Tekscan™

Advancements in Pressure Mapping Technology Drive Robust Tire Analysis

How insights from pressure mapping technology help industry experts analyze and improve the driving experience

Contents

3 Tire Analysis and R&D – Staying Ahead of the Curve

4 It's All About Where the Rubber Hits the Road

5 Limitations of Conventional Testing Techniques

6 The Solution: Dynamic Contact Patch Pressure Testing on a Flat Track

7 How the System Creates a Tire Contact Patch Footprint

8 Where is the Tread Detail?

9 Components of a High-Speed Tire Patch Measurement System

10 Instrumenting a Flat Track

11 Stay in Sync with the Test Plan

12 Validation of Technology

13 Insights Comparing Similar Passenger Tires from Different Manufacturers

14 Vertical Load Sensitivity

15 Impact of Velocity and Slip Angle on Contact Patch Pressure Distribution

16 Extreme Cornering

17 Key Applications for Tire Patch Data

18 Analyzing the Tire from 360 Degrees

Tire Analysis and R&D – Staying Ahead of the Curve

An optimally designed tire influences countless factors in the driving experience, including safety, fuel economy, maximizing charge range performance, shock absorption and more.

As the tire industry continues to grow (presently over $120 billion industry) to keep pace with market demands worldwide, tire manufacturers need to stay ahead of the curve to remain competitive. To do this, they need access to test & measurement technology that can **quickly provide important insights that would otherwise go unrealized.**

There are so many considerations that go into tire development and design. There is one area of assessment in particular that can give researchers critical data about a tire's strength and weaknesses.

It’s All About Where the Rubber Hits the Road

Key elements of a vehicle’s performance, such as load carrying, cornering, traction, braking, and acceleration, are all related to the **tire contact patch**, or the area of the tire tread that meets the road or driving surface. As the tire meets the surface, it deforms in all directions. Understanding the **distribution of this deformation pressure** is invaluable for tire manufactures, who invest countless hours of R&D into optimizing materials in the tire design to achieve the desired stiffness and construction.

While there are multiple techniques for measuring the contact patch while the tire is in a static state, dynamic measurements have consistently been a challenge to capture. As the tire quickly spins, in-plane friction forces across the tire patch, plus centrifugal forces, change the shape of the tire patch, in turn changing the performance of the tire.

Tekscan, leading manufacturer of thin, flexible pressure mapping technology, partnered with Calspan, premier automotive research and test facility, to develop a reliable, repeatable method for measuring the **Dynamic Contact Patch Pressure** (DCPP) of a tire on a flat track machine. The technology used for the DCPP tests is called **High-Speed TireScan™**. It consists of a thin piezoresistive sensor, wireless electronics, and user-friendly software.

Tekscan

Since its founding in 1987, Tekscan has been at the forefront in the research and development of ultra-thin force and pressure sensing technology for use across a wide range of applications. With a strong patent portfolio and proprietary technology, Tekscan maintains its world-leading position in the area of tactile force and pressure sensing by providing customers with actionable information they need to optimize product design and improve clinical and research outcomes.

Calspan

For more than 75 years, Calspan has provided independent research, development, and testing services in the aerospace and automotive industries. Internationally recognized for research and innovation in all ground and air transportation safety and performance, Calspan works with leading aerospace and automotive companies domestically and globally. The company’s headquarters is in Buffalo, NY, with additional operations in Niagara Falls, NY, Newport News, VA, San Diego, CA, and St. Paul, MN

Limitations of Conventional Testing Techniques

Over the years, tire manufacturers have relied on a handful of systems and approaches for evaluating tire contact patch pressures. There are a range of limitations with these methods, for example:

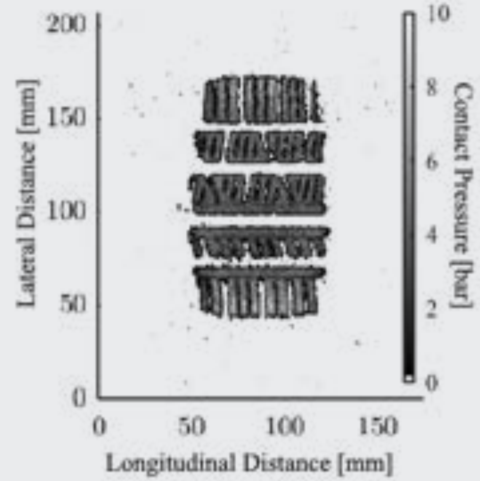
Ink Footprints
This method doesn't account for rolling tires/dynamic forces, and doesn't provide pressure.

On-Road Testing
Too many uncontrolled variables lead to poor measurement repeatability.

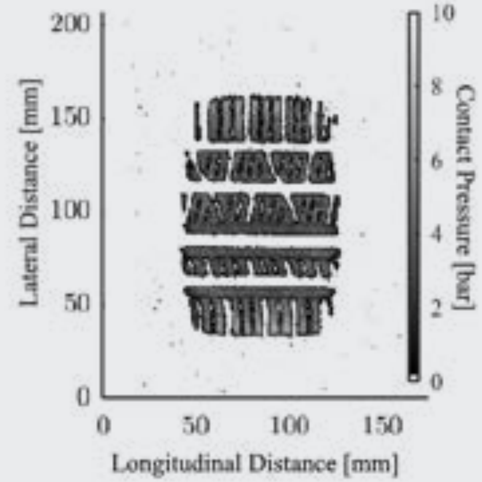
Camera Systems with Glass Plates
Low surface friction of the glass, changes how the rubber interacts with the road surfaces (especially at high slip).

Drum Testing
The curved road surfaces of the drum changes the contact patch shape and pressure distribution, making it difficult to predict real world performance on flat surfaces.

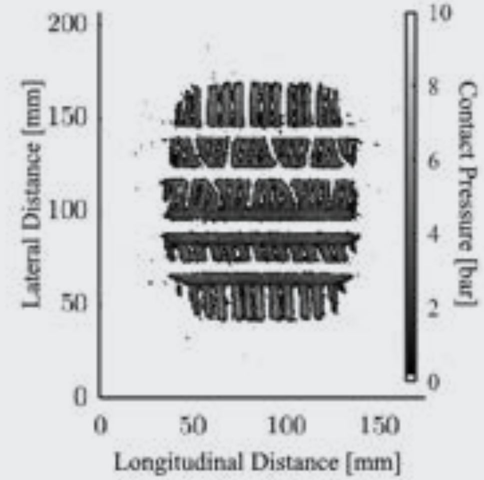
Ink Footprints on 3 testing surfaces



Small Drum
Smaller Diameter Drum



Medium Drum
Standard Diameter Drum



Flat Track

The ink measurements on the various testing surfaces demonstrate the change in tire patch length from the radius of the drum vs. a Flat Track.

The Solution:

Dynamic Contact Patch Pressure Testing on a Flat Track

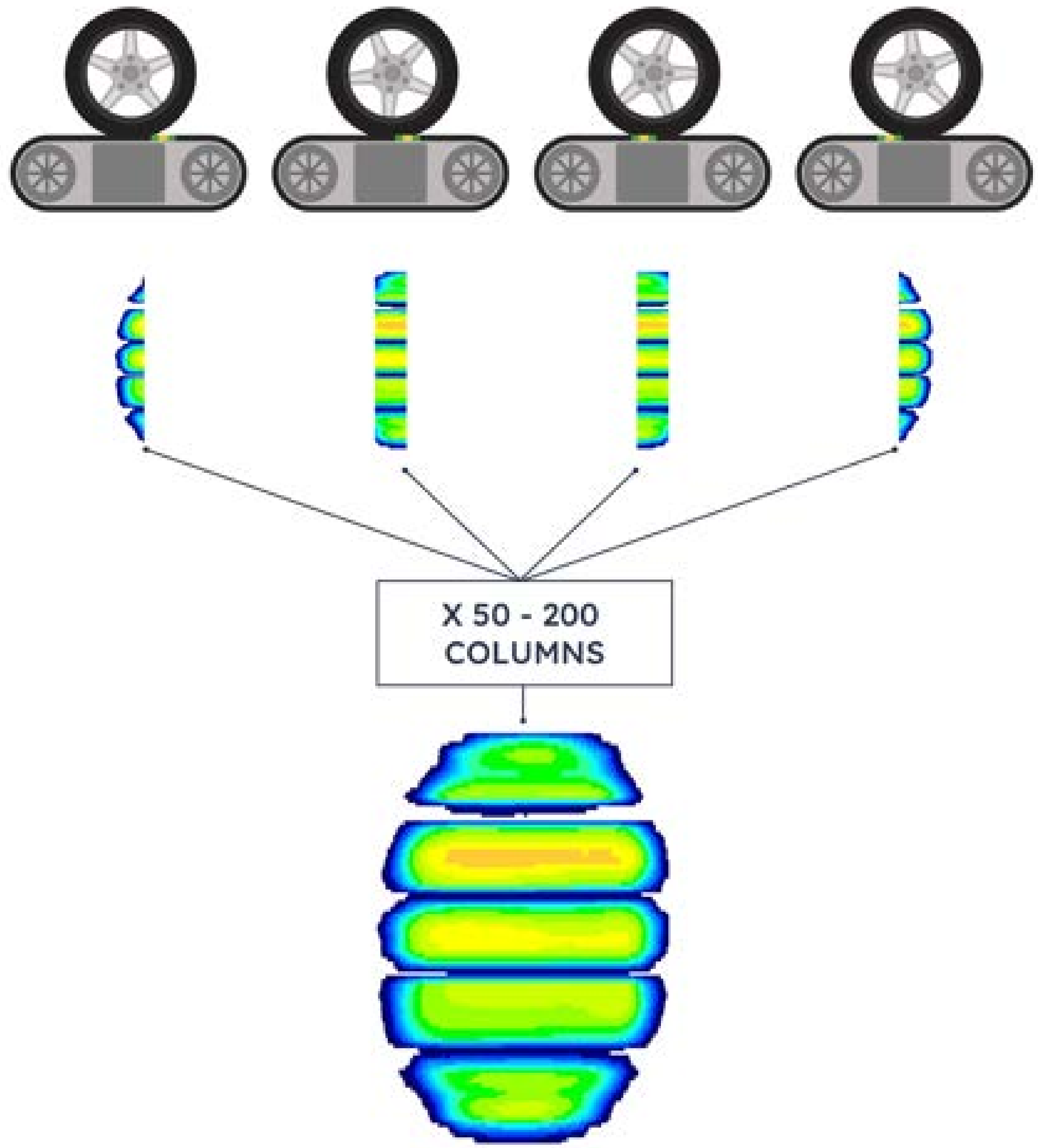
Measuring tire contact patch pressure on a flat track allows for accurate, repeatable, high-speed measurements of the contact patch. In such a test environment, variables can be isolated and introduced in a controlled manner to ensure proper correlation between operating conditions and contact patch pressure behavior.

At Calspan's test facility, the tire test rig actively controls operating conditions such as:

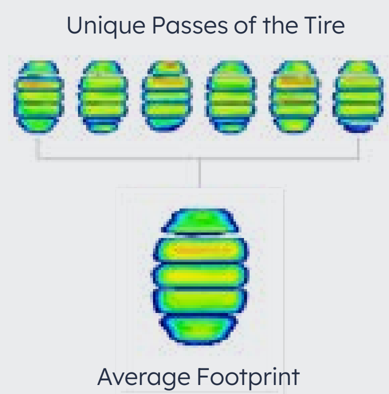
- Load
- Slip Angle
- Acceleration/Braking
- Camber Angle
- Velocity
- Inflation Pressure
- Temperature

How the System Creates a Tire Contact Patch Footprint

To collect a contact patch image, the High-Speed TireScan™ system captures multiple linear arrays across the width of the tire as it rolls across a single-sensing column. The user inputs the velocity of the tire and the software generates a contact patch image, or footprint, that shows the shape and pressure distribution of the tire. The columns in the footprint image represent **different moments in time**. The system uses the velocity input to set the aspect ratio of the columns such that the tire footprint image is an accurate depiction of the contact patch.



Several passes collected are averaged together to account for tread variation across tire surface



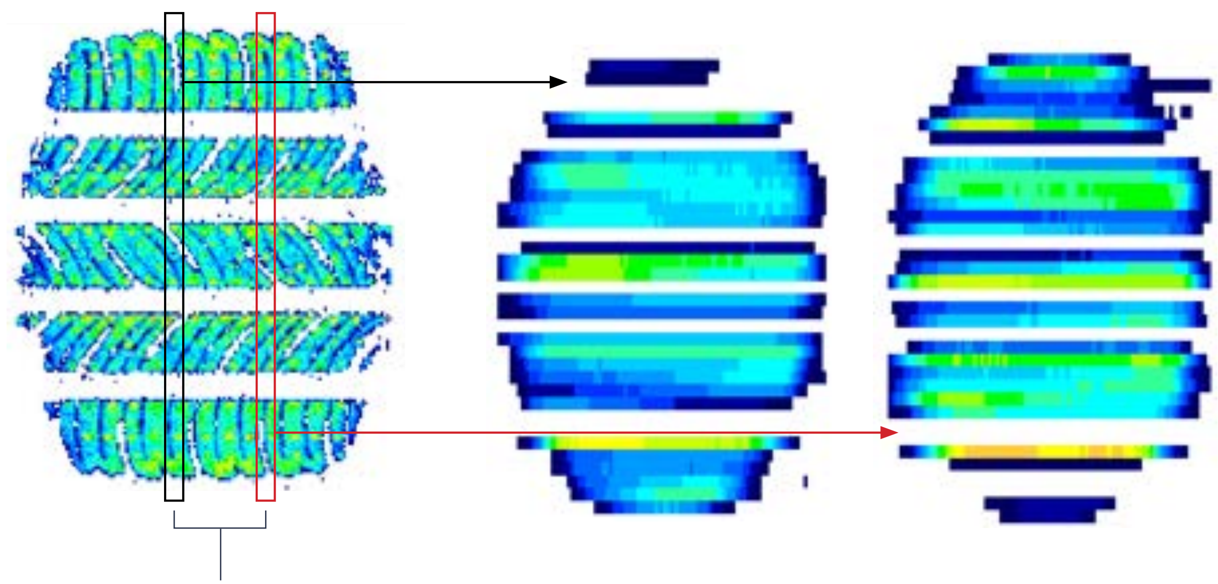
Where is the Tread Detail?

When the High-Speed TireScan™ system measures the tire contact patch, the sensor comes into contact with just 3.6 mm (0.14") of the tire. That section of the tire will experience every segment of the tire patch as it rolls over the sensor. The system measures this sequentially over time and displays the image as a single patch. The depiction of the patch is determined by the contact point of the sensor and face of the tire.

The example below comparing the data of a tire patch made from a 2D matrix pressure sensor (CrossDrive) and the High-Speed system show how the location of contact can change the measurement.

Tire Footprint collected with 2D Pressure Mapping Array

Tire Footprints collected with 1D High Speed Pressure Mapping Array

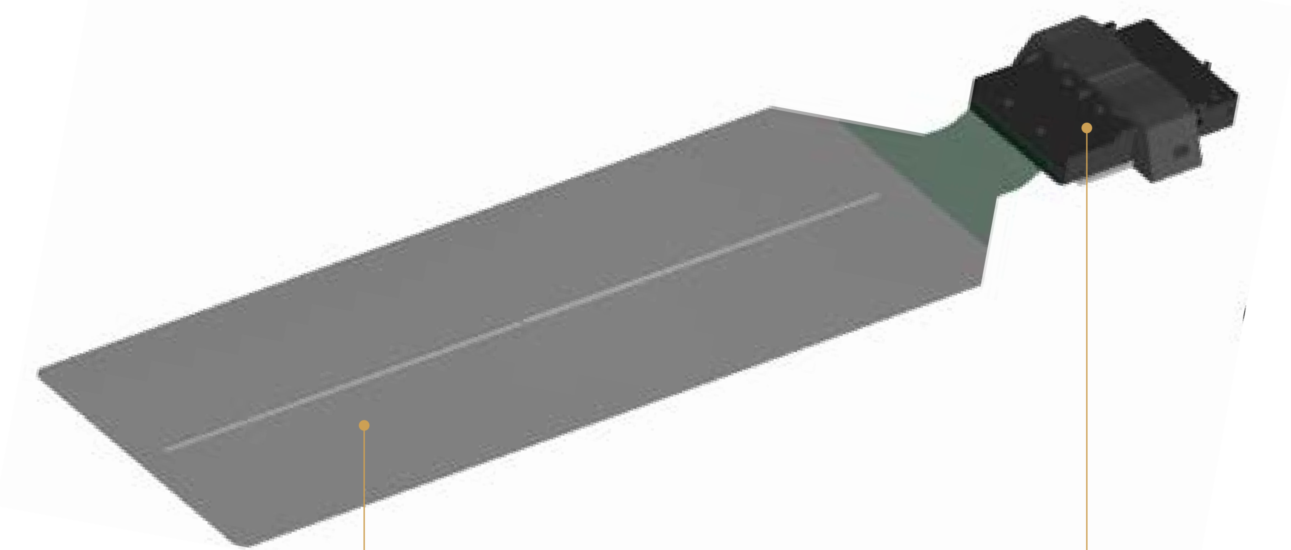


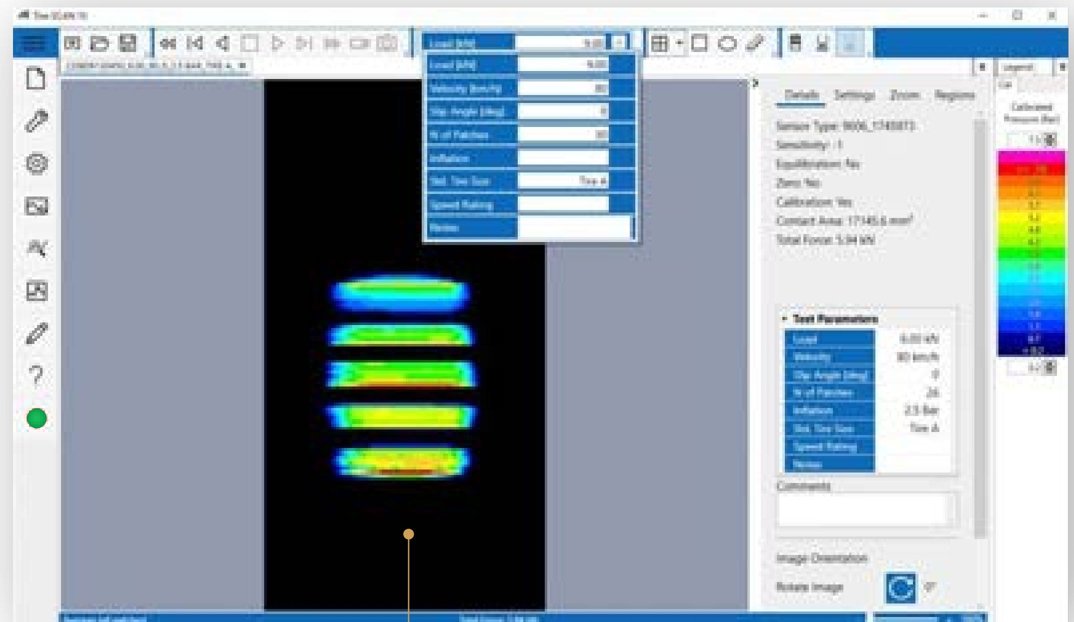
The black and red boxes represent the area of the tire where the sensor can make contact for a pass. The two different locations with unique sipe distribution can yield gaps in a tire patch.

For the best indication of performance, it is recommended that 20-30 patches be measured per test and averaged together.

Components of a High-Speed Tire Patch Measurement System

Tekscan technology has been extensively used by the tire industry for over 25 years to measure detailed tread pattern of static or slow-rolling tires. Incremental updates were made to Tekscan's core technology for the new High Speed TireScan™ System to measure the shape and pressure distribution of the contact patch of fast-moving tires.





Sensor
Minimally invasive piezoresistive sensor can measure the distribution of the vertical load in a variety of load conditions.

Electronics
Housed in a lightweight wireless device that scans the 128-point sensor array at up to 20 kHz, can capture tire contact patches at speeds of up to 265 kmh

Software
Streamlines data collection and creates an image of the tire footprint or contact patch. User can input test parameters from plan and review pressure distribution across various patches.

Instrumenting a Flat Track

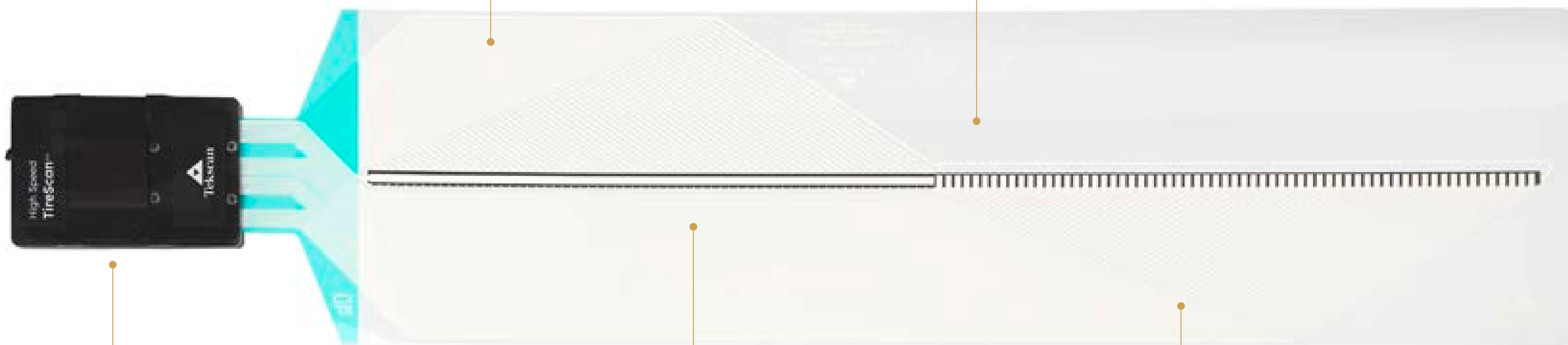
Sensor is mounted perpendicularly across the tire path with a double-sided tape

Can be Mounted Below the Sandpaper

- Does not impact sensor output
- Reduces variability of test. Ensures consistent road friction when traveling over sensor
- Minimally invasive (less than 0.5 mm thick)

2 Sensor Sizes Available

- Large: Truck, Race Tire, Aircraft – 478 mm
- Small: Passenger vehicles – 301 mm



Electronics are mounted to edge of belt surface using a mounting Sleeve that is adhered to the steel.

Measure a Broad Range of Loads

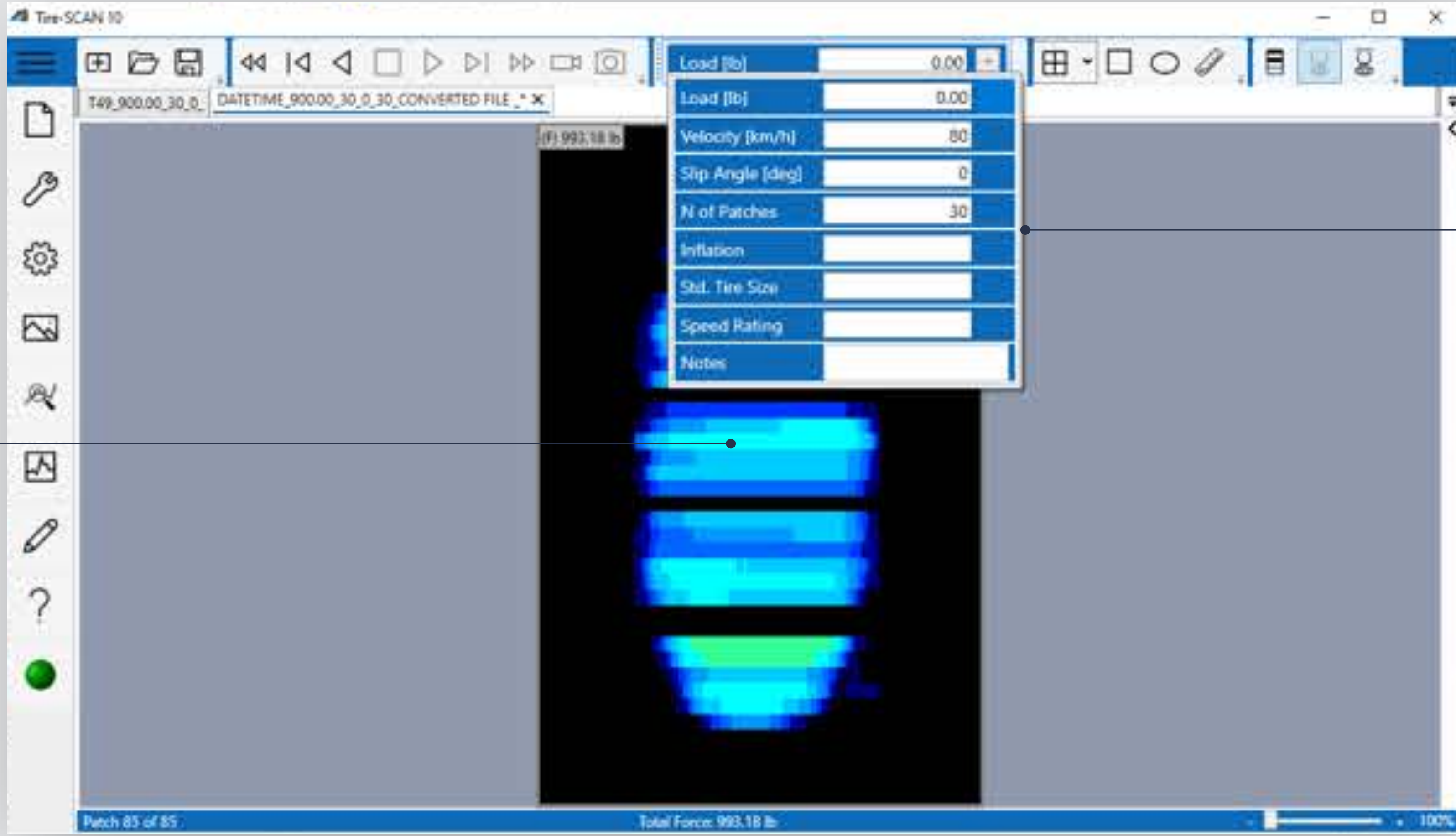
- Tire inflation pressures 20-300 psi (138 & 2068 kPa)
- Pressure loads over 600 psi (4137 kPa)

Thin Durable Construction

- Can endure 15 kN of shear force from slip angle test
- Measures patch at tire speeds of 270 km/h (168 mph)
- Stress tested for 30 days mounted to active system.

Stay in Sync with the Test Plan

As operator runs through test plan, data acquisition from patch is controlled wirelessly. Analysis can be run in High-Speed TireScan™ software or exported (.csv) for synchronization with other data collected.



Individual patch passes can be reviewed, or many averaged together

Input parameters from test specification

- Velocity used to create patch image
- System uses load value to calibrate distribution pressure

All parameters saved to file and auto create file name

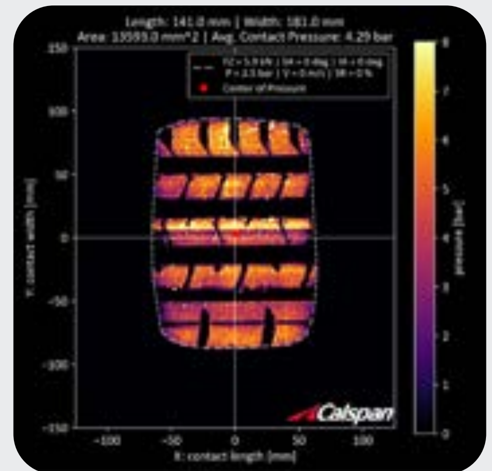
Validation of Technology

Calspan validated the High-Speed TireScan™ on their flat-belt machine against two existing technologies: traditional ink footprint measurements and Tekscan's 2D Pressure Mapping system (Cross-Drive), which is ideal for lower speed testing. This test environment ensured uniform, repeatable tire operating and loading conditions. Tests were conducted at low speed (1 m/s) to minimize the effect of speed on contact patch behavior. As these images display, the dimensions of the tire are consistent among the three technologies used. The results are similar, with minor variation due to resolution differences.

Ink Test

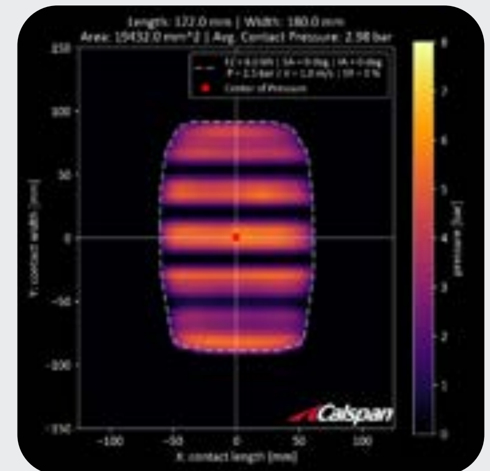
Load	6 kN
Length Ink	125 mm
Width Ink	181 mm

Tekscan's 2-D Pressure Mapping System
(CrossDrive)



Load	6 kN
Length Static	124 mm
Width Static	181 mm

High Speed TireScan™



Load	6 kN
Length DCPP	122 mm
Width DCPP	180 mm

Insights Comparing Similar Passenger Tires from Different Manufacturers

A prime use case example for the High-Speed TireScan™ system is benchmarking similar style tires from different manufacturers. In this example, three high performance summer tires from different manufacturers were tested under a variety of conditions.

Tire A:
235/50R20 104Y

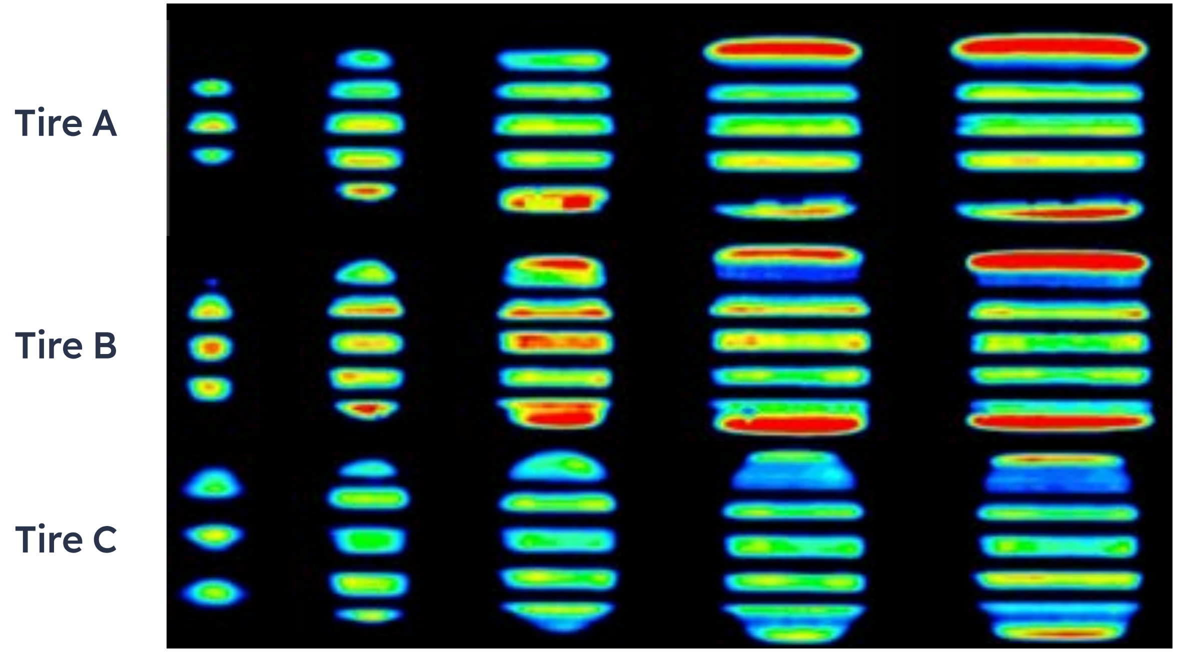
Tire B:
245/45R20 103Y

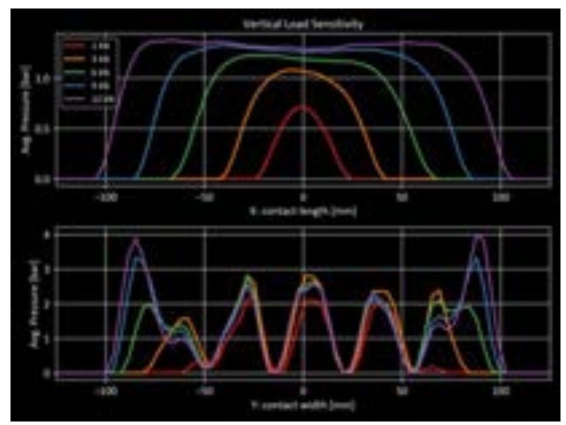
Tire C:
255/45R20 101W

Vertical Load Sensitivity

The High-Speed TireScan™ system shows the contact patch length and width increase as the load on the tire increases. The measurements also illustrate the point where the full width of the tire is in contact and additional load only yields additional contact patch length.

At very high loads some of the tires have significantly higher loading on the edge from sidewalls bearing more load. The highspeed system provides unique insights on how the tire design, material, reinforcements, and construction yield different tire patch load distribution for each of these tires.

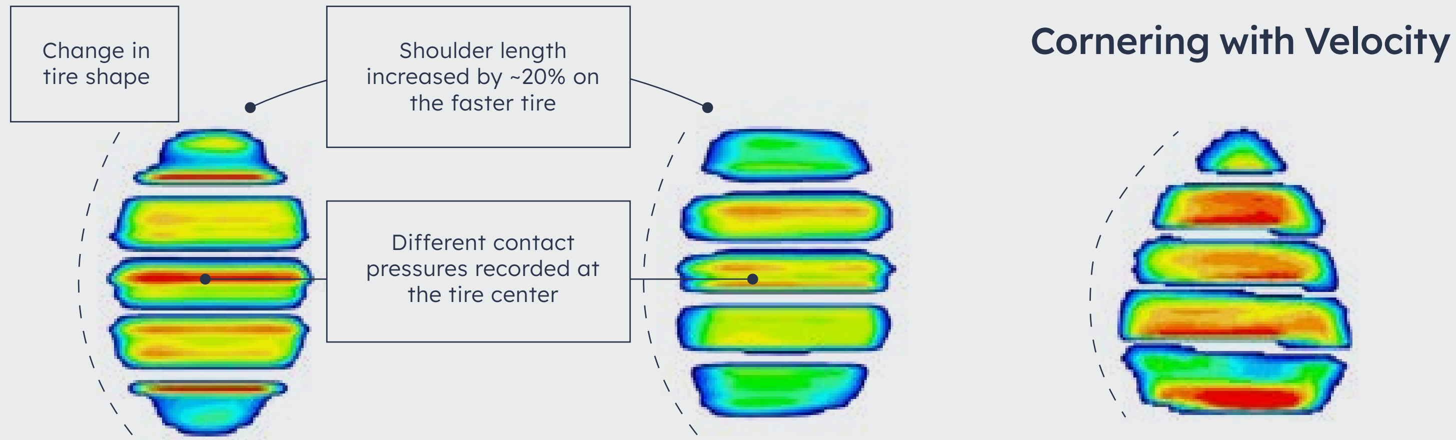




Comparison of pressure distribution of Tire A under different loads. When loads go above 6 kN, excess load begins to appear on the shoulders of this tire design.

Impact of Velocity and Slip Angle on Contact Patch Pressure Distribution

Velocity will also impact the shape of the tire's contact patch. One of the challenges of tire design is to optimize materials and reinforcements to get the right stiffness for target conditions. The High Speed TireScan™ can measure the changes to the contact patch shape and pressure distribution as velocity increases or slip angle is applied.



Tire Footprint Captured at 48 km/h (30 mph)

Same Tire Captured at 193 km/h (120 mph)

Same Tire in a 3.5° Slip Angle Test, Catured at 48 km/h (30 mph)

The robust High Speed TireScan™ sensor can withstand aggressive forces of slip angle tests without a protective cover.

Extreme Cornering

OBSERVATION

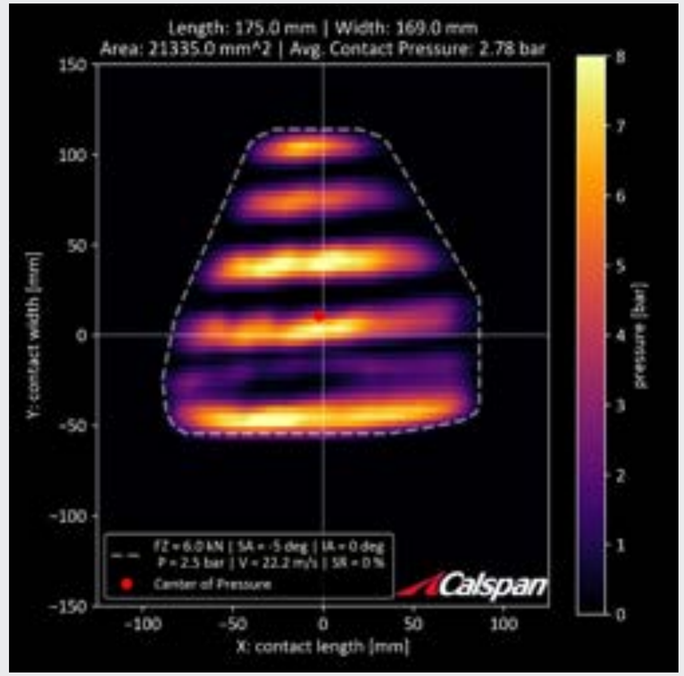
Calspan observed a unique phenomenon during an extreme cornering test with the High-Speed TireScan™ system. The dynamic contact patch measurement revealed a gap in pressure within the contact patch of a tire experiencing 9kN of shear force from cornering.

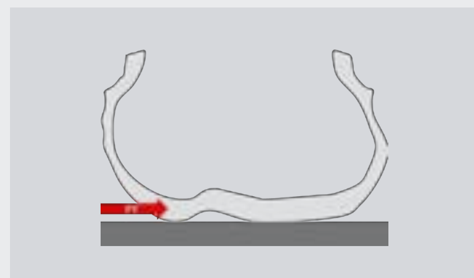
HYPOTHESIS

They hypothesized that lateral forces caused the tires belt package to buckle, which lifted part of the tread off the road, resulting in no contact.

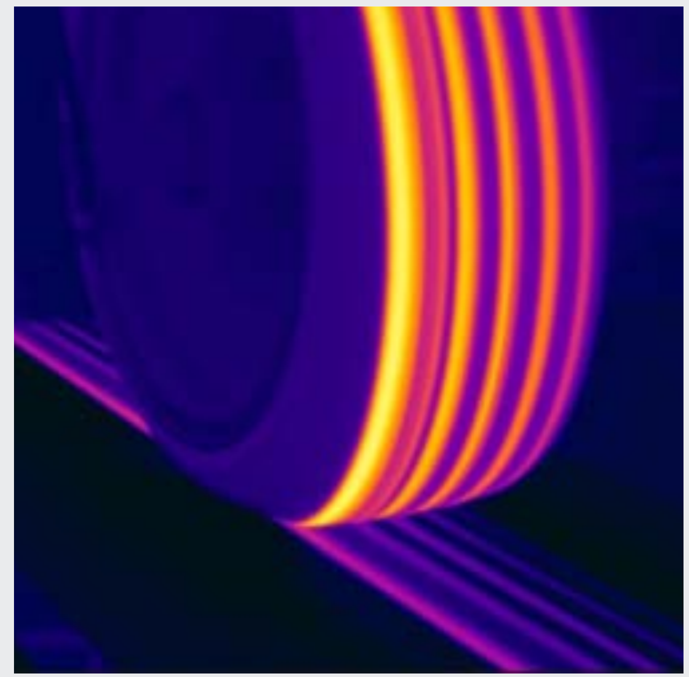
VALIDATION

By synchronizing thermal video with the High-Speed TireScan™ data, Calspan verified their theory. There was a lower temperature detected in the area of the sensor that had no pressure, indicating lack of frictional heating, in turn verifying lack of contact.





Thermal State at the time of DCPP data



Key Applications for Tire Patch Data

With High-Speed TireScan™, researchers can apply insights to optimize parameters for their application. They can conduct new analysis on tires for a clearer picture of performance and apply this incremental data for improved tire modeling.

During their testing with High-Speed TireScan, Calspan was able to observe the impact to the tire patch under a diverse range of test cases:

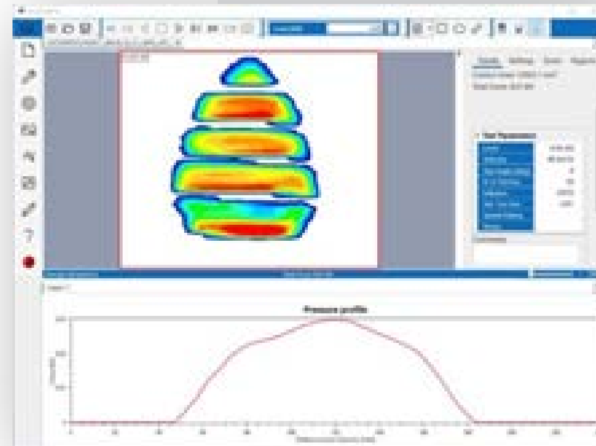
- Vertical Load: 1 kN – 12 kN
- Camber Angle: +/- 5 deg
- Infl. Pressure: 2.2, 2.5, 2.8 bar
- Speed: 5 – 160 kph
- Slip Angle: +/- 5 deg
- Slip Ratio: +/- 8 %

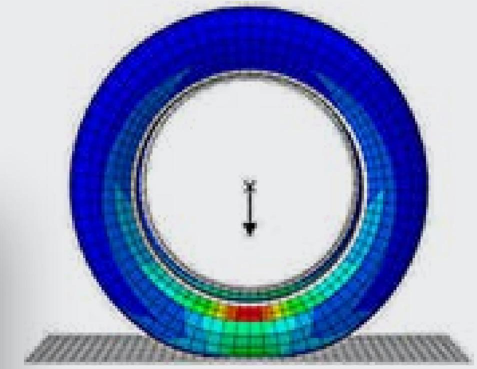
Evaluate Tire Performance

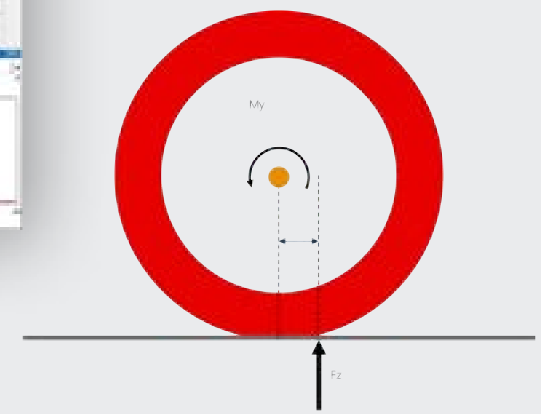
- **Characterize Tire Contact Patch Behavior** – Better understand the specific performance impact of incremental changes to the tire design
- **Illustrate Tire Wear** – With the focus expanding from tire longevity to non-exhaust emissions, measuring how the tire is wearing will provide researchers critical data to help satisfy market demands
- **Evaluate Rolling Resistance** – Understanding the details of the patch distribution under a variety of load conditions, including slip and camber, can help minimize the impact to a vehicle's range rating

Enhance Tire Modeling

- **Validate Existing Finite Element Analysis (FEA) Models** – Currently, static patch data is commonly referenced. However, this approach neglects the impact of centrifugal forces, which can be complicated in slip angle conditions
- **Improve Representation of Patch in Model Formulas** – As the market continues to challenge performance, designers can respond with more accurate models built using data from the High Speed TireScan system



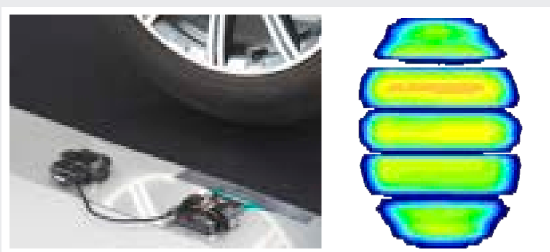




Analyzing the Tire from 360 Degrees

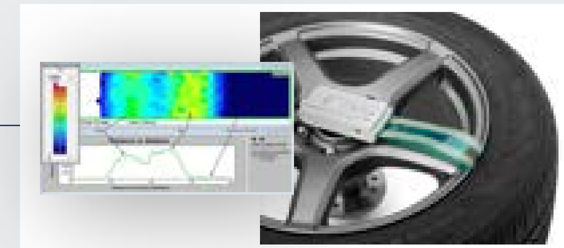
Tekscan offers 3 tire pressure mapping technologies that provide complementary data to get the most comprehensive overview of tire performance.

High-speed Analysis



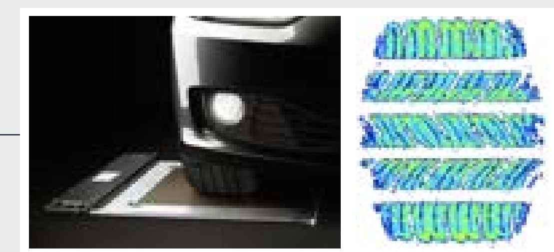
Shows contact shape and pressure distribution of fast moving tires

Tire Bead



Shows tire bead contact pressure profile

Tire Footprint Performance



Shows detailed tread pattern for static or slow rolling tires

Tekscan™

Let’s discuss your next tire application.

We at Tekscan understand the challenges R&D teams face, and the risks they take when investing in test & measurement technology. Whether it’s a standard pressure mapping system, or a custom solution, Tekscan has a proven track record for helping R&D teams achieve a better understanding of their products and procedures by providing trustworthy, actionable data. Your return on investment comes in the form of confidence in your product design, a shortened development process time, and an improved end user experience.

Visit **tekscan.com**
or call **1.617.464.4282**
for more information.