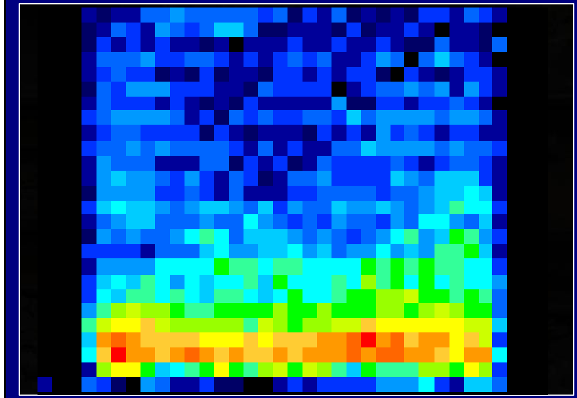
Effect of Lateral Load on Rail Seat Pressure Distributions



RailTEC Industry Partners Meeting

Incline Village, NV

7 October 2013

Matthew J. Greve, J. Riley Edwards, Marcus S. Dersch,
Ryan G. Kernes, and Christopher P.L. Barkan

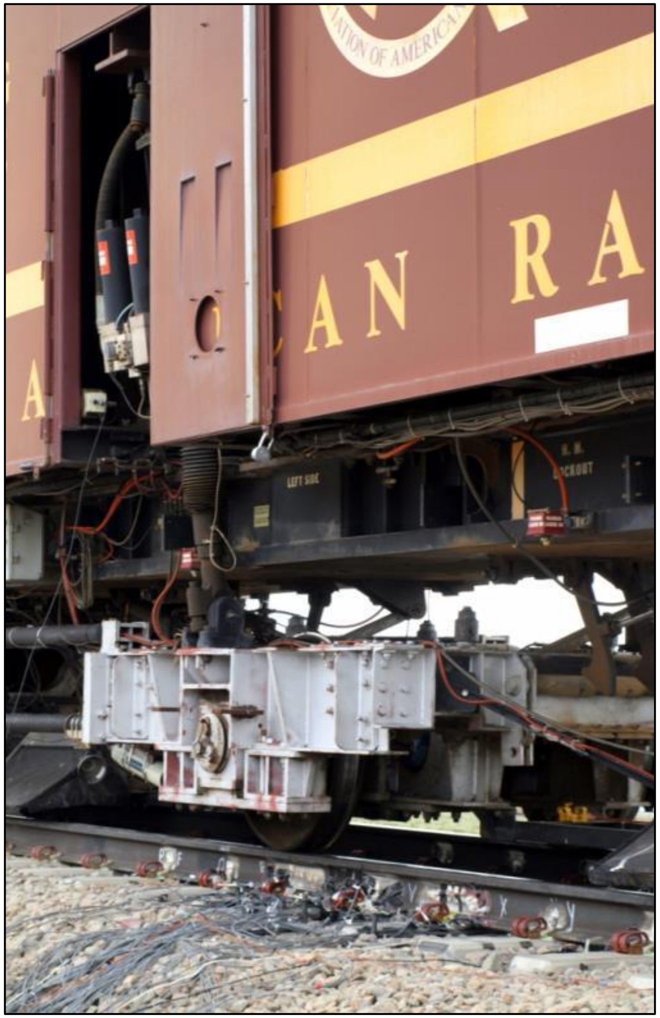
U.S. Department of Transportation
Federal Railroad Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Amsted RPS
Amsted Rail

Outline

- FRA Project Objectives
- RSD Background
- Equipment Overview
- Pressure Distribution Relation to RSD
- Field Data Analysis
  - Load Distribution Progression
  - Contact Areas vs. L/V
  - Pressure Comparison
- Conclusions
- Future Work



FRA Project Objectives

- Expand knowledge of international practices and standards for concrete crosstie and fastening system design
- Improve understanding of vertical and lateral load paths within track superstructure
- Develop recommendations for conventional component and interface design based on findings
- Provide framework for mechanistic design approach for concrete crossties and fastening systems

Overall Project Deliverables

Mechanistic Design Framework

Literature Review

Load Path Analysis

International Standards

Current Industry Practices

AREMA Chapter 30

I – TRACK

Statistical Analysis from FEM

Free Body Diagram Analysis

Probabilistic Loading

Finite Element Model

Laboratory Experimentation

Field Experimentation

Parametric Analyses

Current Objectives of Experimentation with Matrix Based Tactile Surface Sensors (MBTSS)

- Measure magnitude and distribution of pressure at the concrete crosstie rail seat
- **Improve understanding of how load from wheel/rail interface is transferred to rail seat**
- **Compare pressure distribution on rail seats:**
  - **Under various loading scenarios**
  - Under various fastening systems
- **Identify regions of high pressure and quantify peak values**

Rail Seat Deterioration Background

- Rail Seat Deterioration (RSD) is the degradation of concrete directly underneath the rail pad, resulting in track geometry problems
- Surveys conducted by UIUC report that North American Class I Railroads and other railway infrastructure experts ranked RSD as one of the most critical problems associated with concrete crosstie and fastening system performance
- Potential RSD mechanisms as determined through research at UIUC:
  - Abrasion
  - Crushing
  - Freeze-thaw
  - Hydraulic pressure cracking
  - Hydro-abrasive erosion

MBTSS Equipment

- Hardware and software by Tekscan, Inc.
- Components:
  - Sensor
  - Data acquisition handle
  - I-Scan software

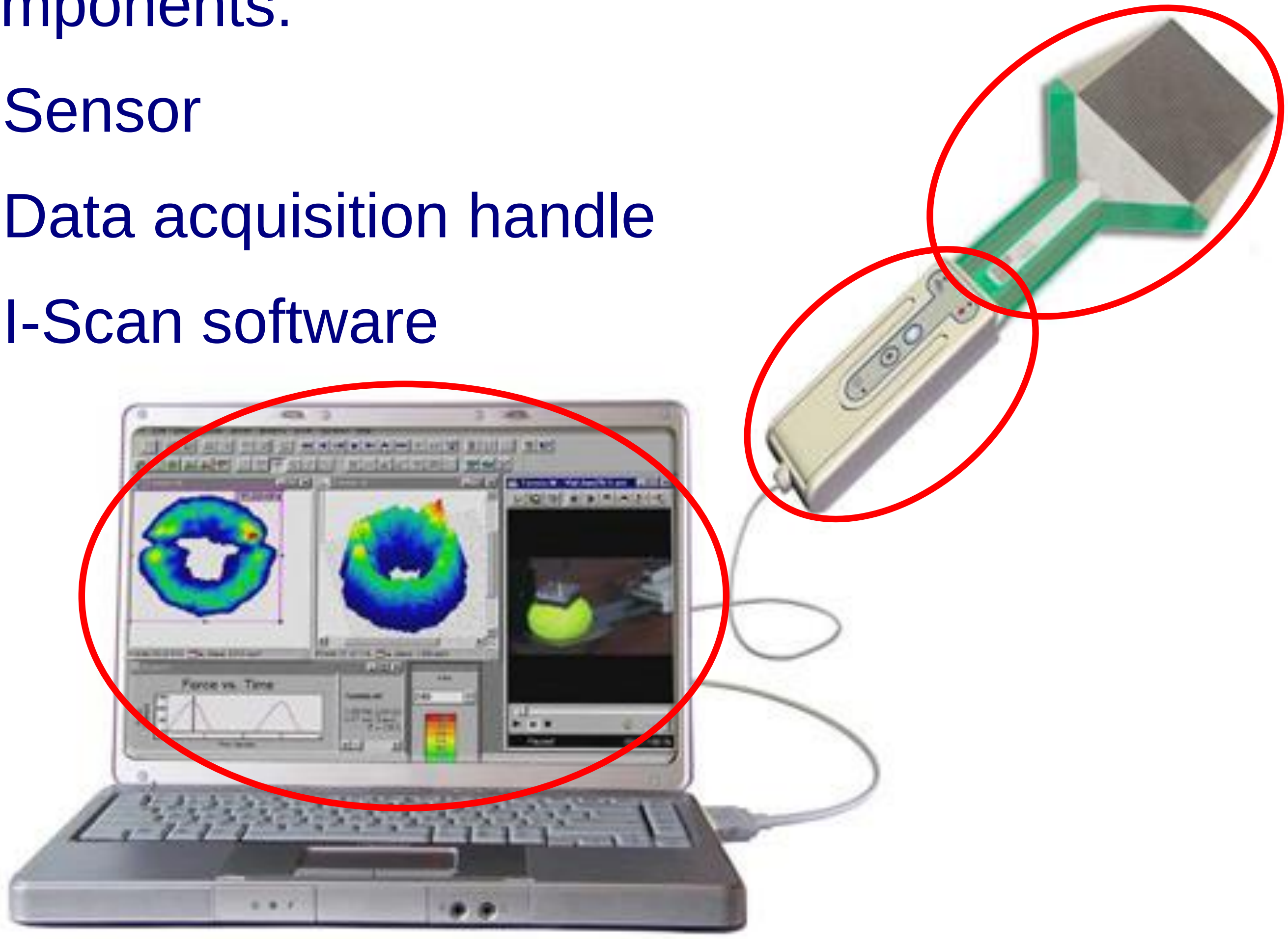
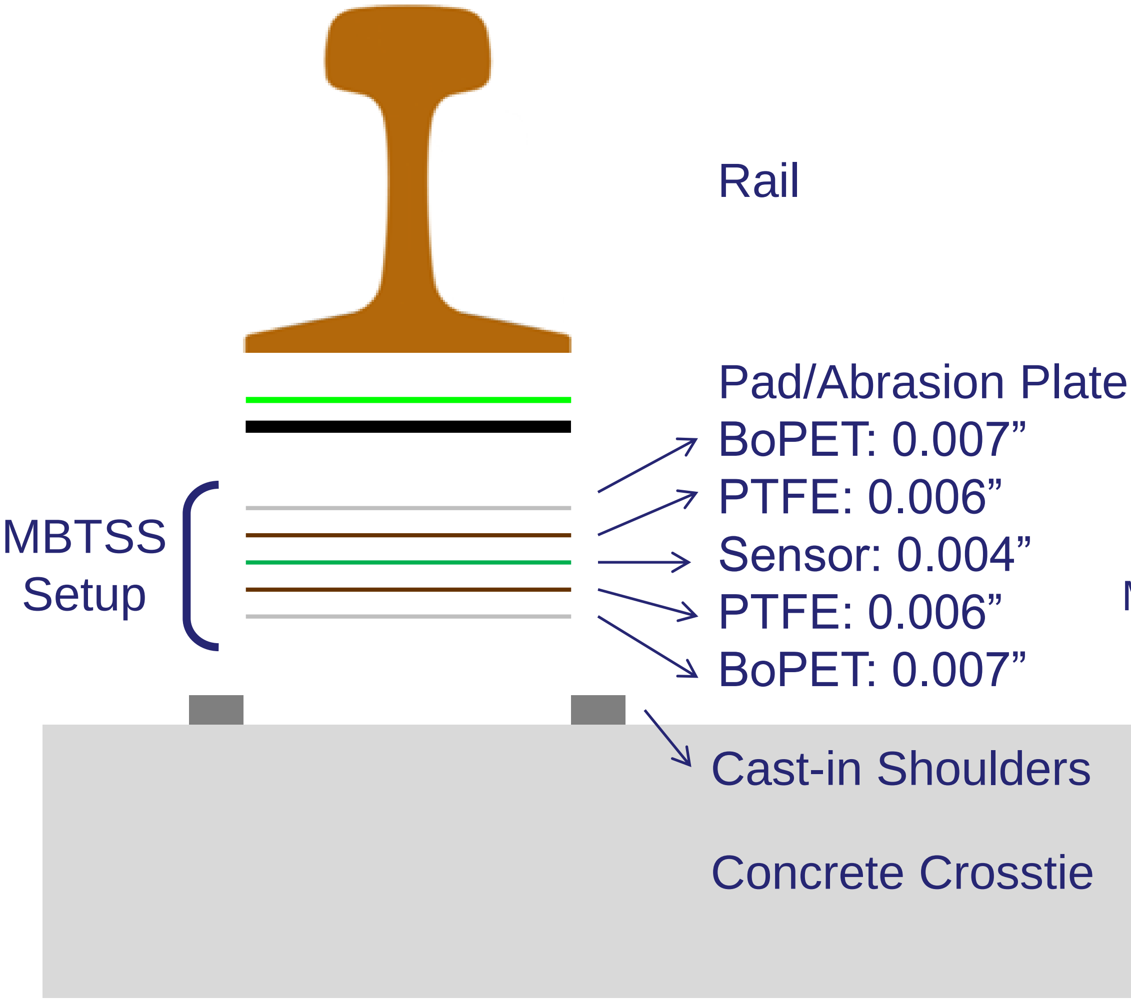


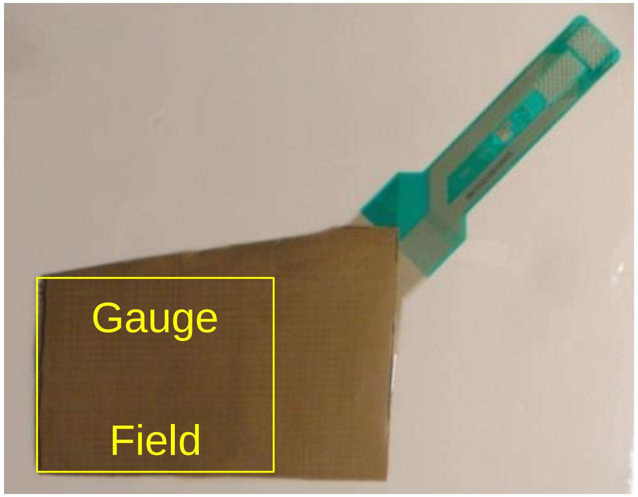
Image from: http://www.tekscan.com/pressure-distribution-measurement-system

Equipment Preparation and Protection

- Sensors trimmed to fit rail seat
- BoPET and PTFE layered on each side of sensor to protect from shear and puncture damage
- Plastic sleeves and plastic bags to protect sensor tabs from puncture and debris between experiments
- Plastic sleeves to protect data acquisition handles during experimentation

Sensor Installation





Matrix Based Tactile Surface Sensor

MBTSS Laboratory Testing Overview

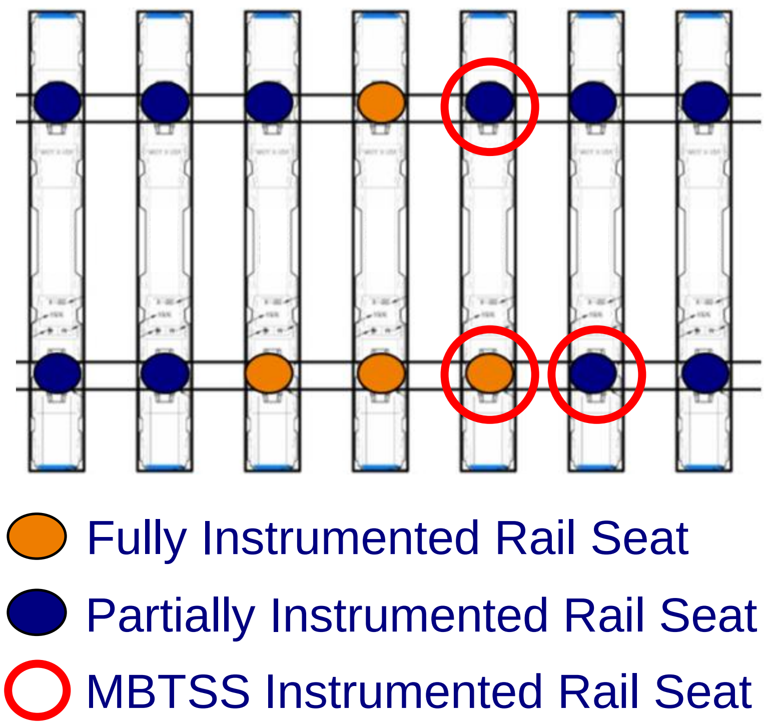
- First used in railroad applications by University of Kentucky on timber crossties
- Laboratory experimentation with Pulsating Load Testing Machine (PLTM)
  - Two 35,000 lb (156 kN) vertical actuators
  - One 35,000 lb (156 kN) lateral actuator
- Ability to simulate various L/V force ratios by varying loads
- Proven feasibility for use on concrete crosstie rail seats
- Laboratory experimentation performed varied:
  - Rail pad materials, geometry, and type
  - Fastening clip type

Field Experimentation Overview

- Field instrumentation at the Transportation Technology Center, Inc. (TTCI) in Pueblo, CO
- MBTSS used with multiple instrumentation technologies to better understand:
  - Tangent vs curved track
  - Effect of reduced contact area
  - Role of individual crosstie support conditions
  - Lab experiments vs in-service conditions
  - Static vs dynamic loading environments

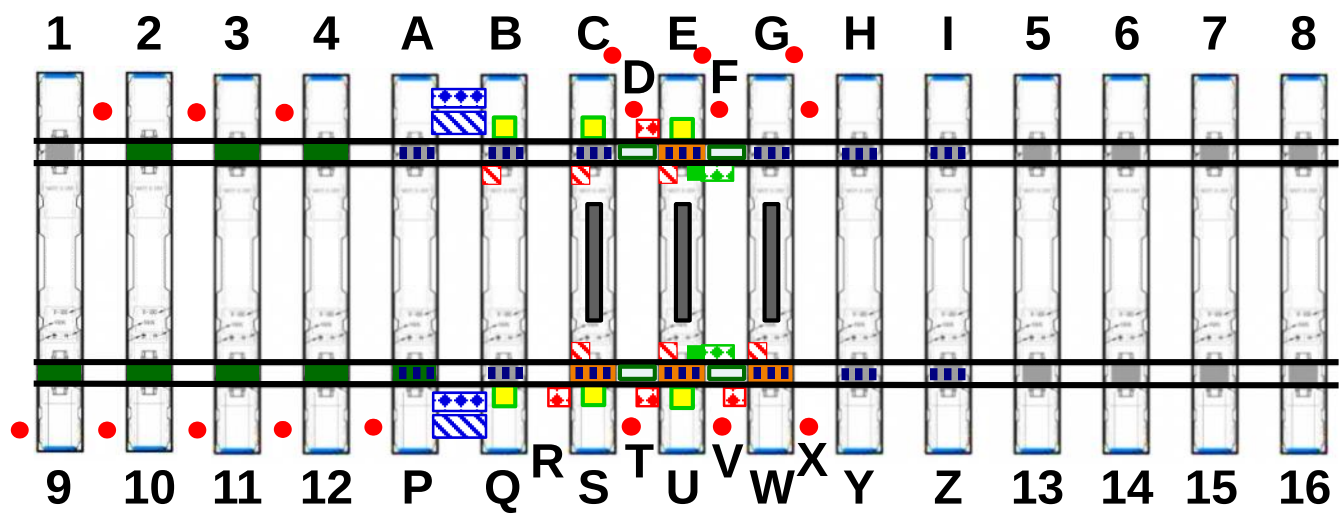
July 2012 Field Instrumentation

- Initial installation of various instrumentation technologies (e.g. MBTSS, strain gauges, potentiometers) to capture loads and behavior of various aspects of the concrete sleepers and fastening systems
- Successes:
  - Proof of feasibility for field applications
  - Effect of lateral load on longitudinal distribution
  - Guidance for future field instrumentation
- Limitations:
  - Limited number of rail seats
  - Did not capture vertical tie displacement
  - Lateral load path affected by protective layers



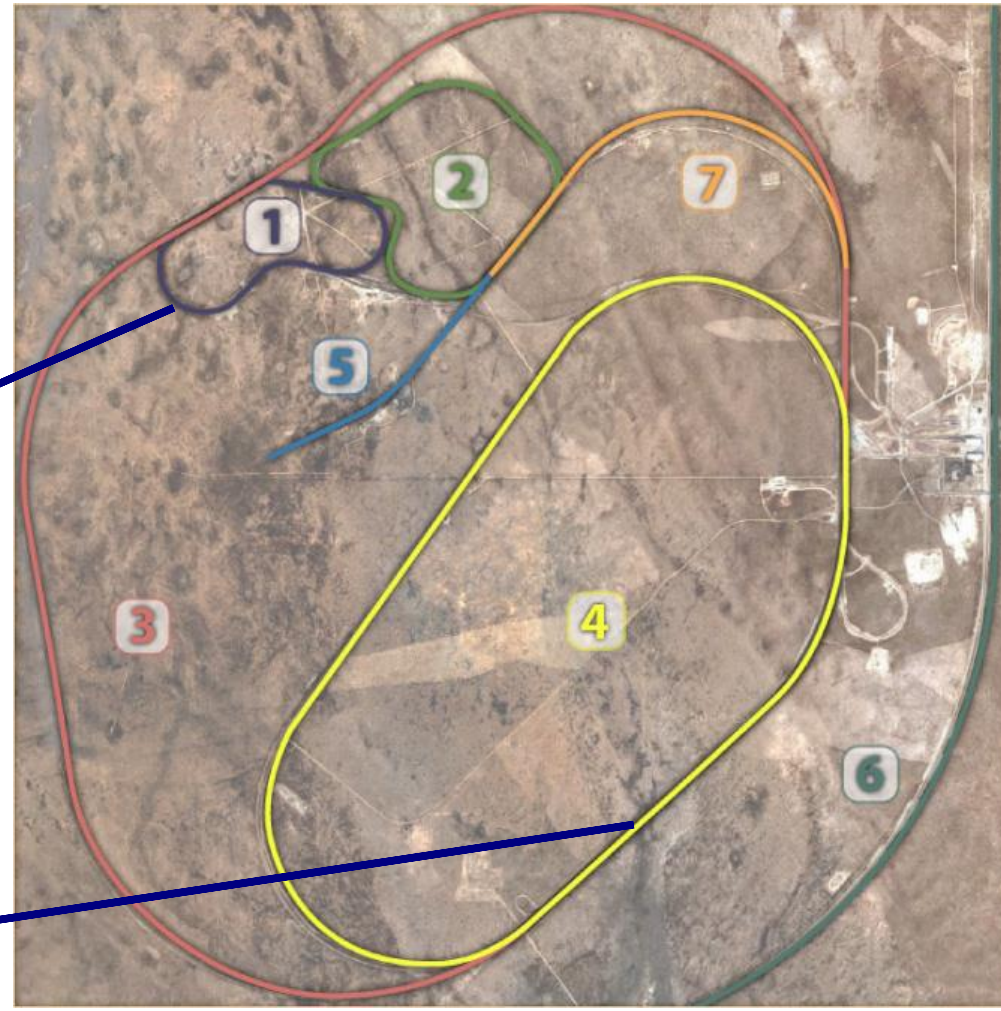
May 2013 Field Instrumentation

- Collected data from 8 MBTSS sensors simultaneously
  - Separation from lateral load instrumentation
  - Effect of individual crosstie support conditions
  - Capture of entire distribution of wheel-rail load



- Rail Displacement Fixture
- Rail Longitudinal Displacement/Strains
- Pad Assembly Longitudinal Displacement
- Pad Assembly Lateral Displacement
- Insulator Longitudinal Displacement
- Insulator Vertical Displacement
- Steel Rods
- Vertical Web Strains
- Vertical and Lateral Circuits
- Shoulder Beam Insert (Lateral Force)
- Embedment Gages, Vertical Circuit, Clip Strains
- Crosstie Surface Strains
- MBTSS

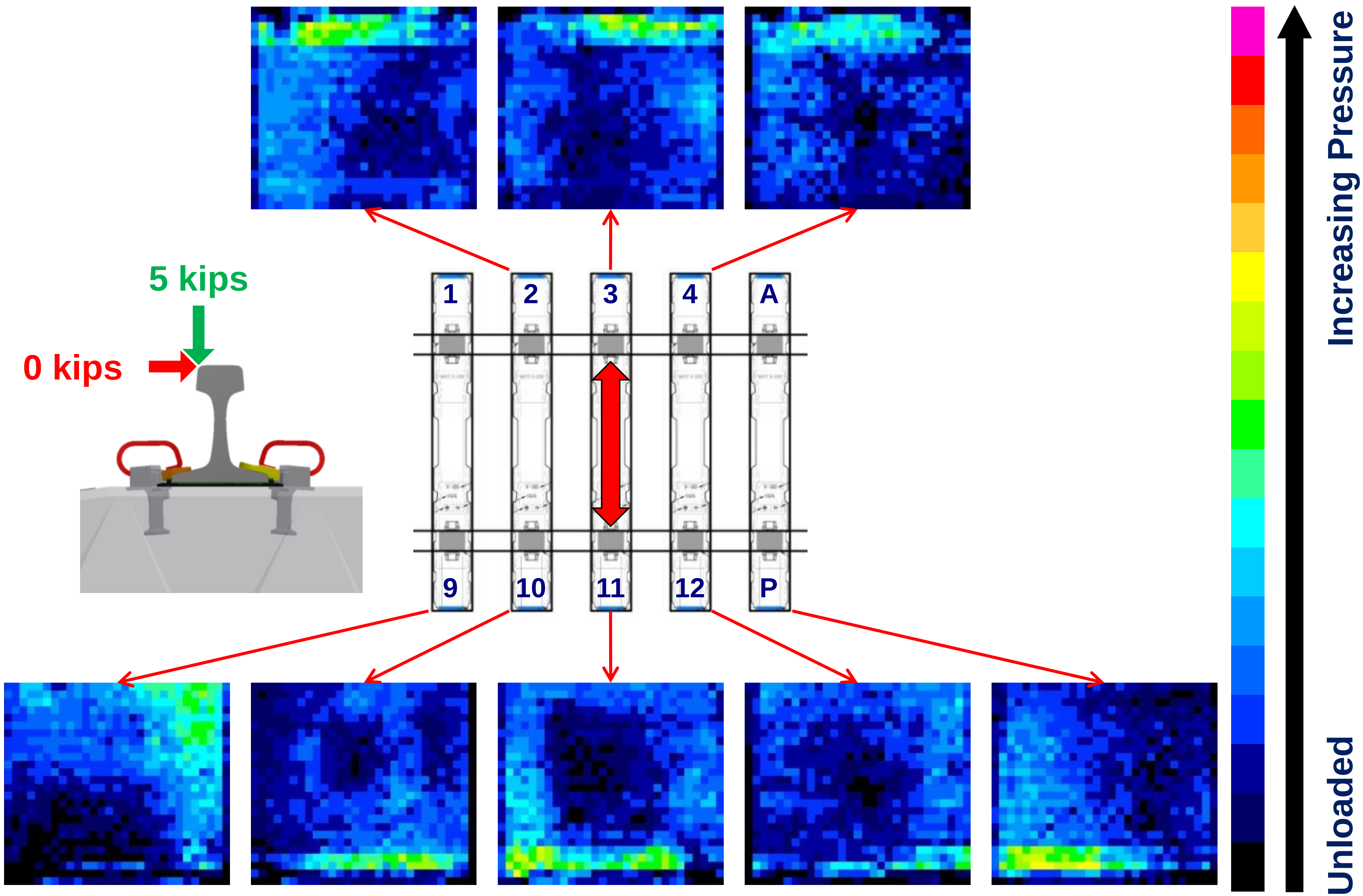
TTC Field Testing Locations



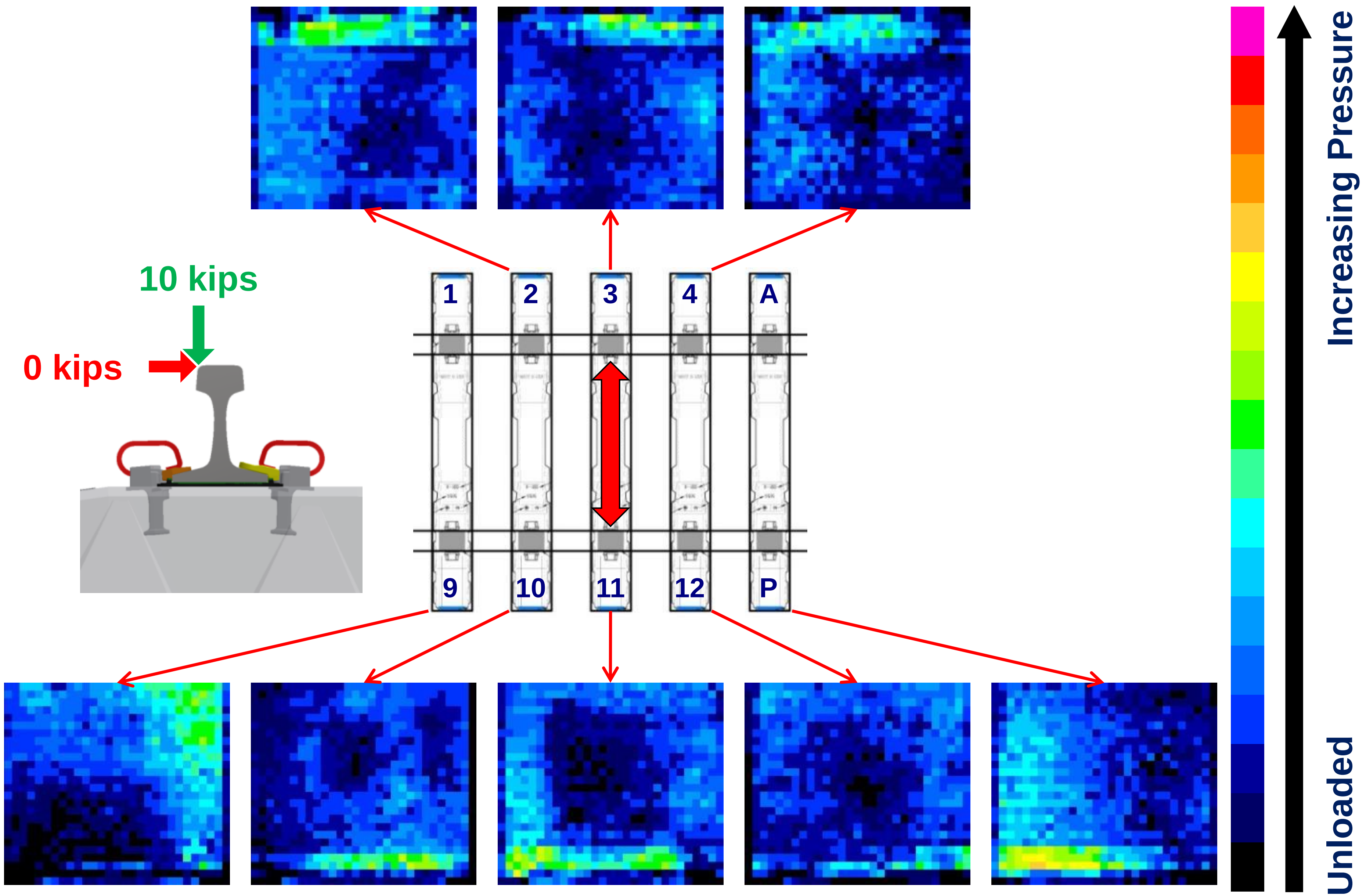
Load Input: Track Loading Vehicle (TLV)

- Modified railcar with instrumented wheelset on hydraulic actuators
- Can apply known and controlled loads to track structure
- L/V force ratio testing:
  - Vertical loads ranging from 0 to 40,000 lbs (178 kN)
  - Lateral loads ranging from 0 to 22,000 lbs (97.8 kN)

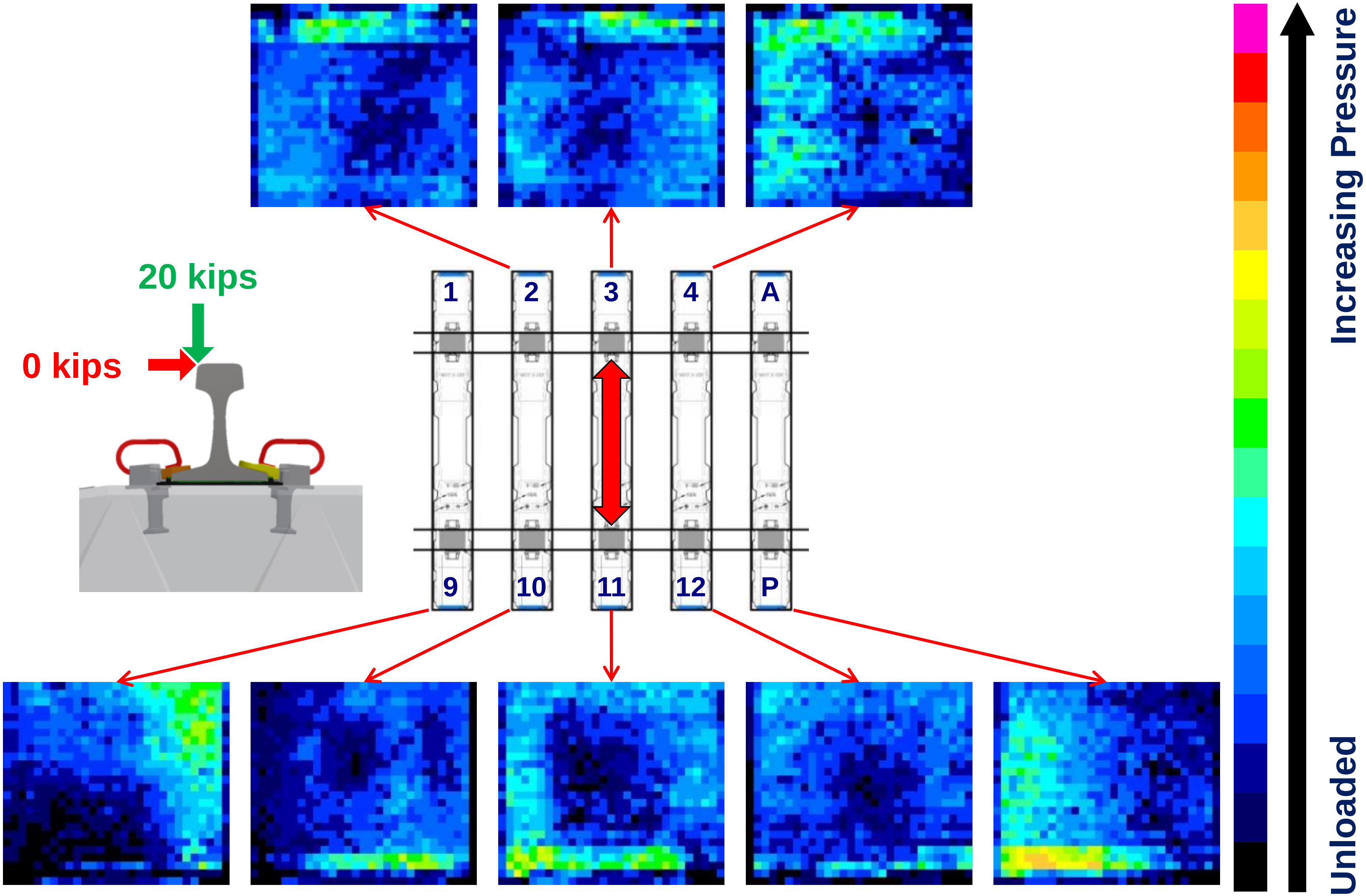
Increasing Vertical Load Magnitudes



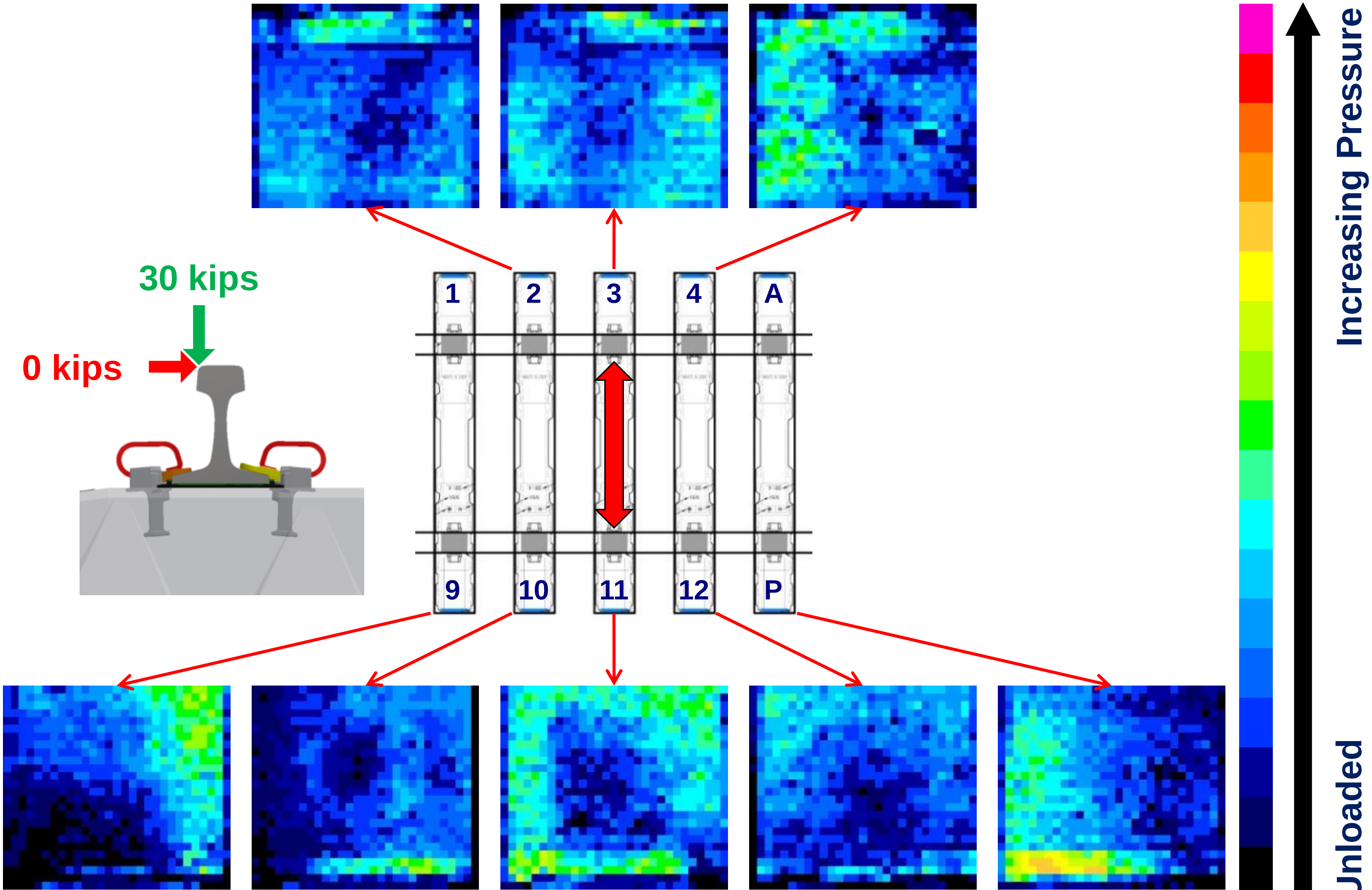
Increasing Vertical Load Magnitudes



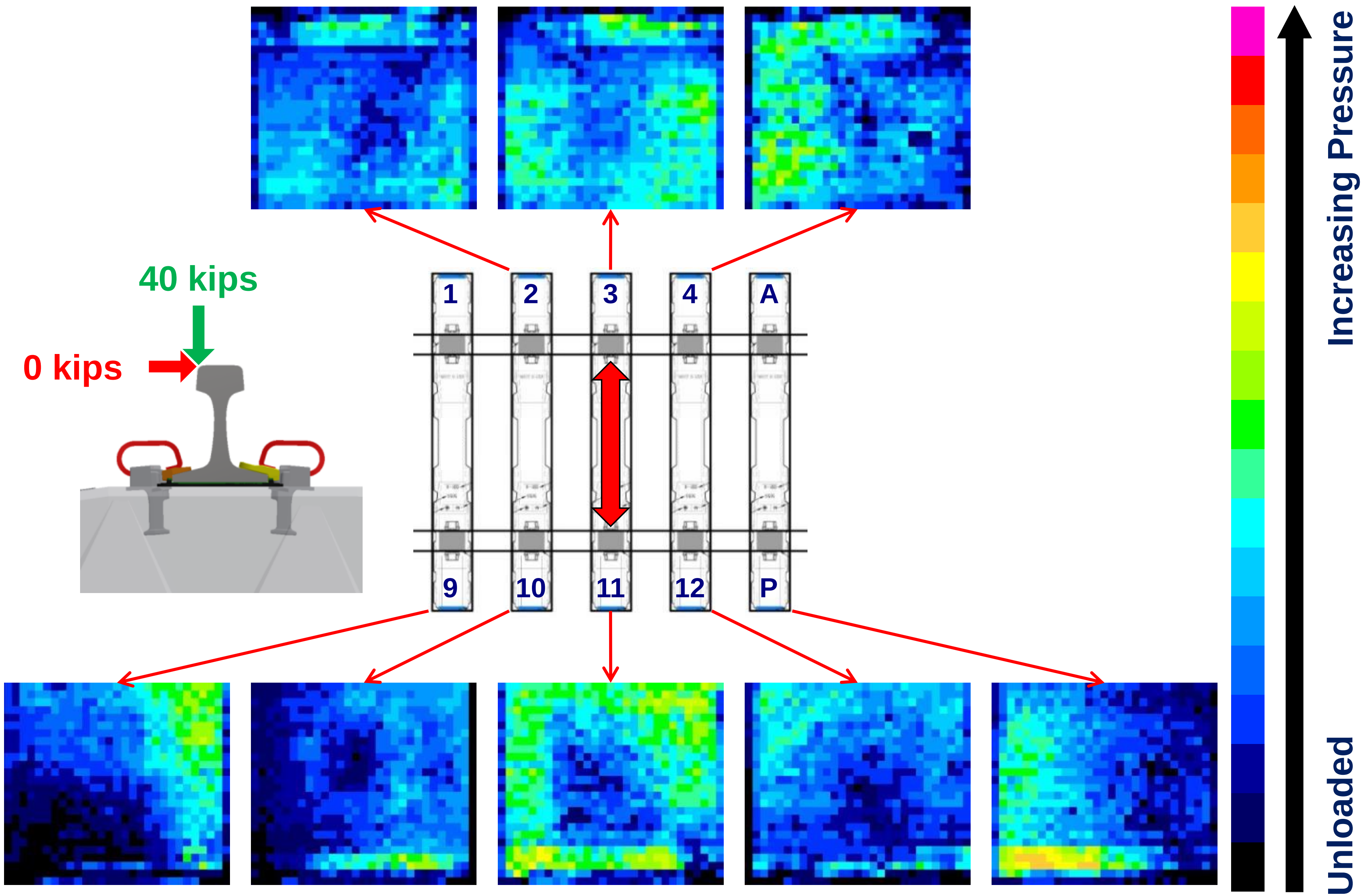
Increasing Vertical Load Magnitudes



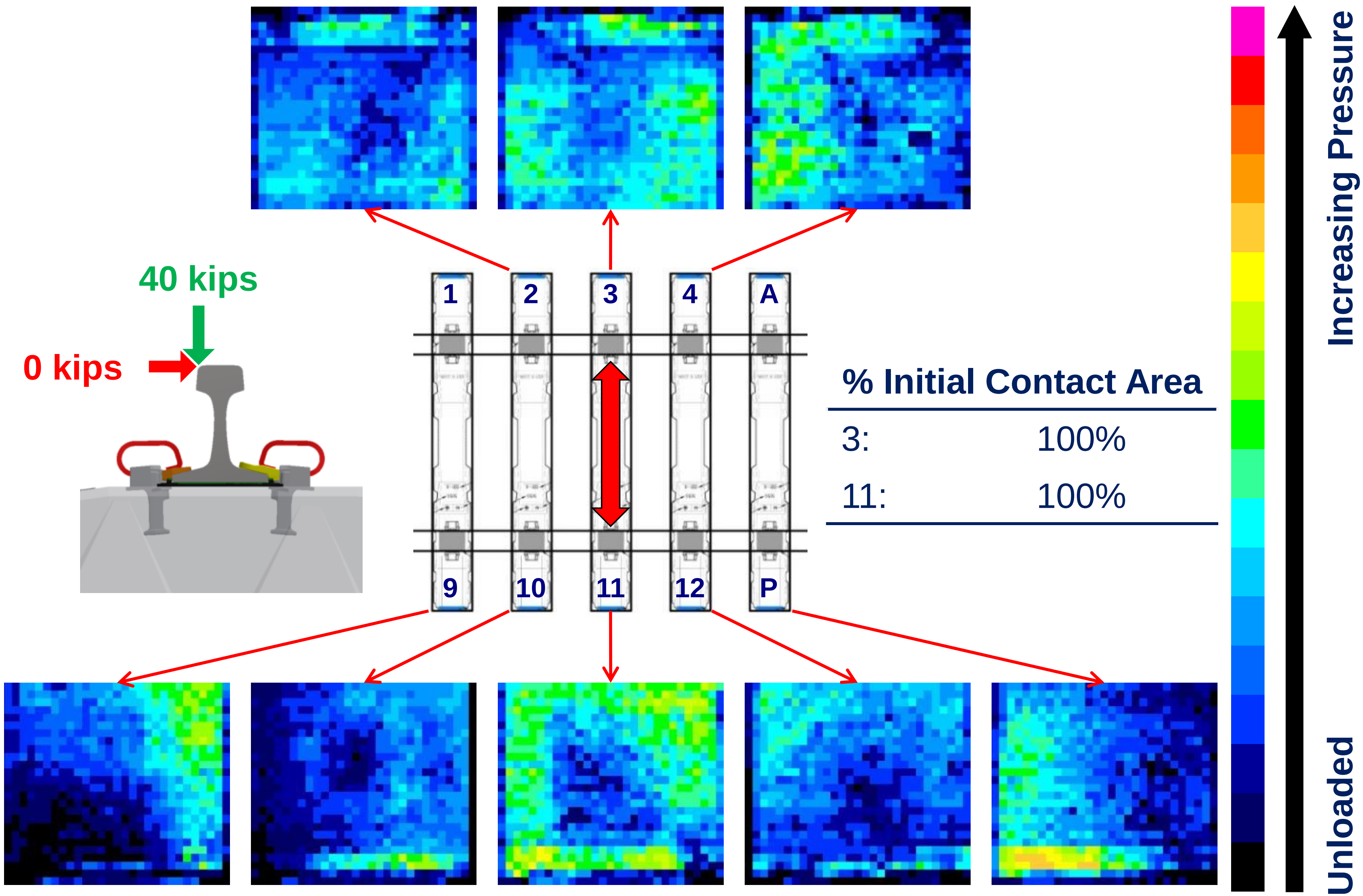
Increasing Vertical Load Magnitudes



Increasing Vertical Load Magnitudes

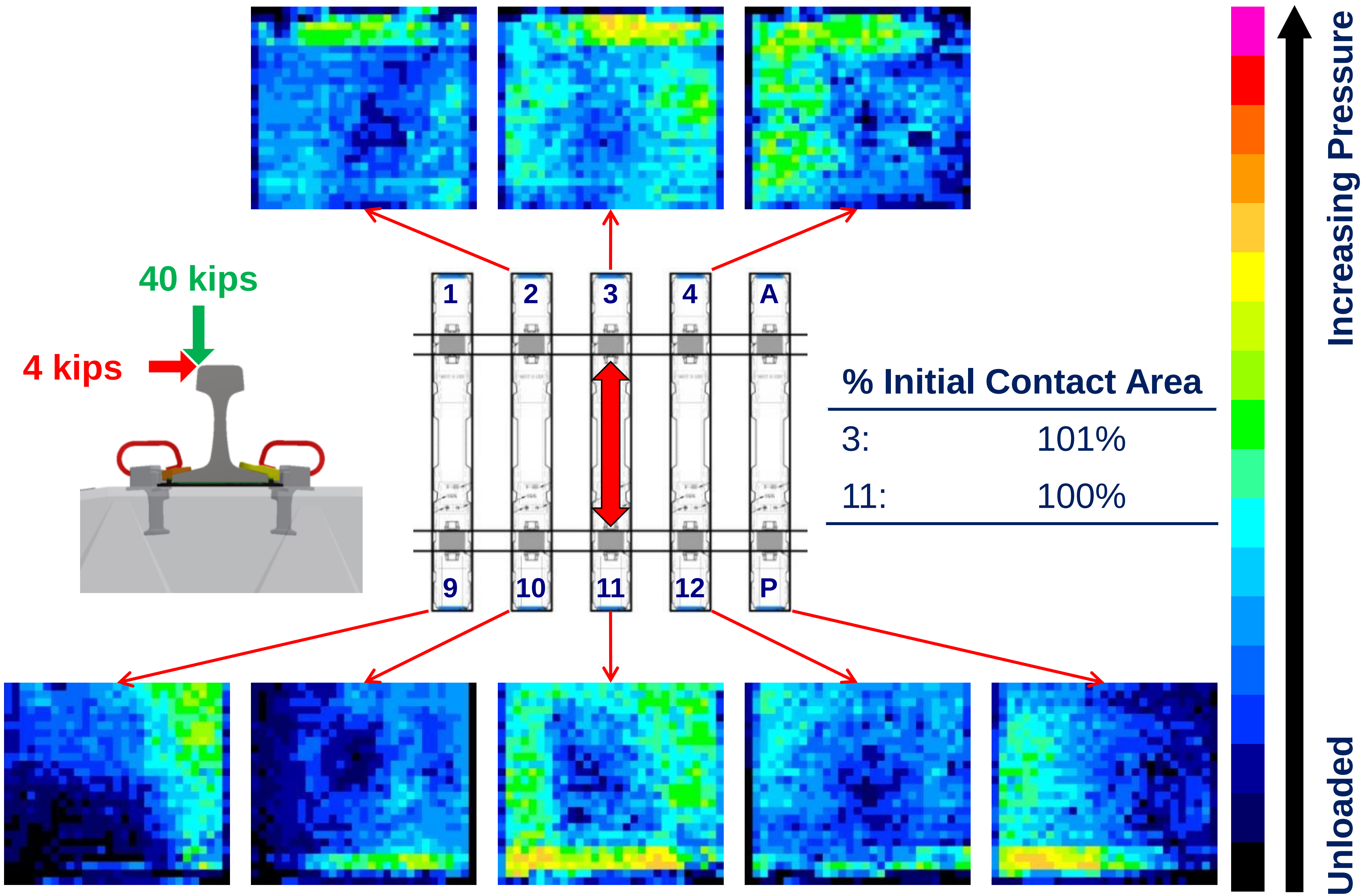


Increasing L/V Force Ratio



% Initial Contact Area	
3:	100%
11:	100%

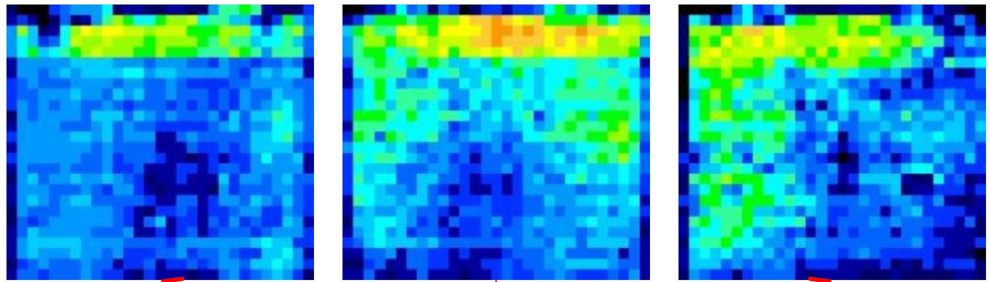
Increasing L/V Force Ratio

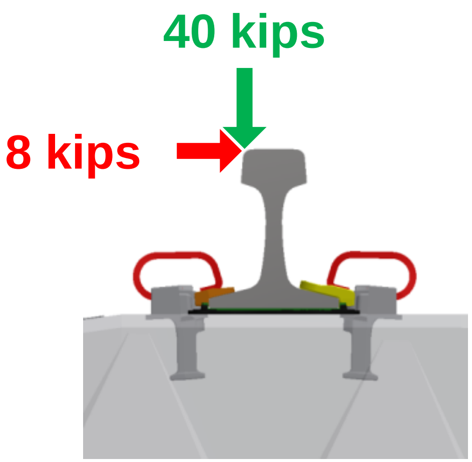


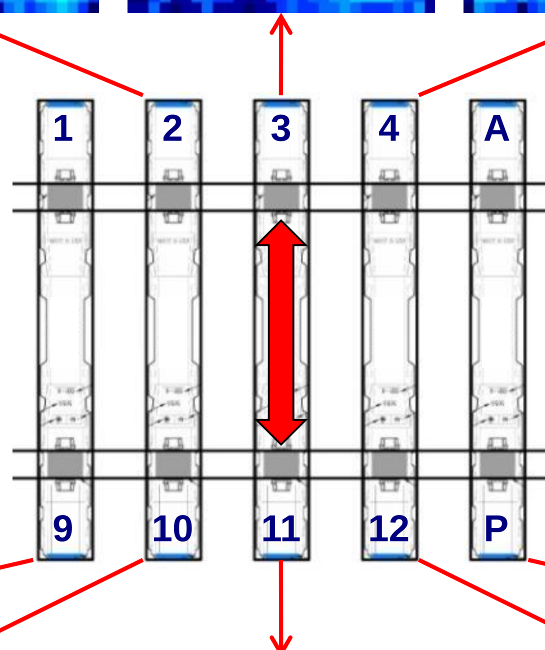
% Initial Contact Area

3:	101%
11:	100%

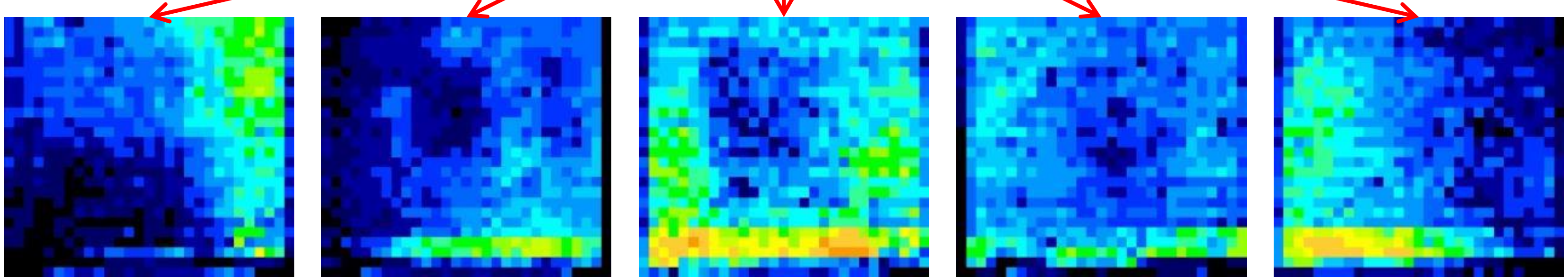
Increasing L/V Force Ratio

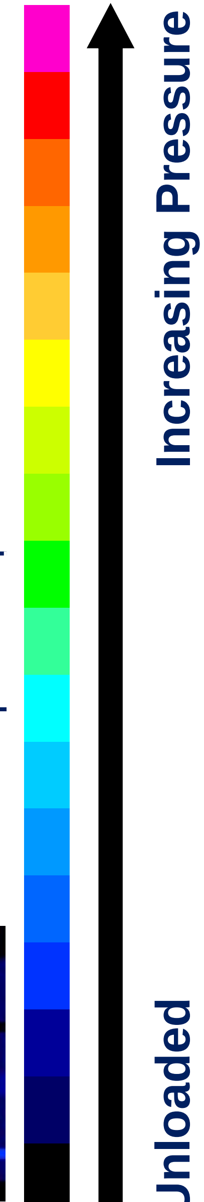




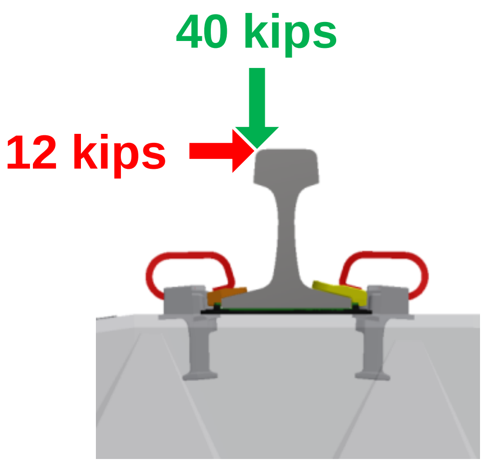


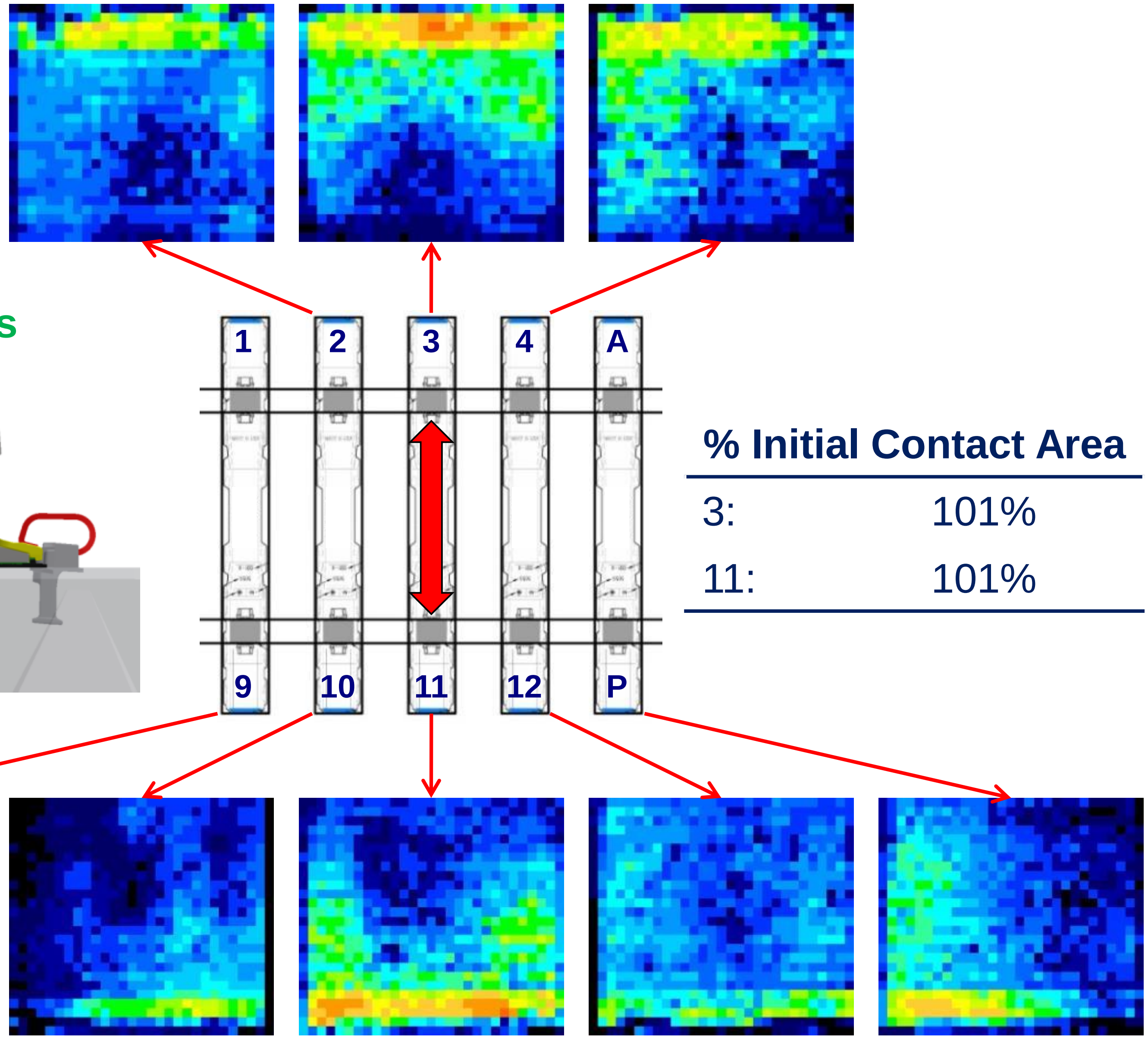
% Initial Contact Area	
3:	101%
11:	101%



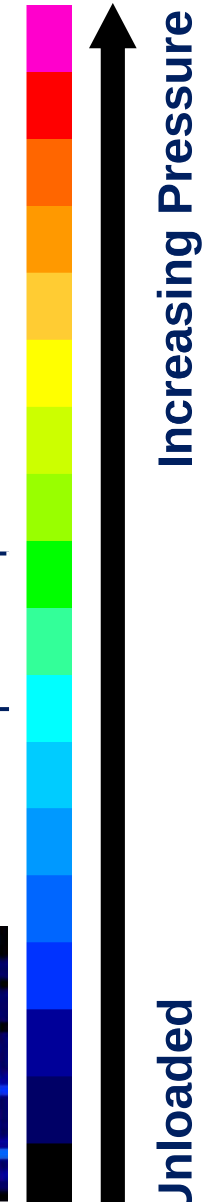


Increasing L/V Force Ratio

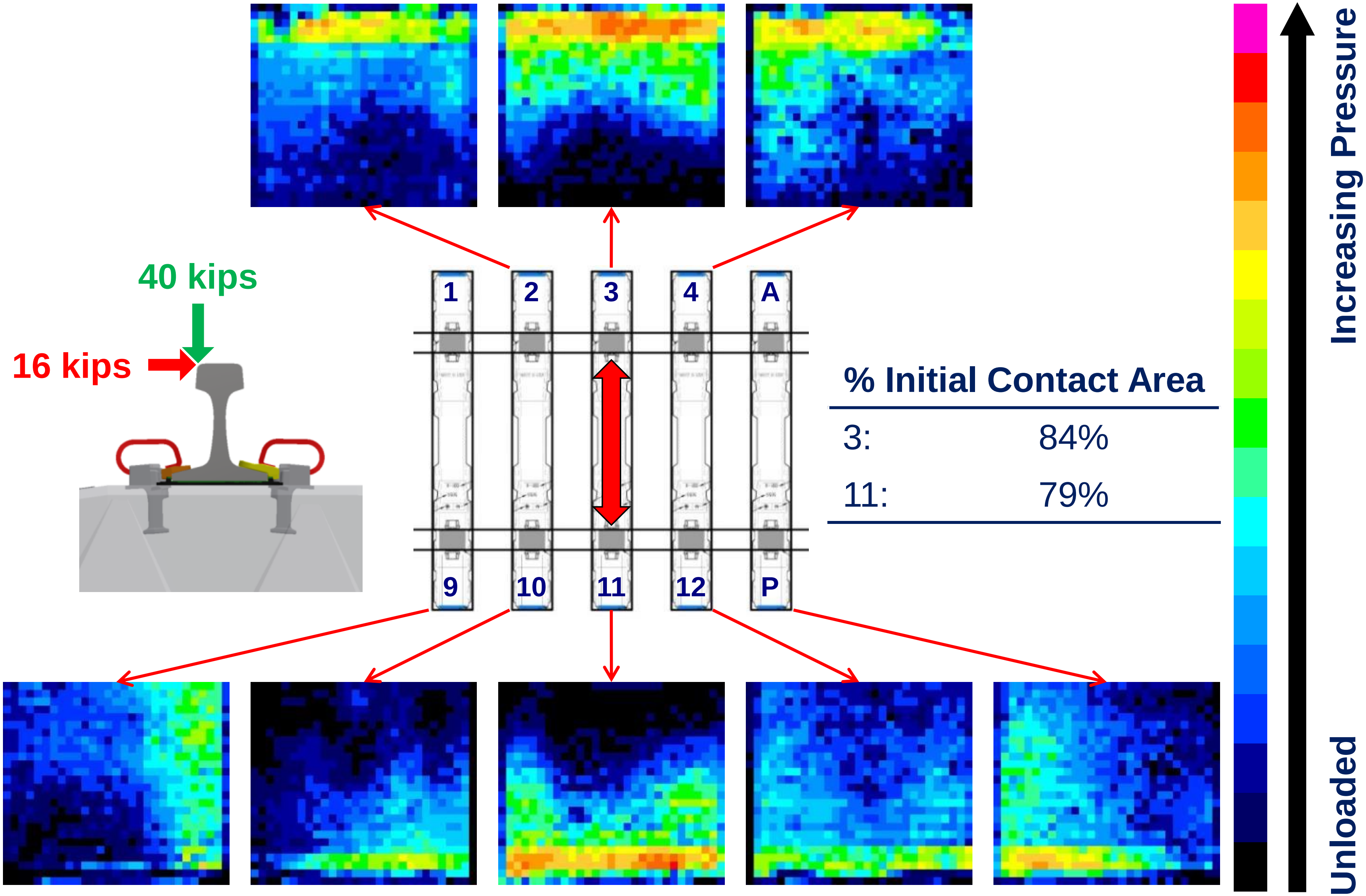




% Initial Contact Area	
3:	101%
11:	101%

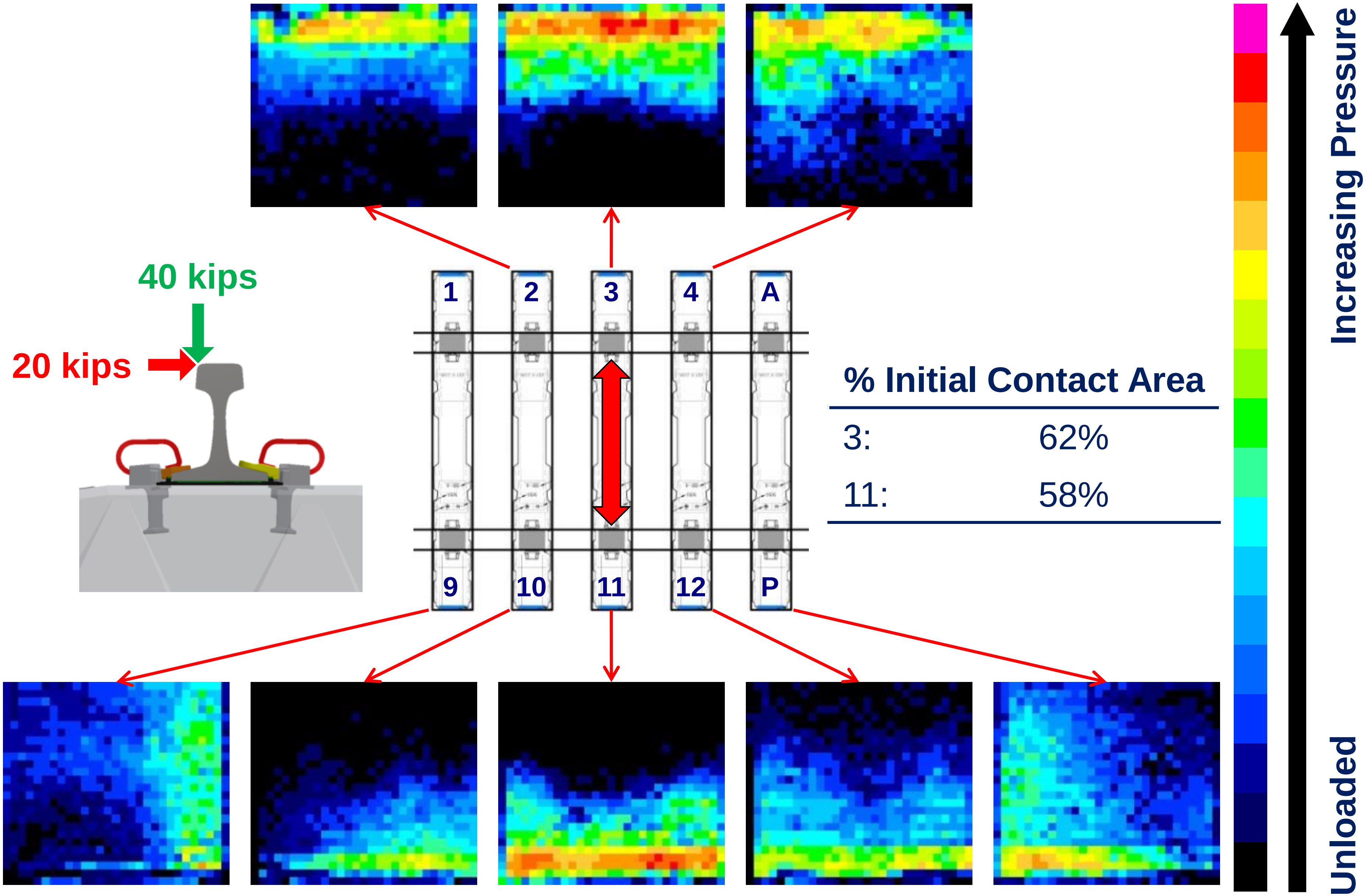


Increasing L/V Force Ratio



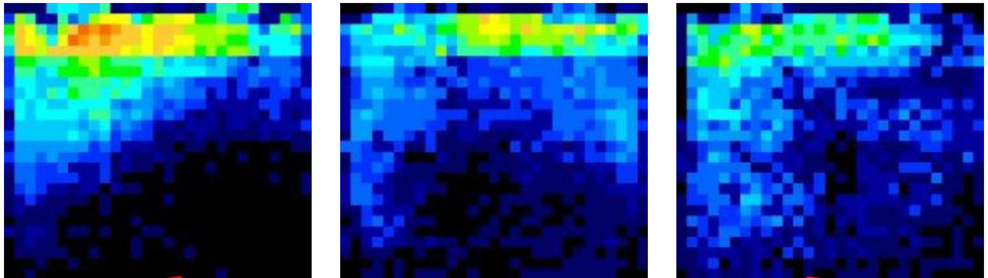
% Initial Contact Area	
3:	84%
11:	79%

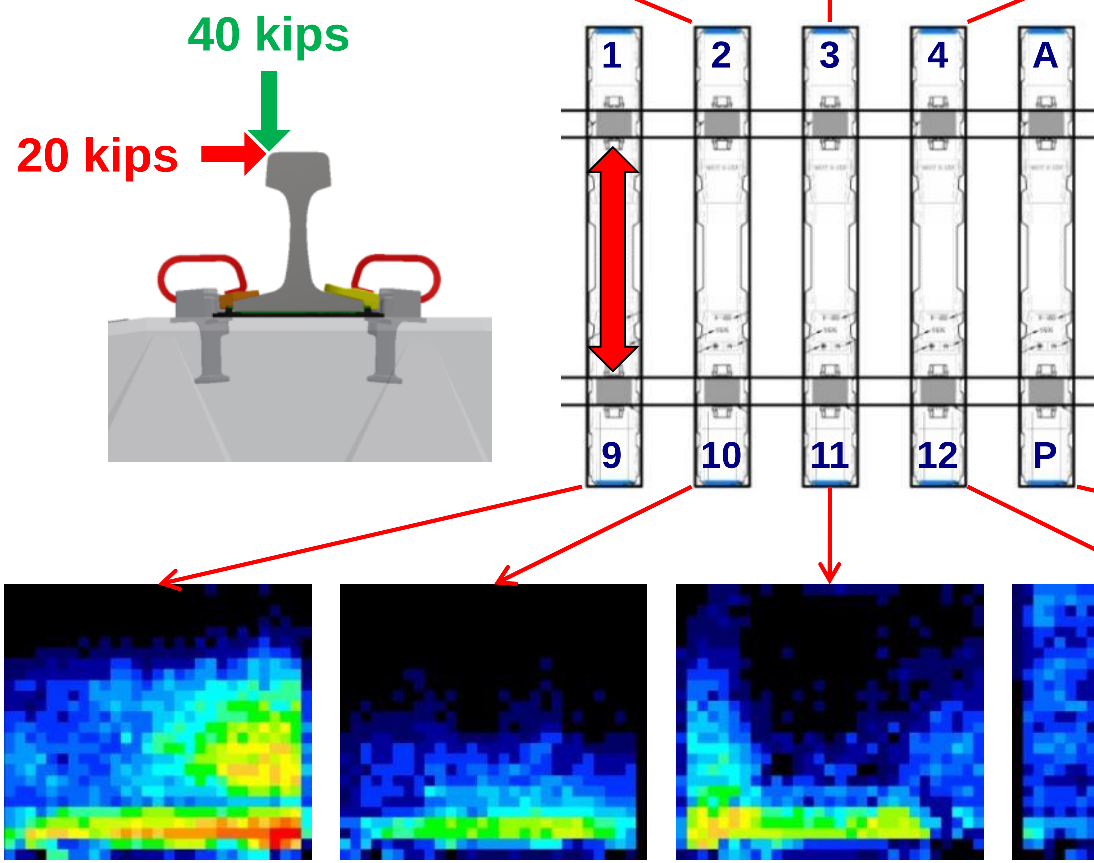
Increasing L/V Force Ratio



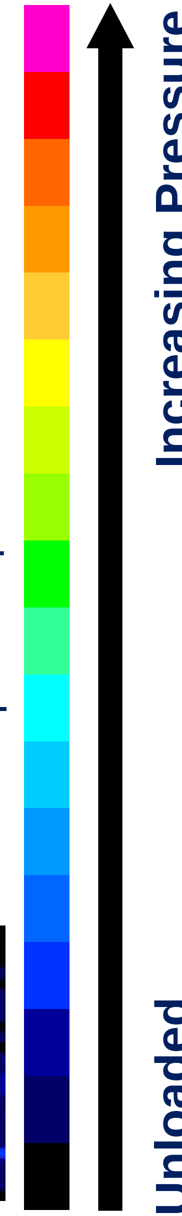
% Initial Contact Area	
3:	62%
11:	58%

Changing Load Location

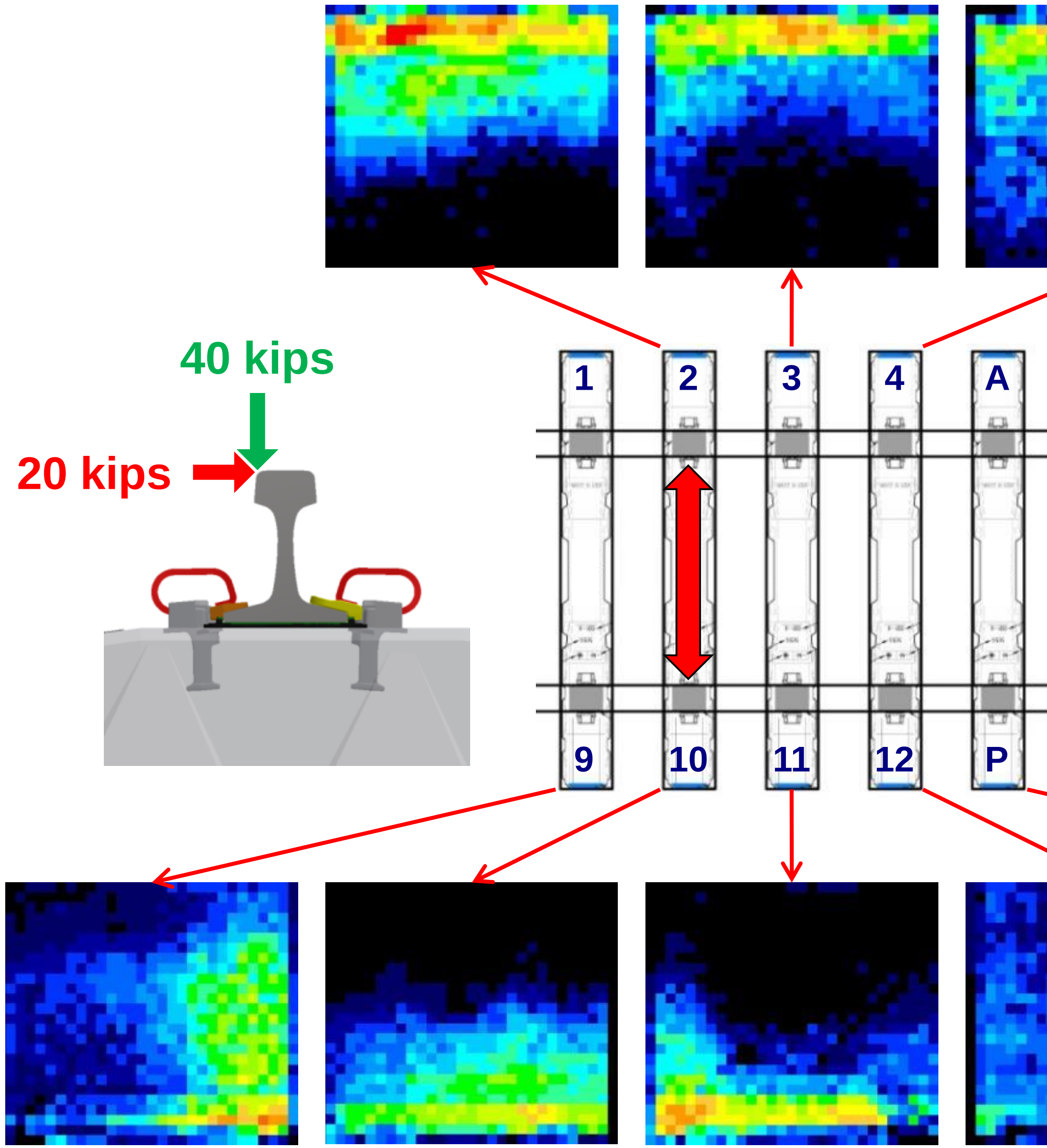




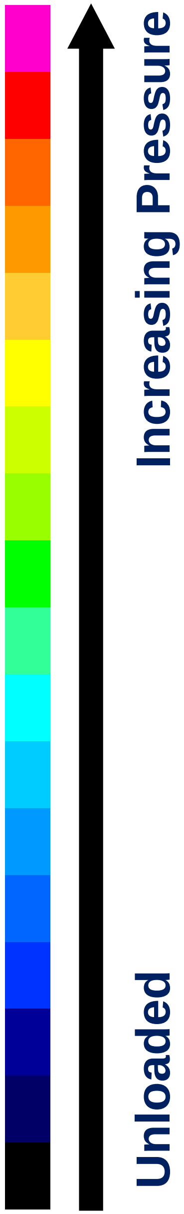
% Initial Contact Area	
1:	N/A
9:	83%



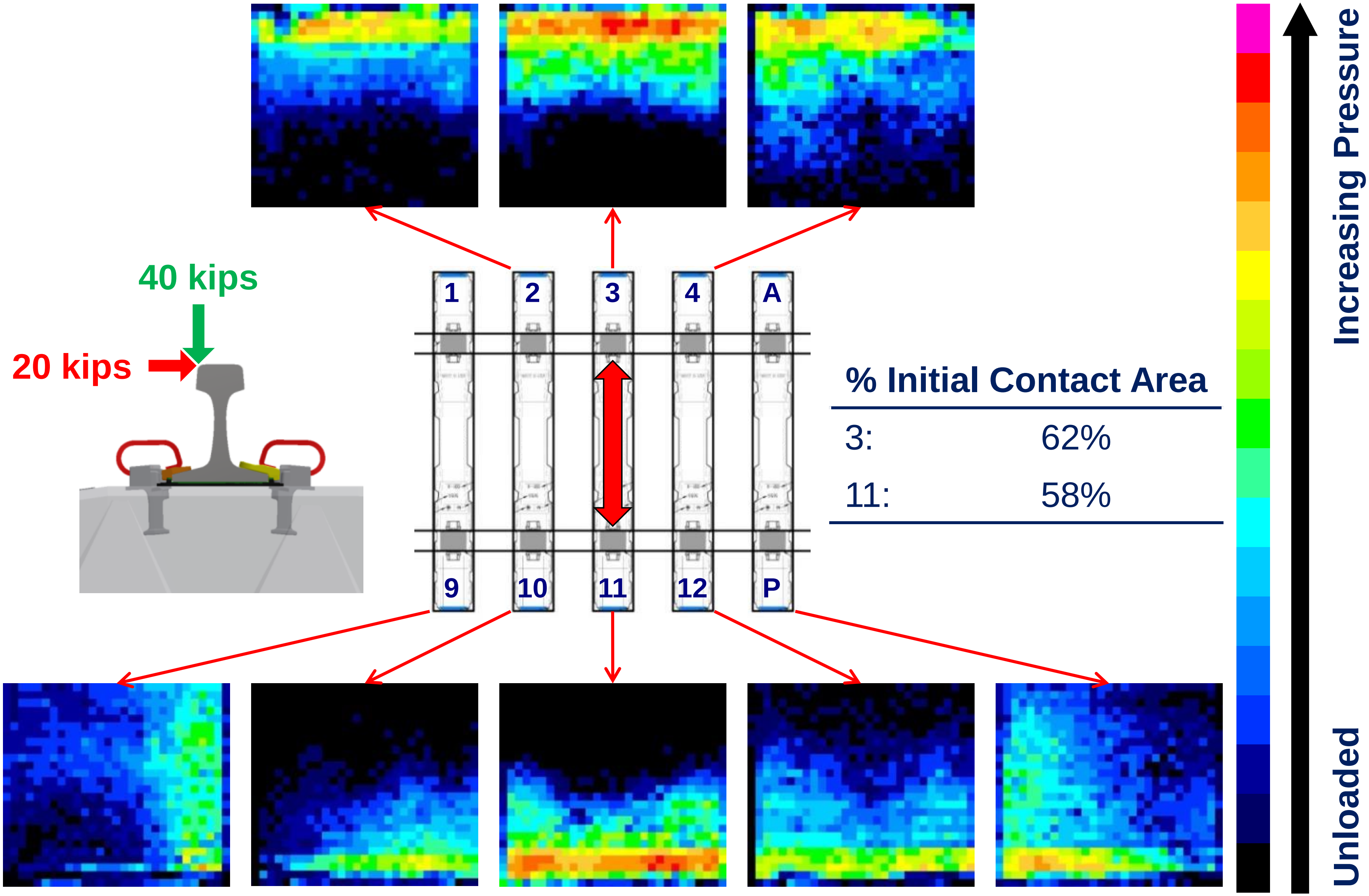
Changing Load Location



% Initial Contact Area	
2:	68%
10:	62%

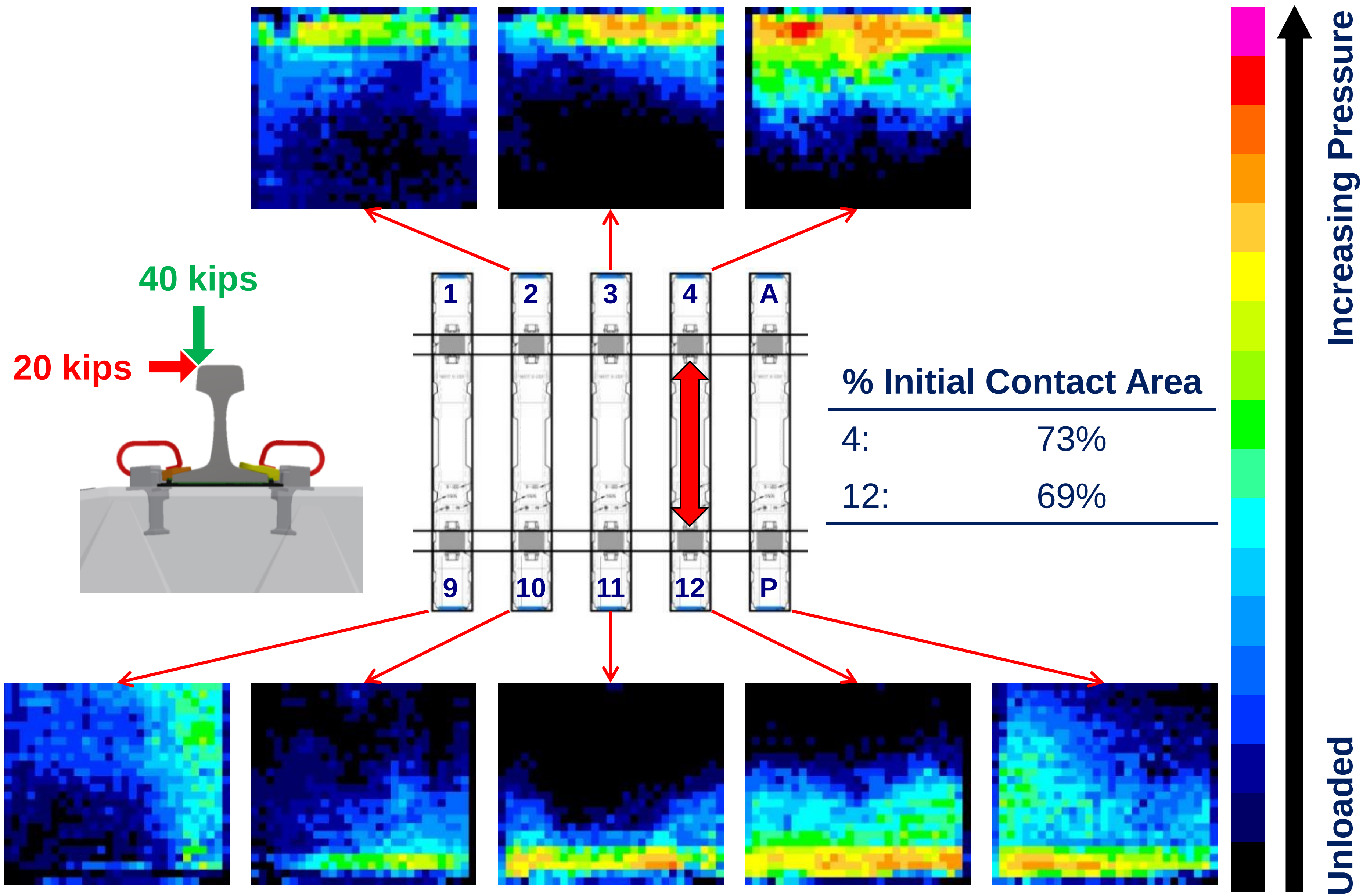


Changing Load Location



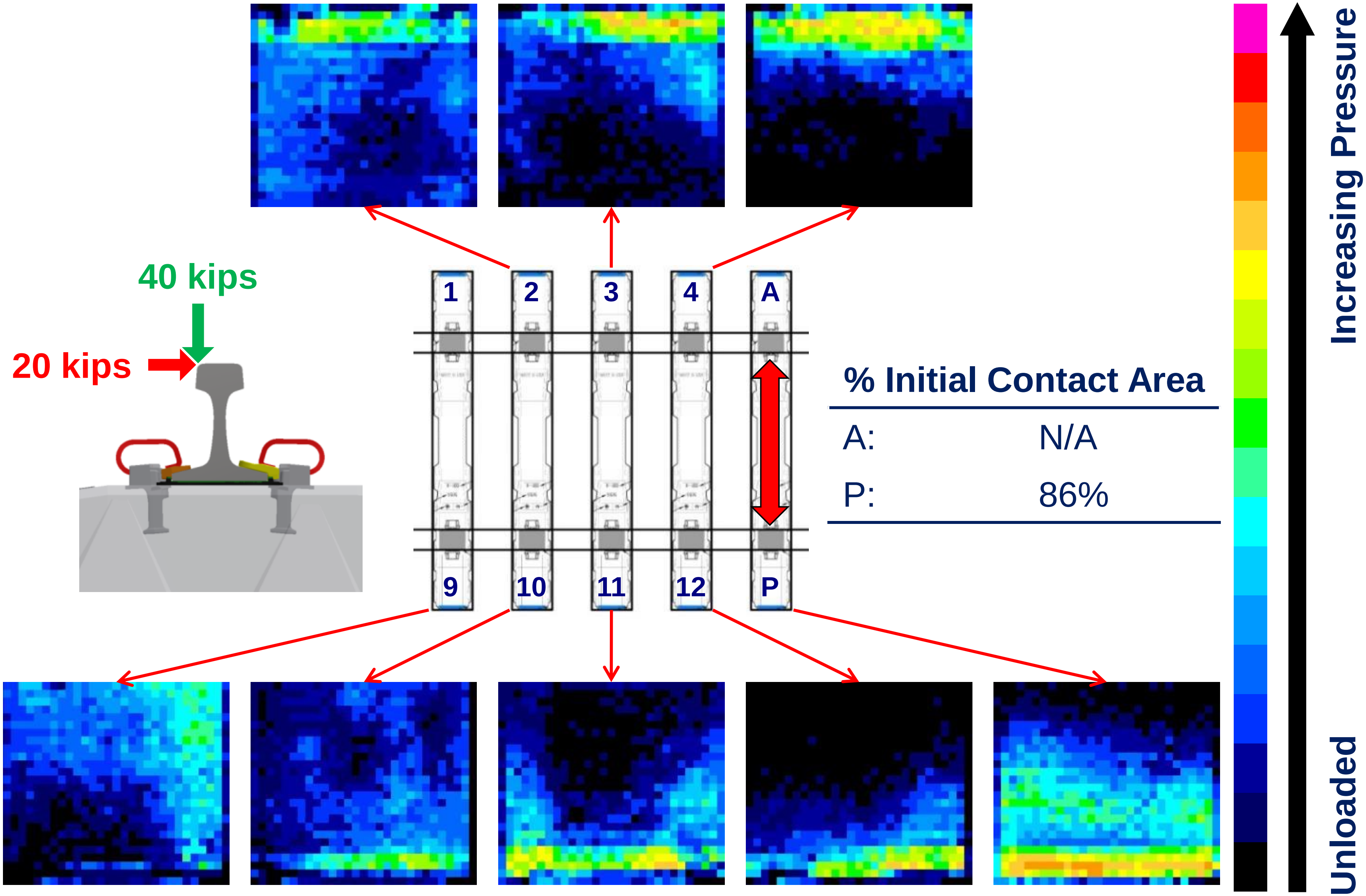
% Initial Contact Area	
3:	62%
11:	58%

Changing Load Location



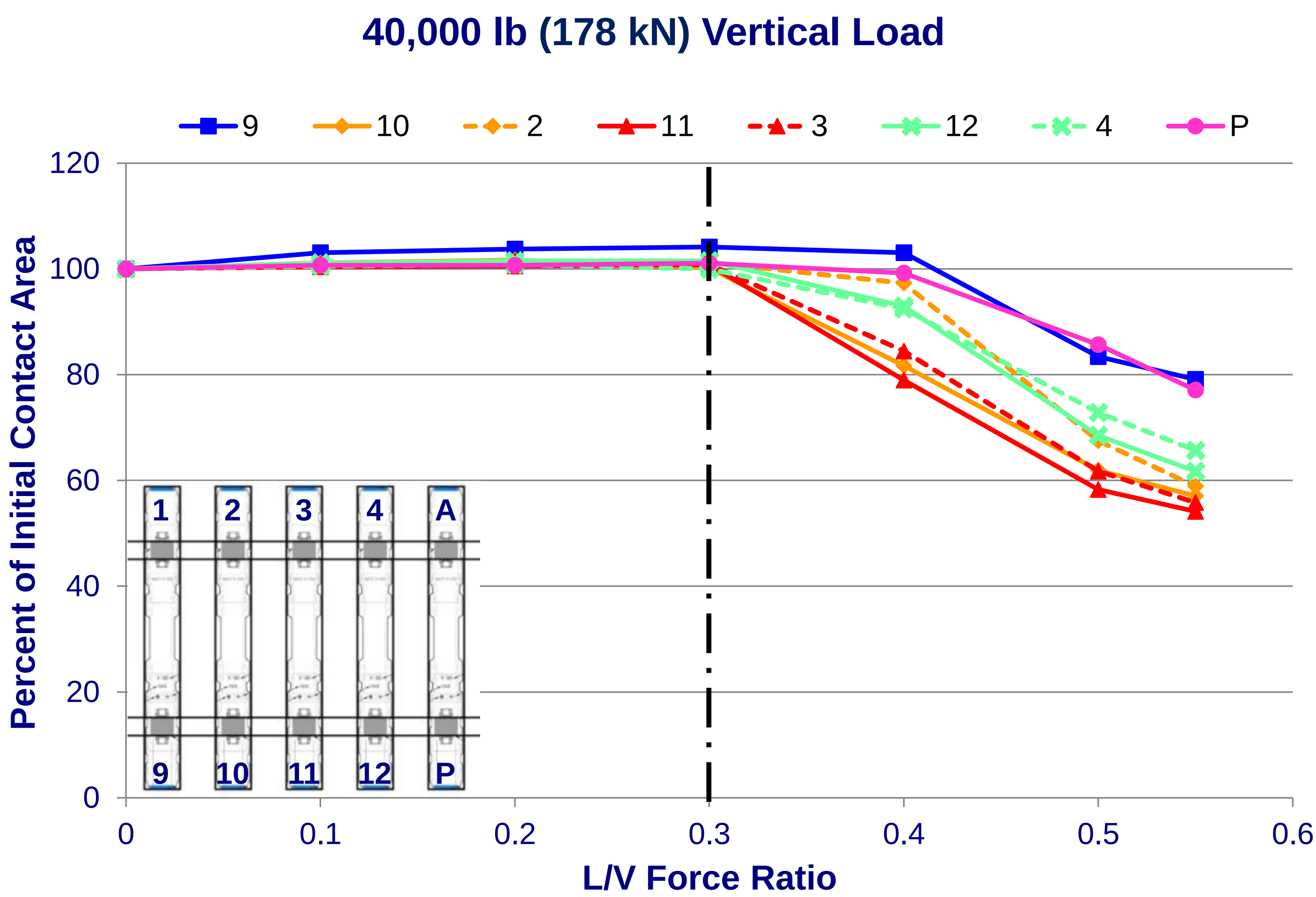
% Initial Contact Area	
4:	73%
12:	69%

Changing Load Location

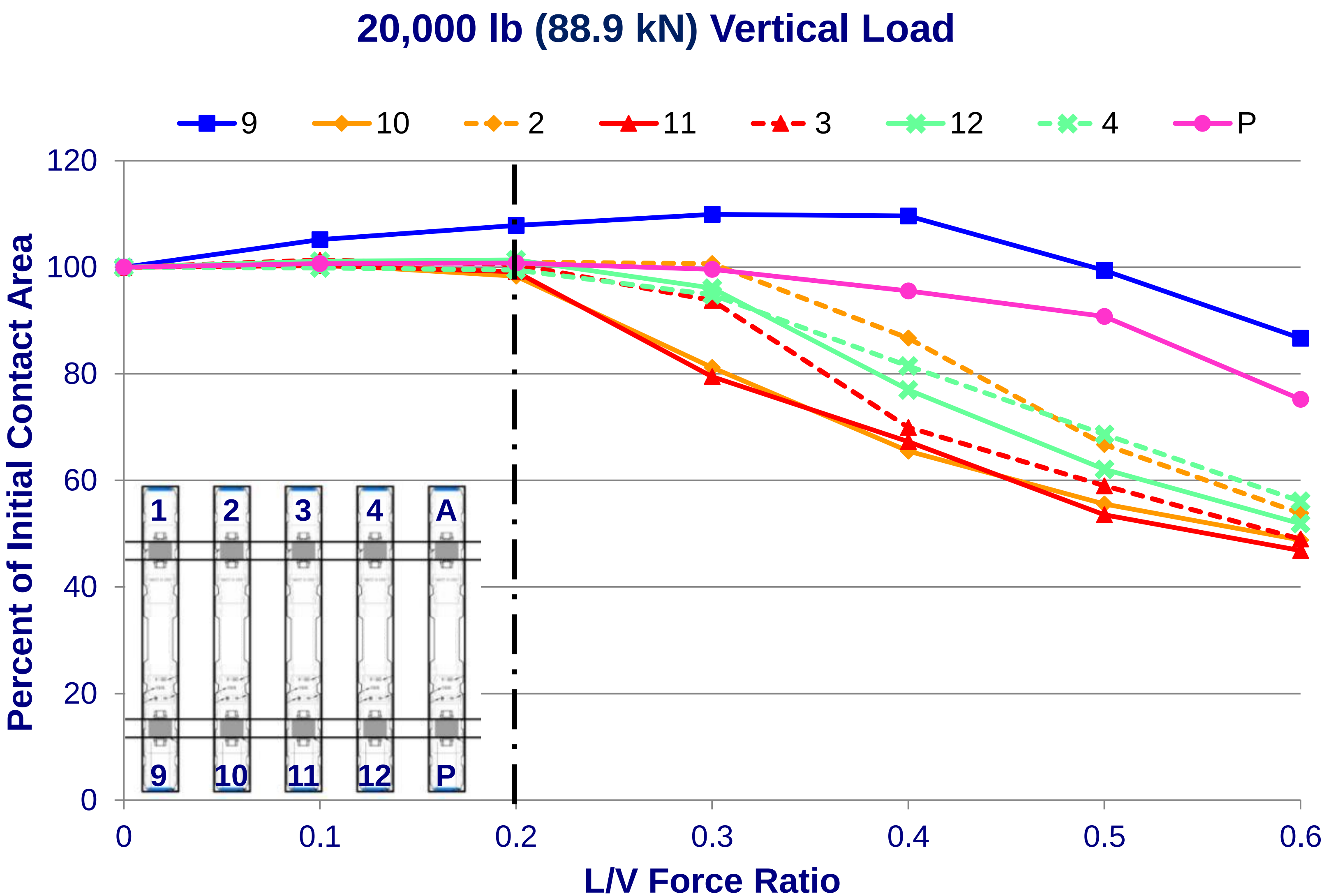


% Initial Contact Area	
A:	N/A
P:	86%

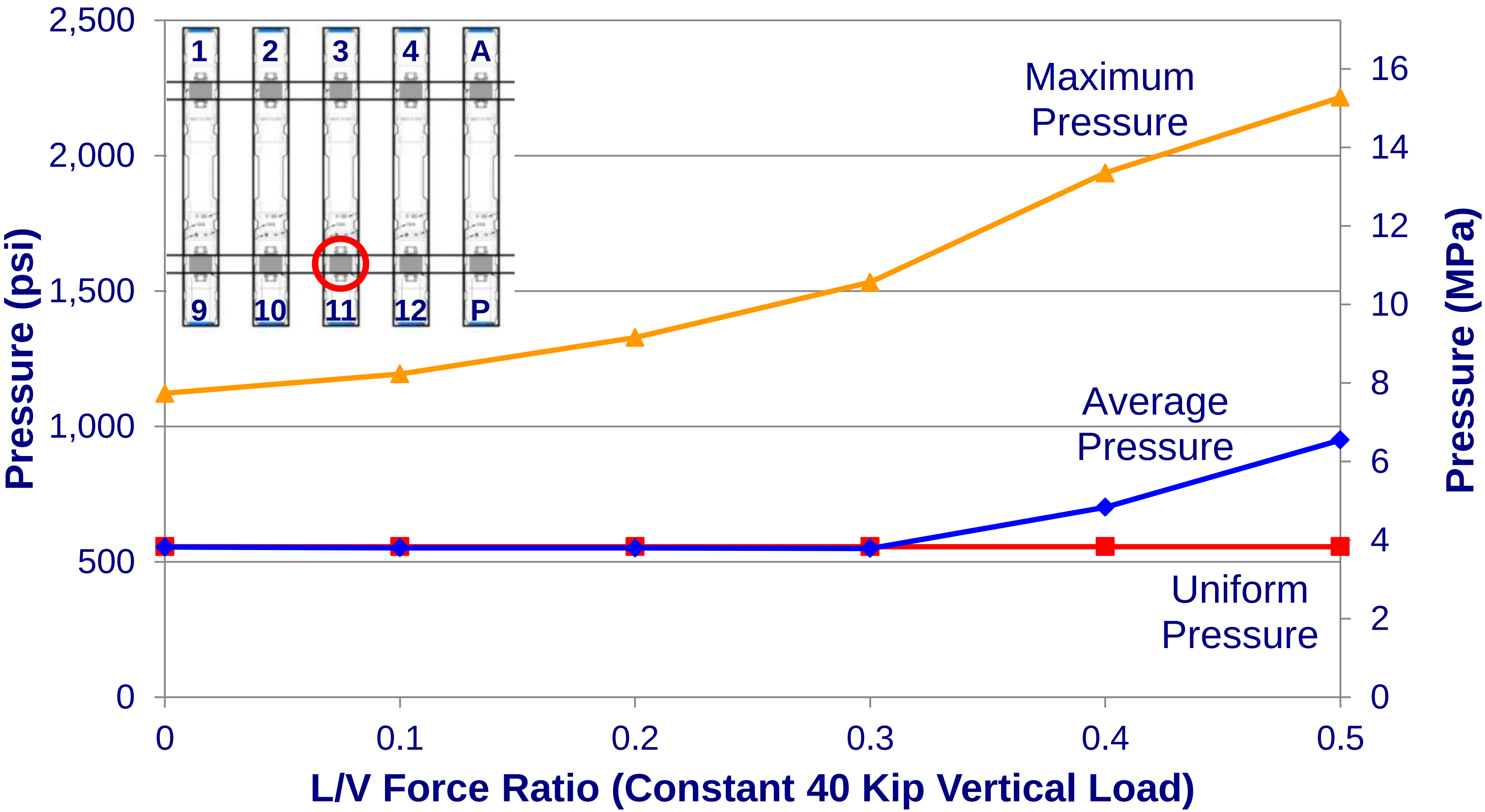
TLV Varying Lateral Load at RTT



TLV Varying Lateral Load at RTT



Effect of Increased L/V Force Ratio



Conclusions

- Rail seat load distribution is highly nonuniform, even between adjacent crossties
- Rail base rotation at “threshold” L/V force ratio can lead to significant load concentration on field side of rail seat
  - Loss of up to 54% of initial contact area
- The behavior of the load distribution under increasing L/V force ratios is affected by the magnitude of vertical load
  - Further analysis required to establish confident relationship between V and “threshold” L/V force ratio
- Average and maximum pressure are affected by reduction of contact area
  - 71% increase in average pressure
  - 98% increase in maximum pressure
- Lateral force plays a more significant role than vertical force in RSD mechanisms because of its effect on contact area

Future Work

- Further analysis of 2013 Field Instrumentation data:
  - Effect of individual crosstie support conditions on wheel load and rail seat load distributions
  - Effect of train weight and speed (relative to balancing speed of a curve) on load distribution
- Additional experimentation:
  - Comparison of full-scale laboratory loading frame to field and current laboratory experimentation
  - Define relationship between vertical load and “threshold” L/V
  - Controlled analysis of effect of crosstie support conditions
  - Further analysis of nonuniform load distribution and maximum pressure

Acknowledgements

U.S. Department of Transportation
Federal Railroad Administration

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  - Federal Railroad Administration (FRA)
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  - National Railway Passenger Corporation (Amtrak)
  - Amsted RPS / Amsted Rail, Inc.
  - GIC Ingeniería y Construcción
  - Hanson Professional Services, Inc.
  - CXT Concrete Ties, Inc., LB Foster Company
  - TTX Company
- UIUC – Zachary Ehlers, Marc Killion, and Timothy Prunkard
- University of Kentucky - Professor Jerry Rose and students

FRA Tie and Fastener BAA Industry Partners:

Questions & Comments

Matthew Greve
Graduate Research Assistant
greve1@illinois.edu

Appendix

Sensor Technology

- Pressure sensitive ink printed in rows and columns to form matrix
- Each intersection creates a sensing point
- As force is applied the resistivity decreases resulting in a higher output to software
- Our sensors:
  - 44 x 44 “sensel” (sensor cell) matrix
  - Each sensel is 0.22 x 0.22 in (5.59 x 5.59 mm)
  - 100 Hz maximum data collection rate
  - Outputs 0-255 “raw sum” scale

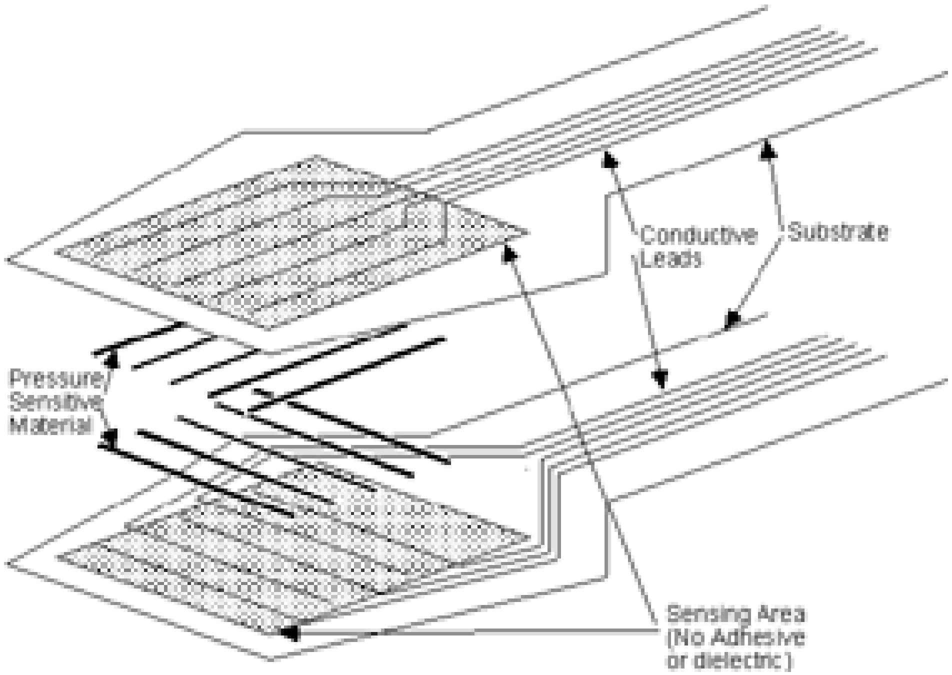
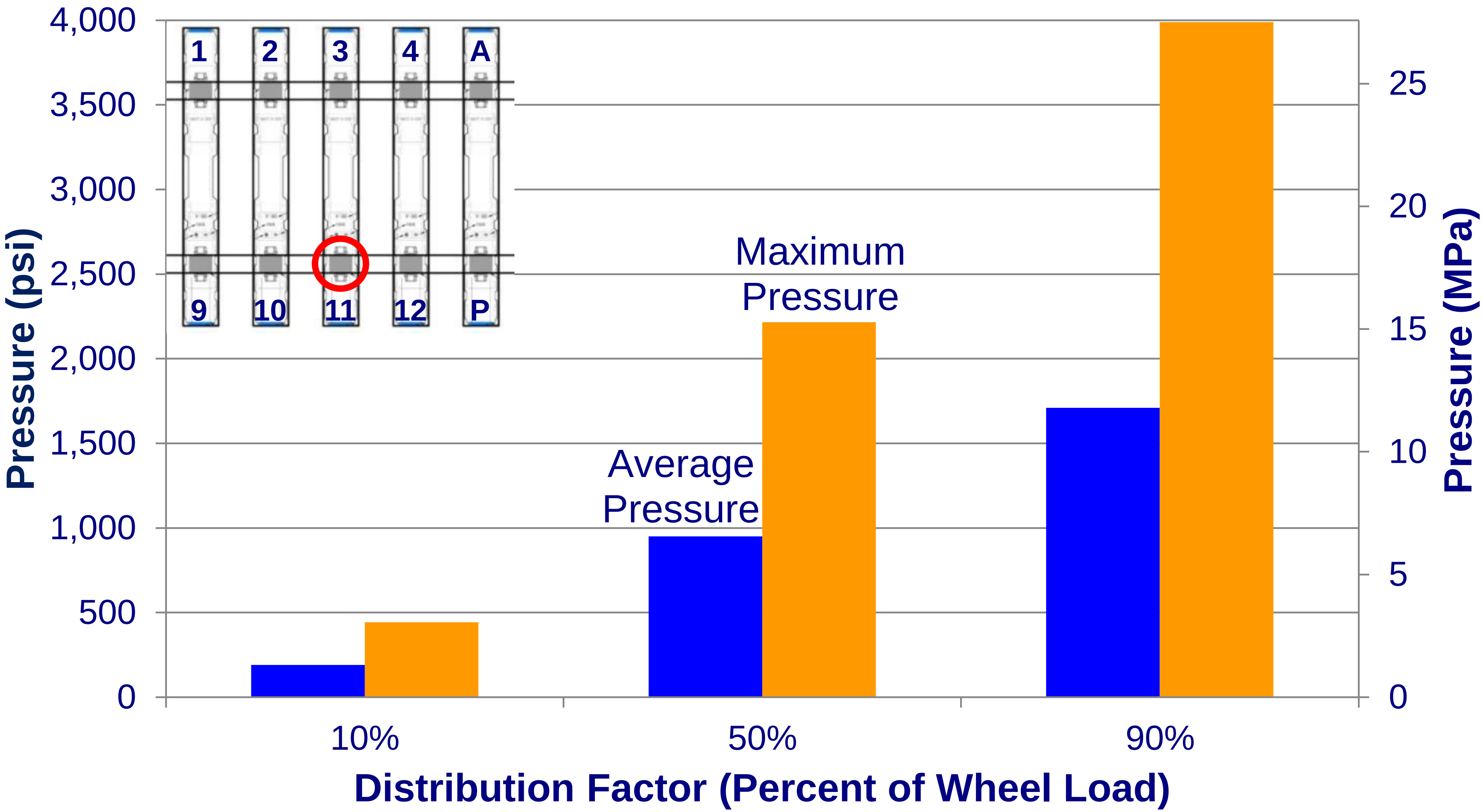


Image from: http://www.sensorland.com/HowPage033.html

MBTSS Limitations

- Protective sleeves required to prevent shear and puncture damage to sensor
  - Sleeves alter friction and lateral load path in system
- Input load needed to correlate raw sum units to engineering units
- 100 Hz maximum data collection rate limits reliability of data from train operations at higher speeds
- I-Scan software unstable if too much data is processed without program restart
  - Problem identified with large installations

Effect of Distribution Factor



40,000 lb (178 kN) Vertical, 20,000 lb (88.9 kN) Lateral Load