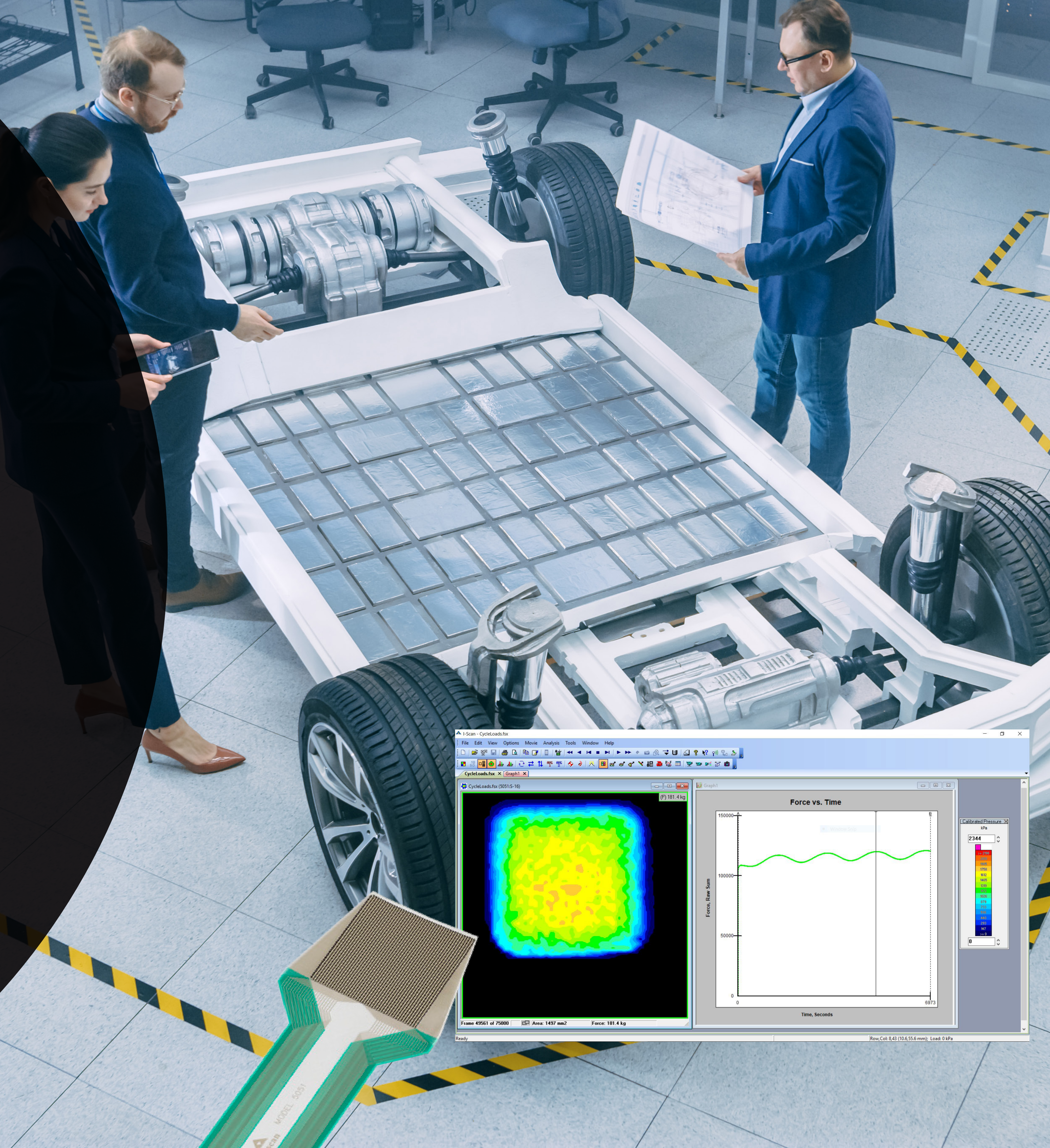
APPLICATION SPOTLIGHT

How Pressure Mapping Insights Improve Battery Performance and Safety



Tekscan™

Technology to See how a Battery Breathes

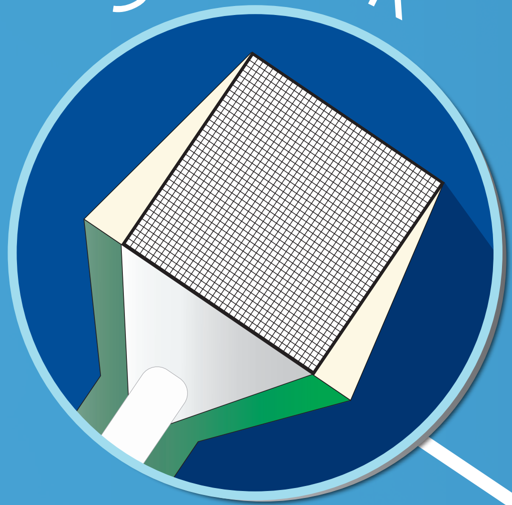
Many familiar with the construction of a prismatic lithium ion battery will say that it breathes. Charging and discharging causes changes to the temperature, electrochemistry, and mechanics of the internal components that, in turn, influences the internal pressures. Over time these pressures can have a dramatic impact on battery life. As manufacturers strive to create a product that is efficient, lightweight, and safe, it is imperative that designers intimately understand these characteristics.

Across market segments, users are requesting batteries that are smaller, more light-weight, and faster-charging. There is also demand for batteries to be safer while carrying a higher energy density. These features can often be in conflict with each other, so it can be a challenge to find a balance and stay cost competitive.

When considering materials and construction of a battery, evaluating the pressure dynamics is critical to maintain the material spacings, control gassing, and prevent excess swelling.

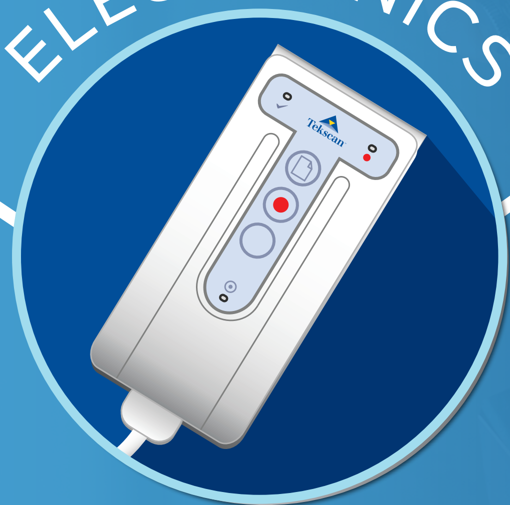
COMPONENTS OF A PRESSURE MAPPING SYSTEM

SENSOR



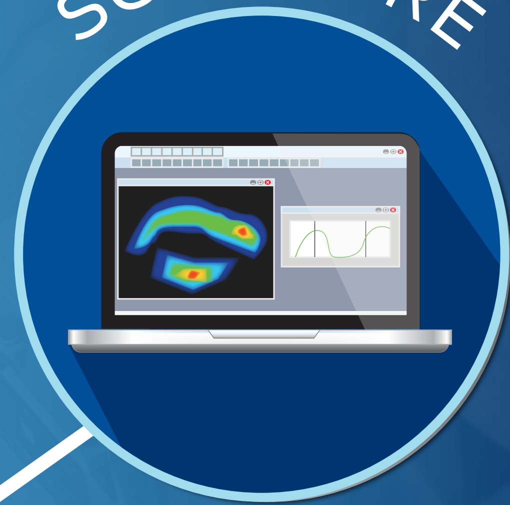
- Minimal invasiveness
- High resolution
- Thin & flexible

ELECTRONICS



- Scan thousands of sensing points within each sensor
- Instant data relay to PC via USB or WiFi

SOFTWARE



- Display pressure distribution data in multiple formats for superior analysis
- Display pressure data graphs in 2D & 3D
- Capture peak pressures and center of force in real-time
- Allow for video playback of pressure data

WHAT IS PRESSURE MAPPING?

Even between relatively flat surfaces, one finds the interface pressure distribution is often not uniform within localized areas of peak pressure. Pressure mapping technology helps design engineers obtain insight into areas that may impact design and quality.

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

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

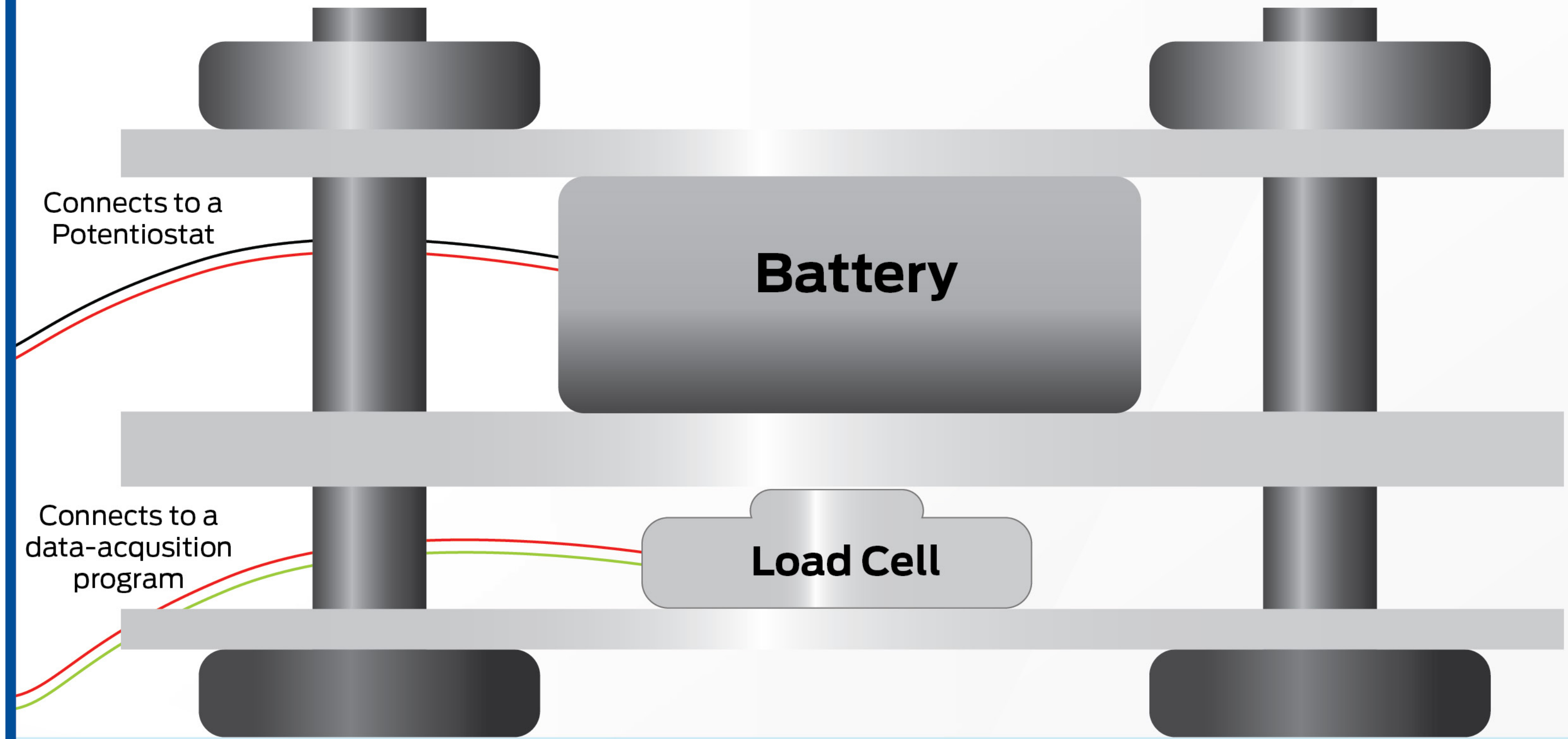
While many manufacturers make significant efforts to maintain constant stack construction during manufacturing, many don't validate the stack pressure as part of their quality procedure. Furthermore, many don't quantify the internal stresses on the stack as the battery is charged and discharged.

In a 2013 Princeton study[1], researchers found that high stack pressures had "a strong effect on long term cell performance, with higher levels of stress leading to higher rates of capacity fade." Significant internal pressures were shown to cause plastic deformation, delamination, and internal impedance increases when the anode and cathode separate. While lower stack pressures provided better long-term performance, delamination may still occur when pressures are too low.

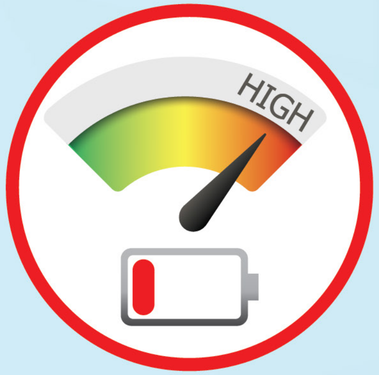
The challenge then becomes finding the "sweet-spot" for housing pressure. A load cell fixture can characterize the average pressure on the battery assembly, as shown on the diagram to the right. While this study was successful in measuring average pressure in cycle testing, pressure mapping technology offers engineers an opportunity to gain more insight into this application and identify specific regions of pressure.

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[1], 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.

(1) 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

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

Pressure mapping has been used in multi-month studies evaluating the pressure profile during thousands of charging and discharging cycles — principles that can be applied to evaluating battery housing materials.

The thin and flexible array of sensing elements provides comprehensive data of the different pressures between nearly any two surfaces. As shown on the right, in the case of battery charge/discharge cycle testing, a 0.01mm thick sensor can be wrapped around the battery to provide a 360° view of the battery.

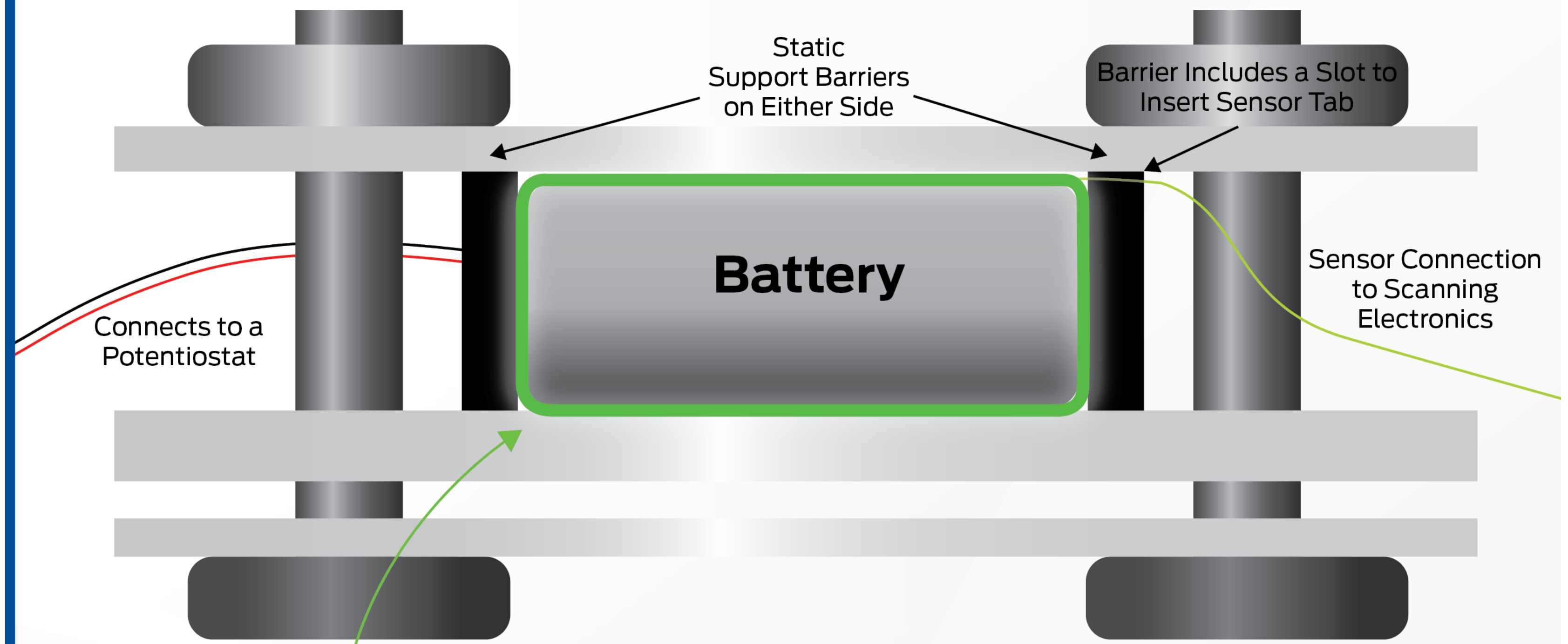
This testing method becomes increasingly important with solid state lithium ion batteries. Solid state batteries are appealing for safety reasons; their composition makes them less volatile and vulnerable to fire than liquid li-ion batteries. The ultimate hope is that they will also last longer and charge faster. However, their ineherent mechanical properties pose some challenges. The rigid electrolyte generates a non-uniform pressure distribution. Concentrated pressures can lead to cracking in the material, reducing the battery efficiency.

Due to the extreme volume expansion of silicon/carbon materials, they are vulnerable to fractured delamination, leading to capacity fading during use. One approach to mitigate these effects is application of mechanical pressure on the cell. A 2019 study published in the *Journal of the Electrical Chemical Society*[2] used pressure mapping sensors and software as a visual tool and means of data gathering over time to reveal hot spots at various pressure applications. The team used this data to help identify optimal mechanical pressures aimed at preserving battery life.

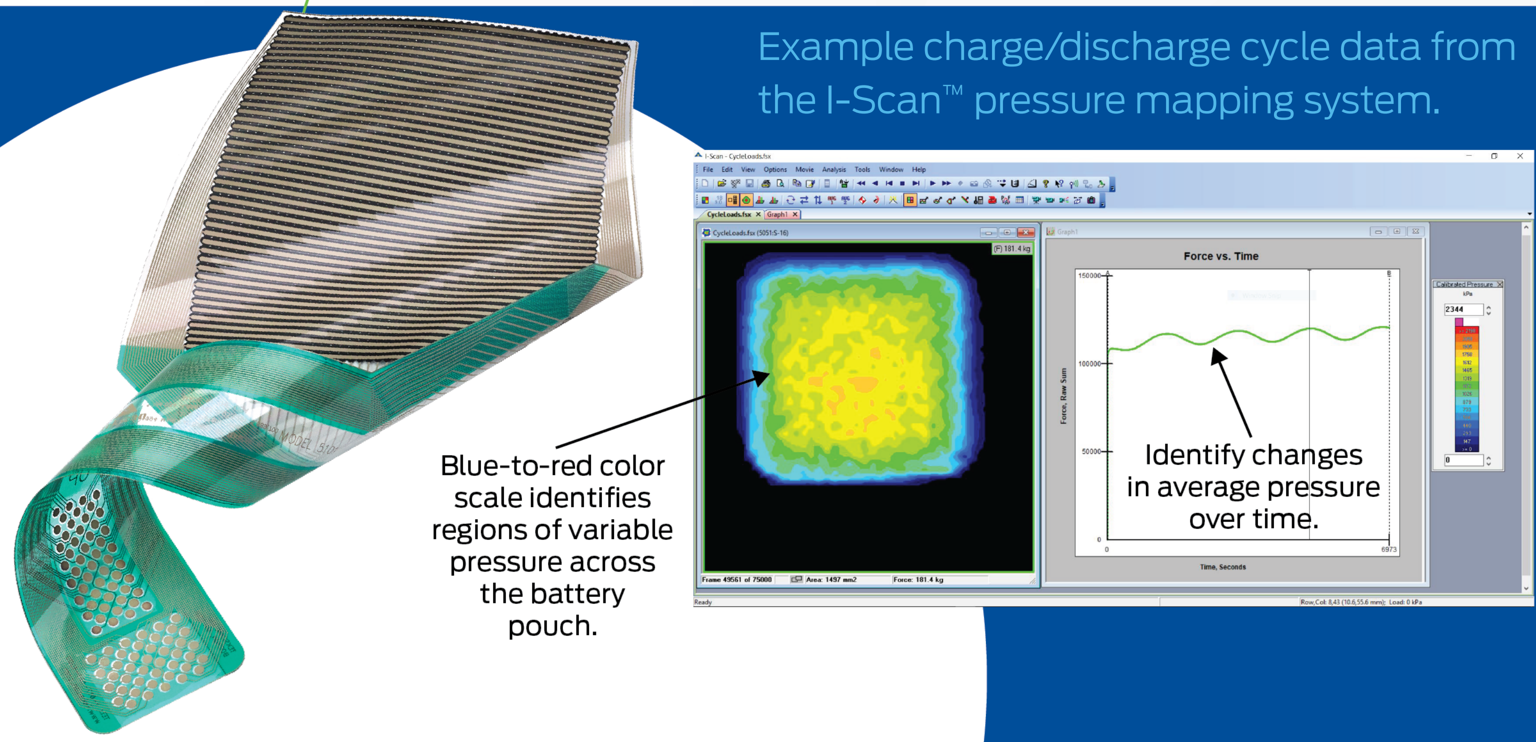
Every industry can benefit from advances and improvements to battery technology and performance. The Electric Vehicles market is particularly invested in using pressure mapping as a tool to help quantify and understand battery dynamics in a number of applications.

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.



Example charge/discharge cycle data from the I-Scan™ pressure mapping system.



Pressure Mapping Is an Integral Tool for Electric Vehicle Battery Applications

Research and Development
Optimize battery design to meet performance needs

Lifecycle Testing
Measure pressure changes over long durations of charging & discharging cycles

Durability Testing
Characterize vibration response & impact from debris

Quality Control
Validate proper stack pressure for manufacturing quality records

CONCLUSION:

Pressure mapping technology becomes an important method to help engineers identify areas of localized pressure at virtually any position of a prismatic battery cell, leading to better design decisions, longer-lasting technology, and a clear edge over competitors.

This technology has also been used to evaluate housing designs, or identify vulnerable locations on a battery in impact testing.

While trying to optimize the characteristics described in this document, designers must make sure to never make a compromise on the safety of their products. The temperature increases during charging can lead to lithiation or mechanical stresses in the housing. This undesired behavior can generate mechanical separations or micro fractures that reduce capacity. In more dramatic instances these failures can cause gassing that leads to thermal runaway reactions.

With pressure mapping, researchers and battery designers are provided a wealth of evaluation tools and insights on the impacts of different use parameters of their designs. These studies have helped designers find the correct materials and construction for their needs, leading to better designs with repeatable results.

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