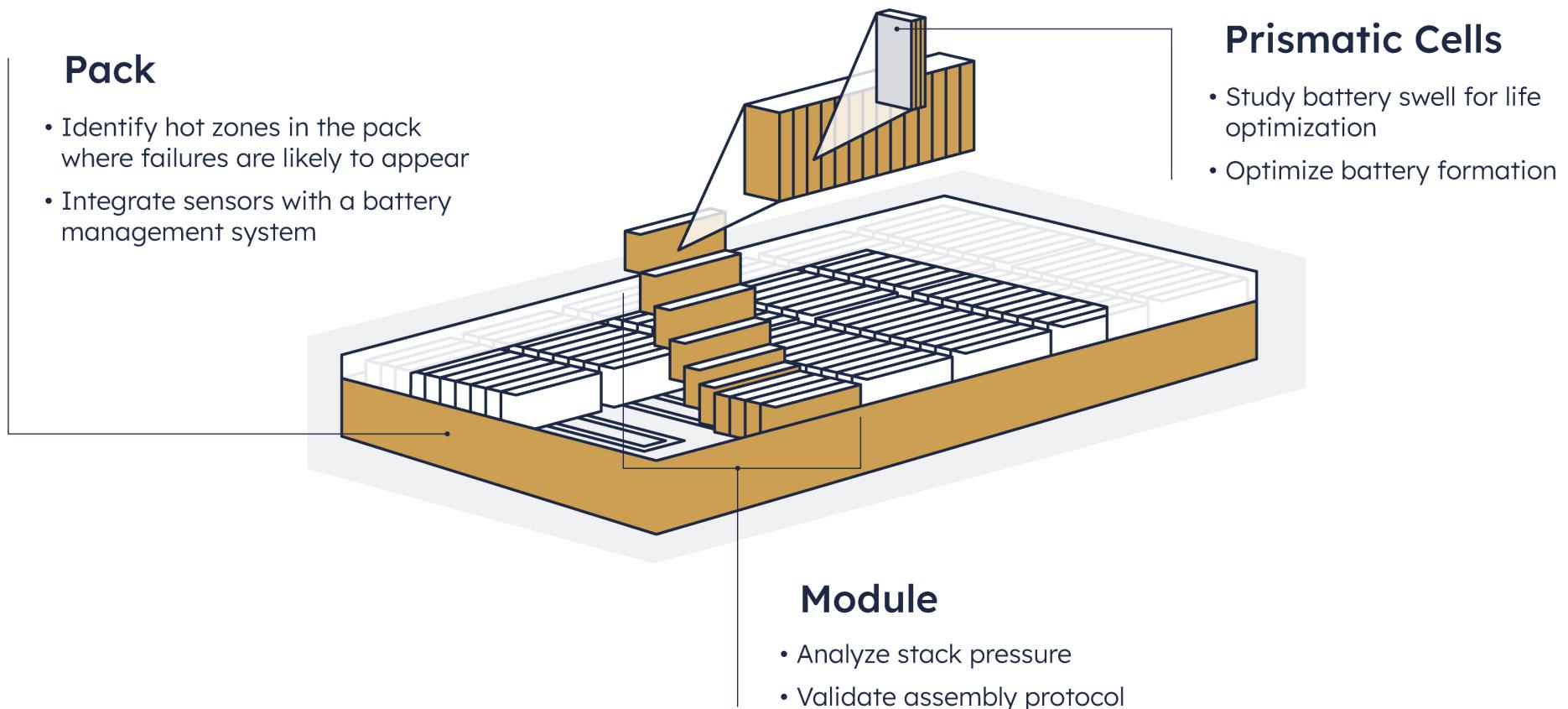
Based on extensive customer input, Tekscan developed a pressure sensor model tailored for battery stack integration. Its compact, trimmable form factor and improved electronics placement make it ideal for in-situ testing—and now, **companion temperature sensors** are available for a complete view.

## Using Pressure Mapping Technology to Improve Upon a Tried & True Method

The thin, flexible pressure mapping sensor offers the ability to conform to the entire battery pouch. This allows the engineers to simulate what may happen in a real-world battery stack array.



# Pressure Mapping Is an Integral Tool for Electric Vehicle Battery Applications



# Optimizing Battery Formation with Pressure & Temperature Mapping

Battery formation is a critical – and costly – step in the manufacturing process, often accounting for up to one-third of total production costs. Tightly controlling pressure and temperature during this stage helps ensure battery performance, cycle life, and safety in the following ways.

## 1. Performance & Efficiency

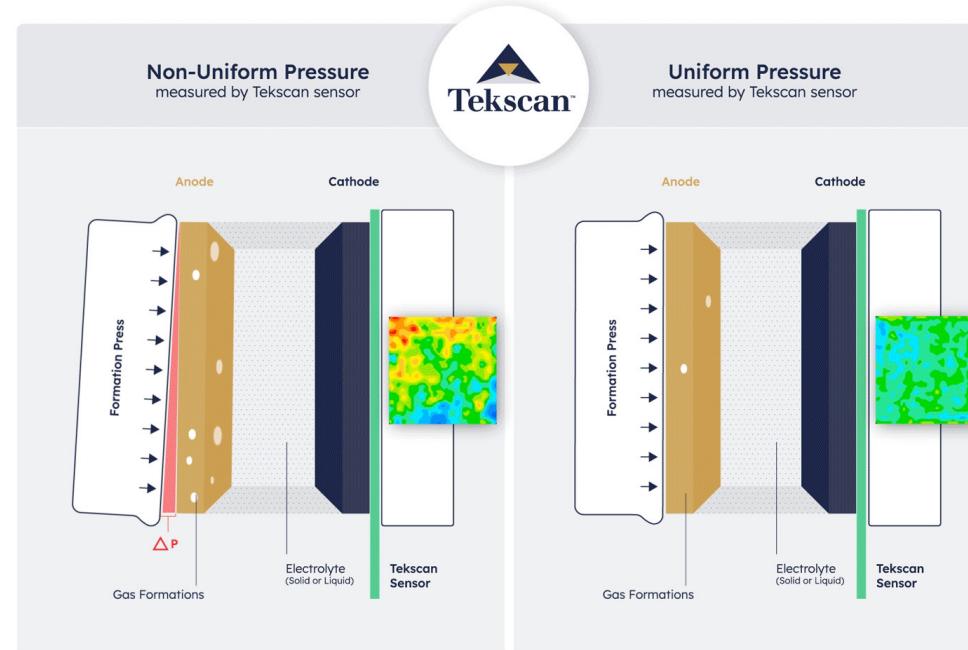
- Optimize Formation Time:** Precise pressure and thermal control enhances ion transport and surface reactions, resulting in faster formation times and increased manufacturing output.
- Boost Efficiency:** Identifying and eliminating reject cells early prevents wasted energy cycles and scrap.

## 2. Process Control

- Tailor Cycling Profiles:** Understanding how pressure and heat together influence formation across different battery chemistries
- Enhance Degassing Process:** Preventing excess pressure and temperature help minimize gas formations in the anode layer, reducing potential waste.

## 3. Quality & Consistency

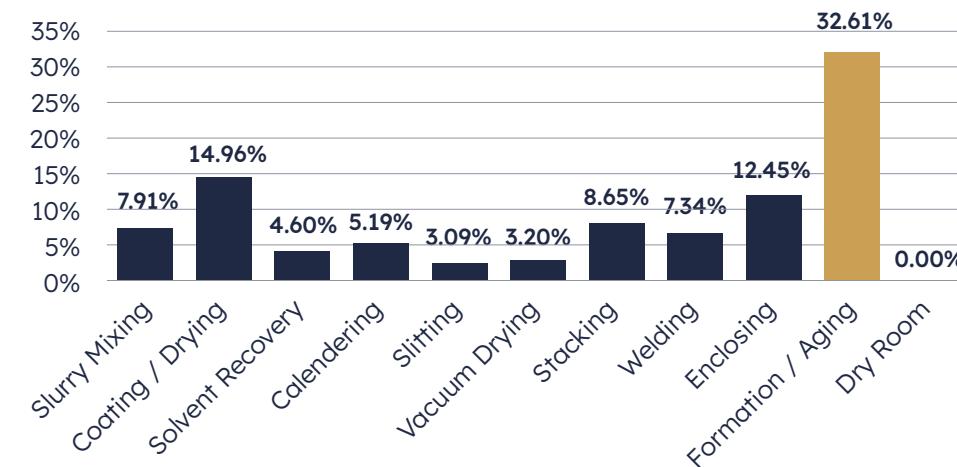
- Strengthen SEI Layer:** Stable pressure and temperature conditions promote a robust Solid Electrolyte Interface (SEI). Imperfections to this layer can propagate, accelerating the degradation of the cell over time.
- Ensure Electrode-Electrolyte Contact:** Balanced force and thermal distribution ensure proper material bonding.
- Improve Power & Energy Density:** Uniform conditions lead to consistent electrode density, improving storage and charge rates.
- Achieve Repeatability:** Maintain consistent pressure/thermal profiles across batches for reliable results.



For a detailed visual explanation, including an animated image illustrating this process

[Visit Our Website](#) →

## Cost breakdown of LIB manufacturing processes



# A Smarter, Safer Way to Design Batteries

Pressure and temperature are two of the most critical variables in lithium-ion battery development. Surface sensing technologies from Tekscan help engineers pinpoint localized pressure and thermal irregularities at any stage, from R&D to production.

## Where Pressure & Temperature Mapping Add Value:

- **Cell Design:** Understand how internal swelling, stack compression, and heat buildup affect longevity and performance.
- **Housing Optimization:** Detect where excessive pressure or thermal stress may cause delamination, microfractures, or impedance shifts.
- **Safety Prioritization:** Identify hotspots and mechanical triggers that could lead to thermal runaway or failure events.

## Integrated Tools for Confident Design Decisions

Tekscan's pressure and temperature mapping systems give R&D and production teams a quantitative, visual way to evaluate material choices, layer alignment, and assembly conditions—ultimately leading to:

- Better, safer products
- Faster development cycles
- More consistent manufacturing outcomes

**Pressure and temperature mapping offer the insight battery designers need to stay ahead of risk—and ahead of the competition.**

## Citations

(1) Cannarella, J., Arnold, C., "Stress Evolution and Capacity Fade in Constrained Lithium-Ion Pouch Cells" Journal of Power Sources. 245 (2014) 745-75 <https://doi.org/10.1016/j.jpowsour.2013.06.165>

(2) Verena Müller et al 2019 J. Electrochem. Soc. 166 A3796 <https://iopscience.iop.org/article/10.1149/2.1121915jes>

(3) iScience Current and future lithium-ion battery manufacturing Yangtao Liu, April 23, 2021

## Let's discuss your next battery or power application.

Tekscan understands the high-stakes decisions R&D teams make when investing in new test & measurement technologies. Whether you need a standard system or a custom solution, our team has a proven track record of helping engineers:

- Gain deeper insight into product behavior
- Validate new materials and processes
- Accelerate development timelines
- Improve product performance and reliability

### Your return on investment?

Confidence in your design—and the data to back it up.

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