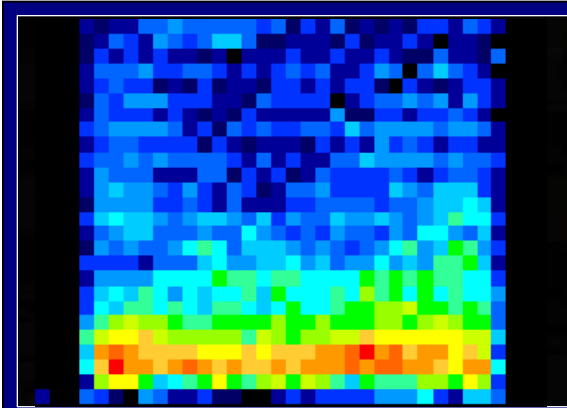# Rail Seat Load Results from July 2012 Field Testing at TTC

AREMA Committee 30 Fall 2012 Meeting

Tampa, FL

25 October 2012

Christopher T. Rapp, Marcus S. Dersch, J. Riley Edwards

U.S. Department of Transportation
Federal Railroad Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
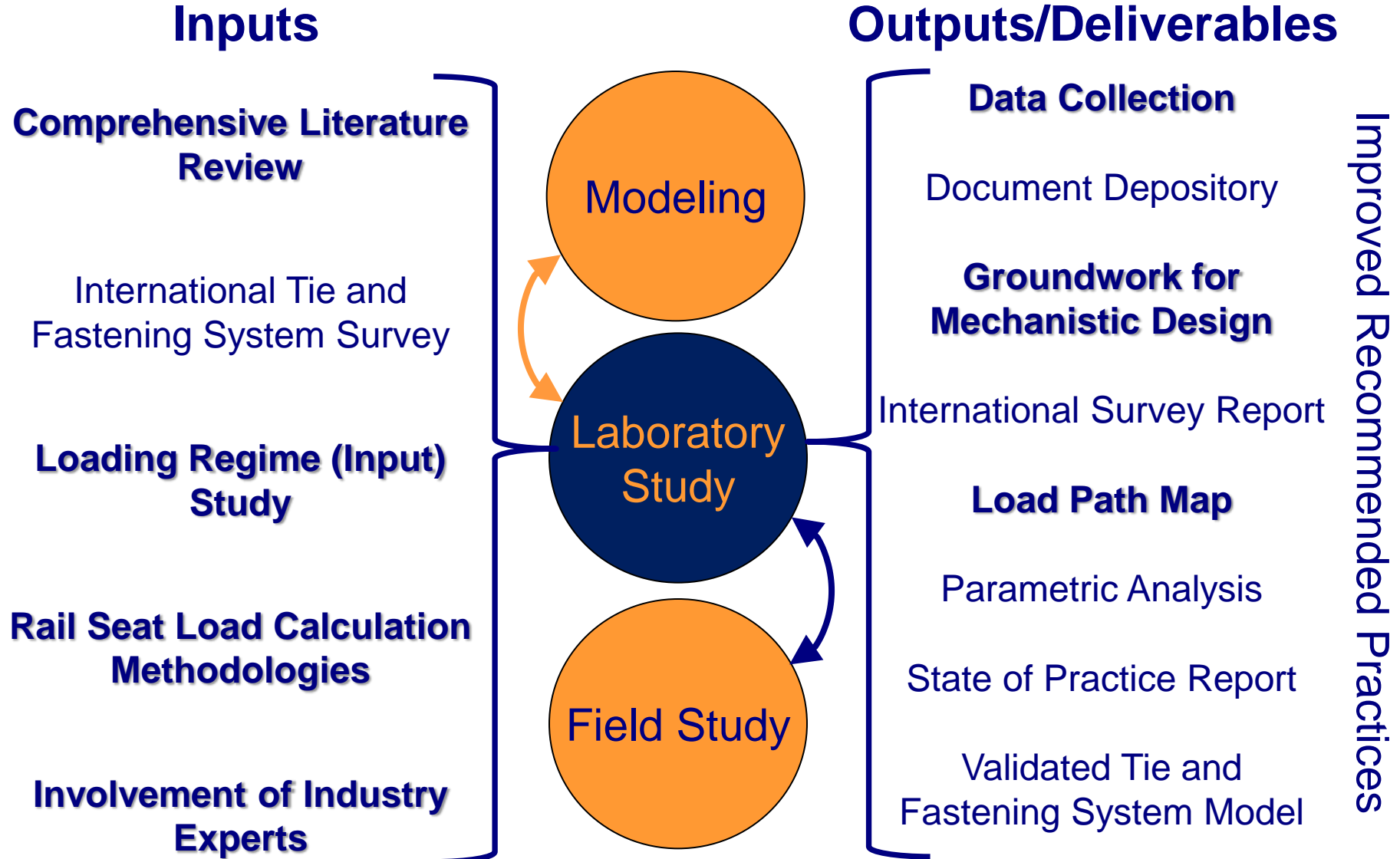
Amsted RPS
Amsted Rail

Outline

- Current Objectives of Experimentation

- Chapter 30: Rail Seat Pads

- Testing Background

- Laboratory Experimentation: Rail Seat Pads

- Field Test Setup and Locations

  – Rail Seat Load Calculation

  – Train Operation Data

  – Preliminary Conclusions

- Future Work

- Appendix

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

- **Measure magnitude and distribution of pressure at the concrete crosstie rail seat**

- Investigate the feasibility of crushing as a mechanism leading to rail seat deterioration (RSD)

- Gain better 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

FRA Tie and Fastener Program Structure

Inputs

Outputs/Deliverables

Comprehensive Literature Review

International Tie and Fastening System Survey

Loading Regime (Input) Study

Rail Seat Load Calculation Methodologies

Involvement of Industry Experts

Modeling

Laboratory Study

Field Study

Data Collection

Document Depository

Groundwork for Mechanistic Design

International Survey Report

Load Path Map

Parametric Analysis

State of Practice Report

Validated Tie and Fastening System Model

Improved Recommended Practices

Railseat Pads
AREMA Chapter 30 Section 1.7.3.4

- **Existing Content:**
  - Purpose, recommendations for varying loading environments
  - Recommended railseat pad property tests
- **Proposed Improvement:**
  - Improve description of purpose
  - Recognize effect of varying pad moduli and geometries
- **Methodology:**
  - Laboratory experiments with varying pad moduli and geometries
  - Field experimentation to better understand actual loading conditions
- **Timeline:**
  - Submit to full committee for ballot (Spring 2013)

MBTSS Testing Background

- Proven feasibility for use on concrete crosstie rail seats

- Laboratory experimentation performed to vary:

  – Rail pad materials and type

  – Fastening clip type

- Lessons learned from testing at Transportation Technology Center (TTC) in November 2011

  – Protection and sizing of sensors is critical

  – Need for an input load to correlate to raw sum data
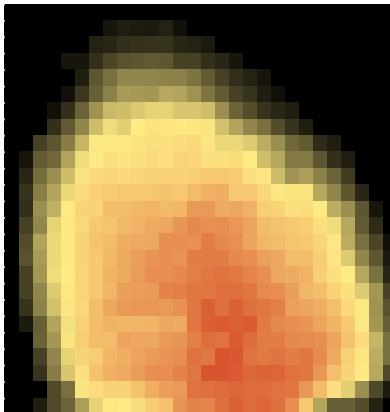
- Data collection speed limitations (100 Hz)

Laboratory Experimentation: Railseat Pads

- Load Applied: 32.5 kip vertical, 16.9 kip lateral (0.52 L/V)

TPV

MDPE

Two-Part
Pad Assembly
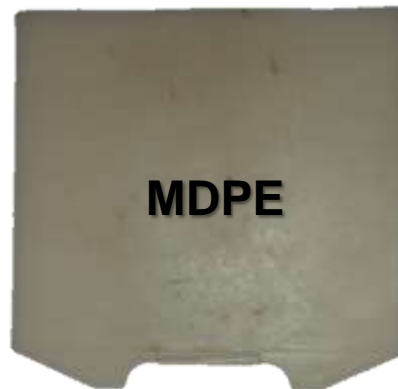
GAUGE
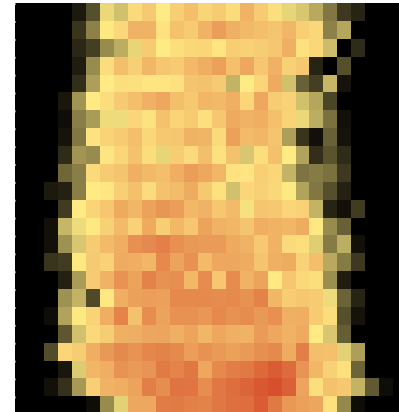
FIELD

Contact Area (in^2)	25.8	19.0	23.9
Max Pressure (psi)	2,925	3,721	2,990

Conclusions from Laboratory Testing

- **Effect of L/V Ratio**

  – Lower L/V ratios distribute the pressure over a larger contact area

  – Higher L/V ratios cause a concentration of pressure on the field side of the rail seat, resulting in higher peak pressures

- **Rail Pad Test**

  – Lower modulus rail pads distribute rail seat loads over a larger contact area

    • Reduces peak pressure values

    • Mitigates highly concentrated loads at this interface

  – Higher modulus rail pads distribute rail seat loads in more highly concentrated areas

    • Possibly leads to localized crushing of the concrete surface

  – Two-Part Pad Assembly

    • Maintains relatively consistent contact area under increasing L/V ratios

    • Peak pressures similar to the lower modulus TPV pad

TTCI Field Testing Locations
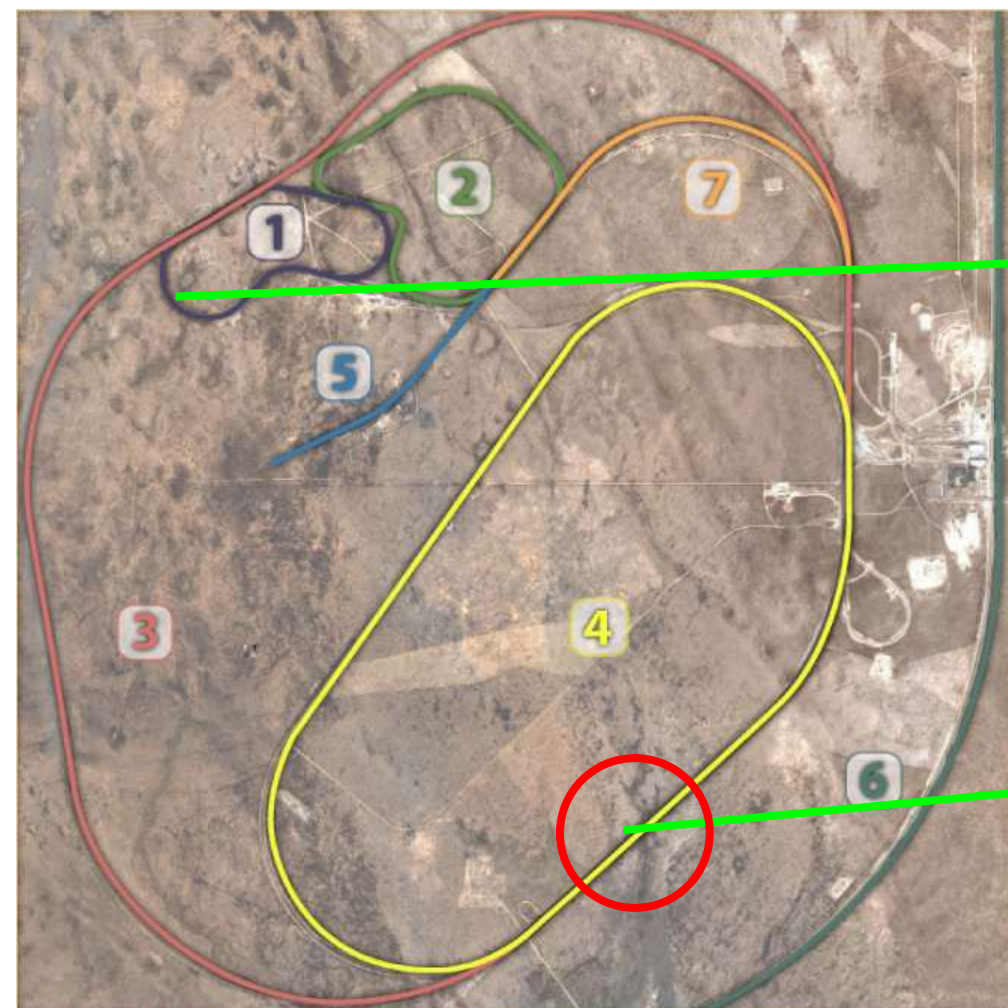
5 degree curve
Balance Speed = 33 mph

Tangent
Speed up to 105 mph

Test Setup and Locations

- Instrumented sections at both Heavy Tonnage Loop (HTL) and Railroad Test Track (RTT)
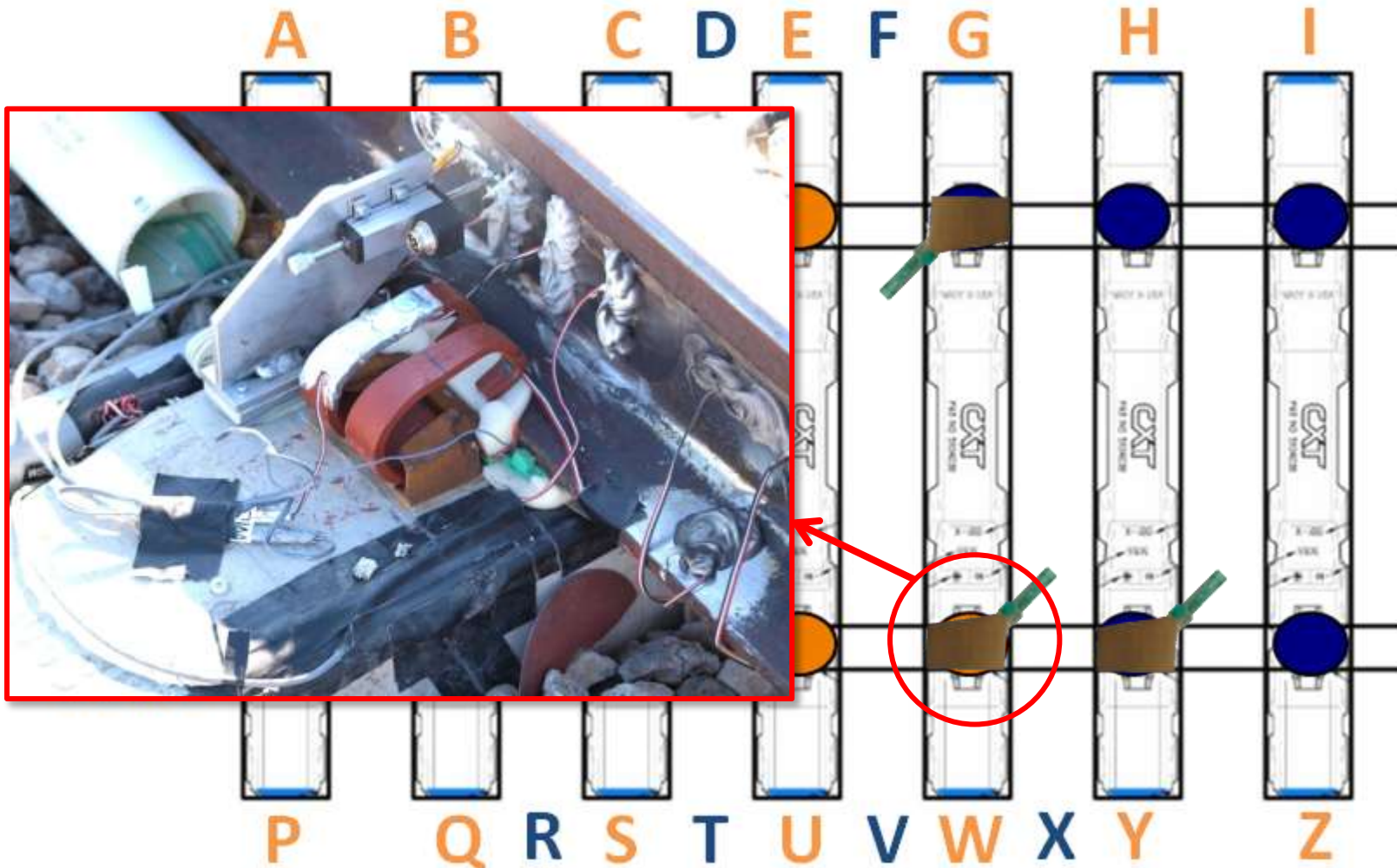
Field Rail Seat Load Calculation

1. Calibrate strain gauge bridges with track loading vehicle (TLV)

2. Determine wheel force

3. Determine wheel force minus rail seat force

4. Difference is rail seat load

RTT Passenger Consist

- Runs at **15**, 30, **50**, 60, 80, 90, 102 mph

- Locomotive Weight: 255,475 lbs (4 axles)

- Passenger Car Weights: 86,000 – 88,000 lbs (4 axles)

RTT Freight Consist

- Runs at 2, **15**, 30, 38, 41, **60** mph

- Locomotive Weight: 393,000 lbs (6 axles)

- Freight Car Weights: 250,000 – 315,000 lbs (4 axles)

RTT Passenger Consist - 15 mph

GAUGE
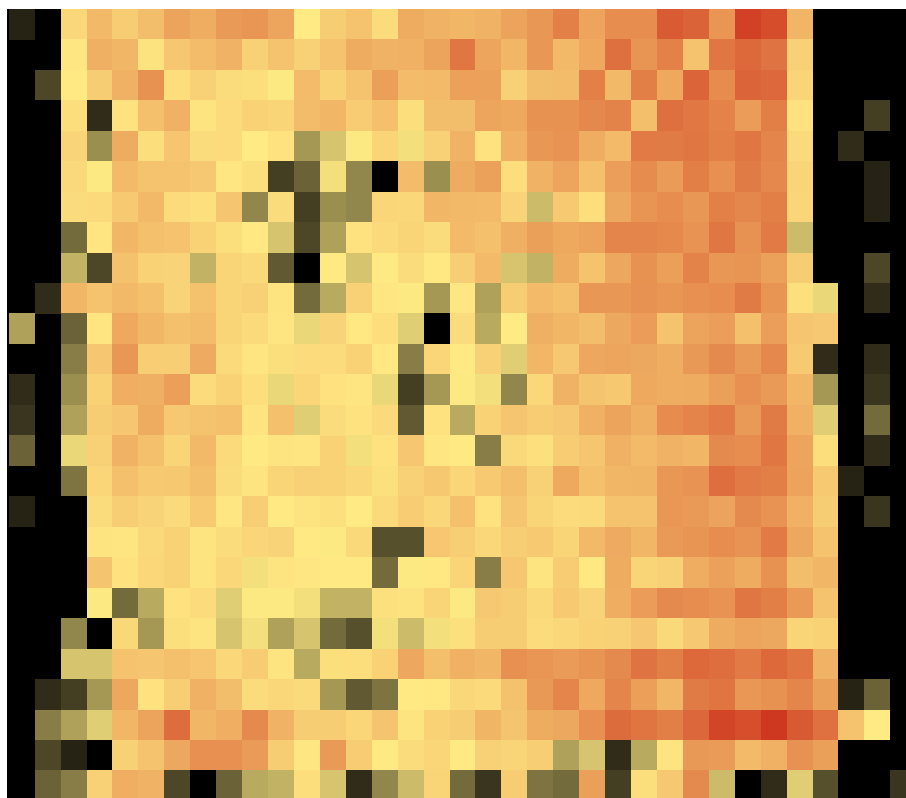
FIELD

Lead Truck, Lead Axle of Locomotive	
Wheel Load, lbs	30,600
Rail Seat Load, lbs	15,800
% of Wheel Load Carried by Rail Seat	52
Maximum Pressure, psi	1,584
Average Pressure, psi	538
Contact Area, in^2	38.2

Pressure (psi)

0   1000   2000
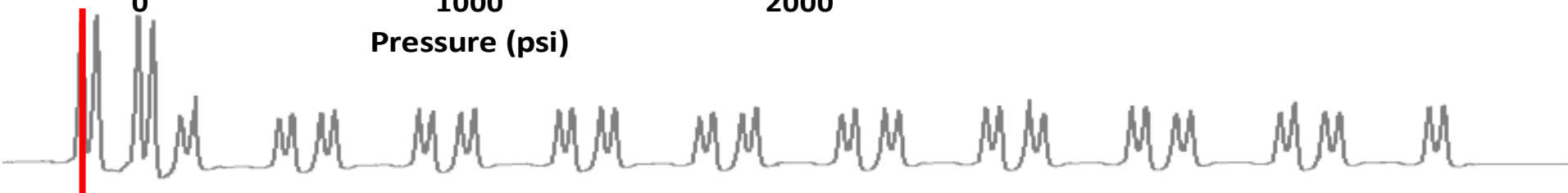
RTT Freight Consist - 15 mph

GAUGE
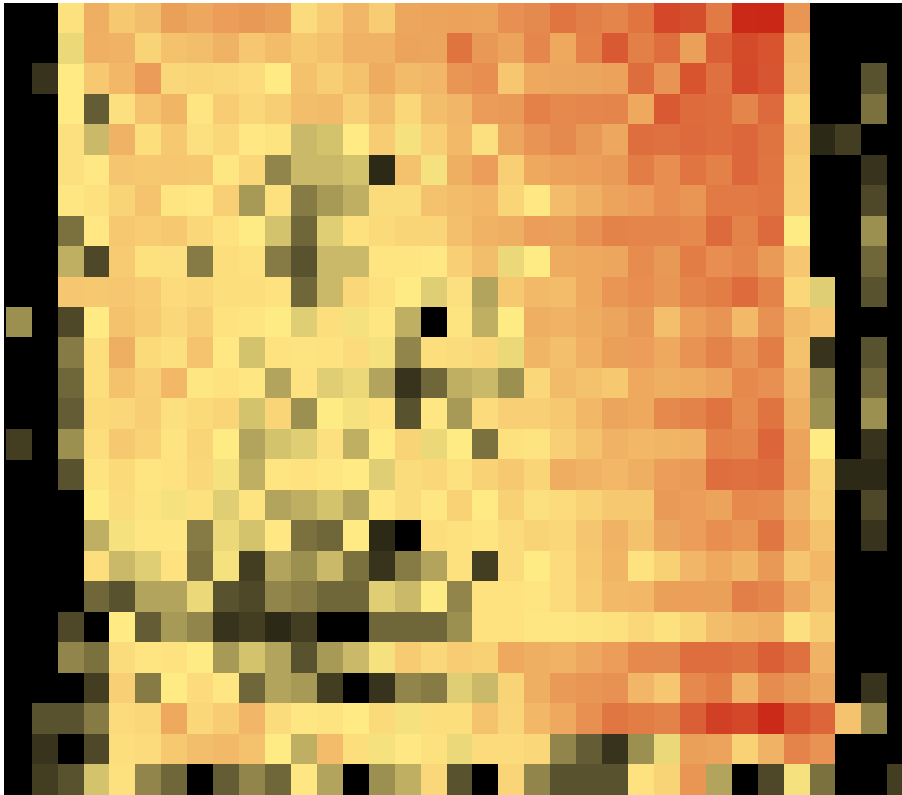
FIELD

Pressure (psi)

0   1000   2000
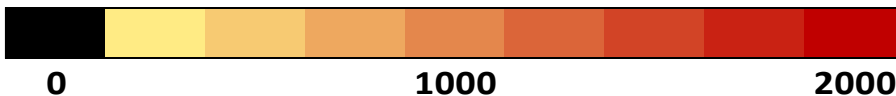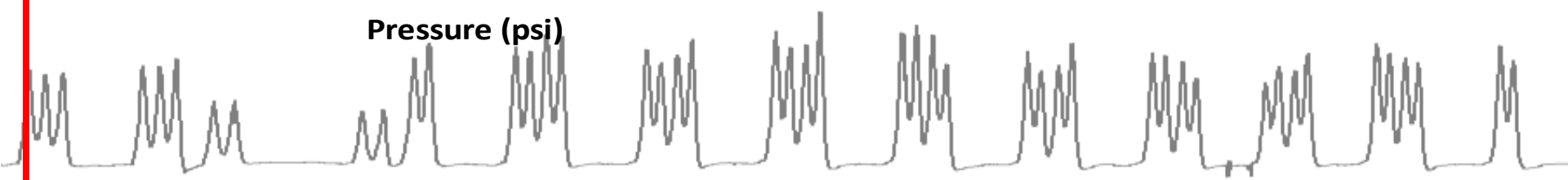
Lead Truck, Lead Axle of Locomotive	
Wheel Load, lbs	30,100
Rail Seat Load, lbs	14,500
% of Wheel Load Carried by Rail Seat	48
Maximum Pressure, psi	1,710
Average Pressure, psi	509
Contact Area, in^2	37.9

Passenger Consist

Location	Speed	Wheel Load (lbs)	Rail Seat Load (lbs)	Maximum Pressure (psi)	Average Pressure (psi)
Locomotive: Lead Truck, Lead Axle	15	30,600	15,800	1,584	538
Locomotive: Lead Truck, Lead Axle	50	27,200	11,300	1,273	425
Passenger Car: Lead Truck, Lead Axle	15	11,790	6,410	1,244	320
Passenger Car: Lead Truck, Lead Axle	50	9,900	3,100	941	229

Freight Consist

Location	Speed	Wheel Load (lbs)	Rail Seat Load (lbs)	Maximum Pressure (psi)	Average Pressure (psi)
Locomotive: Lead Truck, Lead Axle	15	30,100	14,500	1,710	509
Locomotive: Lead Truck, Lead Axle	60	23,400	8,700	1,342	348
Freight Car: Lead Truck, Lead Axle	15	34,500	16,700	1,816	561
Freight Car: Lead Truck, Lead Axle	60	39,100	24,300	2,486	746

Preliminary Observations

- Pressure values are governed by a combination of factors:

  – wheel load, rail seat load, contact area, etc.

- Pressure values are not always speed dependent

- Locomotive is the governing weight for the passenger consist for well-maintained wheels

- Crushing mechanism does not appear feasible under well-maintained track and rolling stock

- However, we still believe a "perfect storm" for crushing would be:

  – Adjacent ties not supporting load

  – Flat spots on wheels

  – Imperfect rail seat surface and/or external particles intruding into rail seat

Future Work with MBTSS

- Continue laboratory testing with external particles on the rail seat and non-perfect rail seats

- Continue field testing at TTC in Pueblo, CO to understand pressure distribution varying track and loading conditions

  - Instrument high and low rail seats of a crosstie to compare varying track geometries

  - Instrument consecutive rail seats to see load transfers between crossties

- Continue testing common North American fastening systems

- Incorporate rail seat pressure results into other RSD mechanism studies

Acknowledgements

- Funding for this research has been provided by the Federal Railroad Administration (FRA)

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    - Specifically for use of Pulsating Load Testing Machine
  - GIC Ingeniería y Construcción
  - Hanson Professional Services, Inc.
  - CXT Concrete Ties, Inc., LB Foster Company

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- University of Kentucky - Professor Jerry Rose and students

- Association of American Railroads (AAR) and Transportation Technology Center, Inc. (TTCI)

U.S. Department of Transportation
Federal Railroad Administration

FRA Tie and Fastener BAA
Industry Partners:

UNION PACIFIC   BUILDING AMERICA

BNSF RAILWAY

AMTRAK

Amsted RPS

Amsted Rail

GIC
GIC INGENIERÍA Y CONSTRUCCIÓN S.A. DE C.V.

HANSON

LBFoster
CXT Concrete Ties

ASSOCIATION OF AMERICAN RAILROADS

TTCI
Transportation Technology Center, Inc.

Questions?

Christopher T. Rapp
Graduate Research Assistant
ctrapp3@illinois.edu

Appendix

- RTT Train Operation Data

- TLV Data from TTC HTL Testing

- Laboratory Rail Pad Test Results

- Laboratory and Field Comparison

RTT Passenger Consist - 15 mph
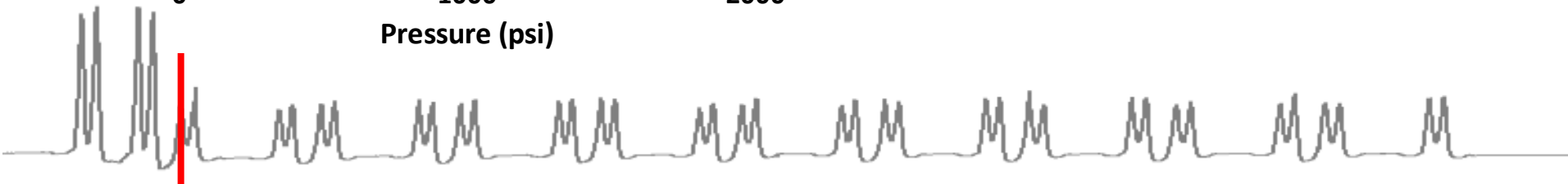
GAUGE

FIELD

Truck 1, Axle 1 of Passenger Car	
Wheel Load, lbs	11,790
Rail Seat Load, lbs	6,410
% of Wheel Load Carried by Rail Seat	54
Maximum Pressure, psi	1,244
Average Pressure, psi	320
Contact Area, in^2	34.9

Pressure (psi)

0   1000   2000

RTT Passenger Consist - 50 mph

GAUGE
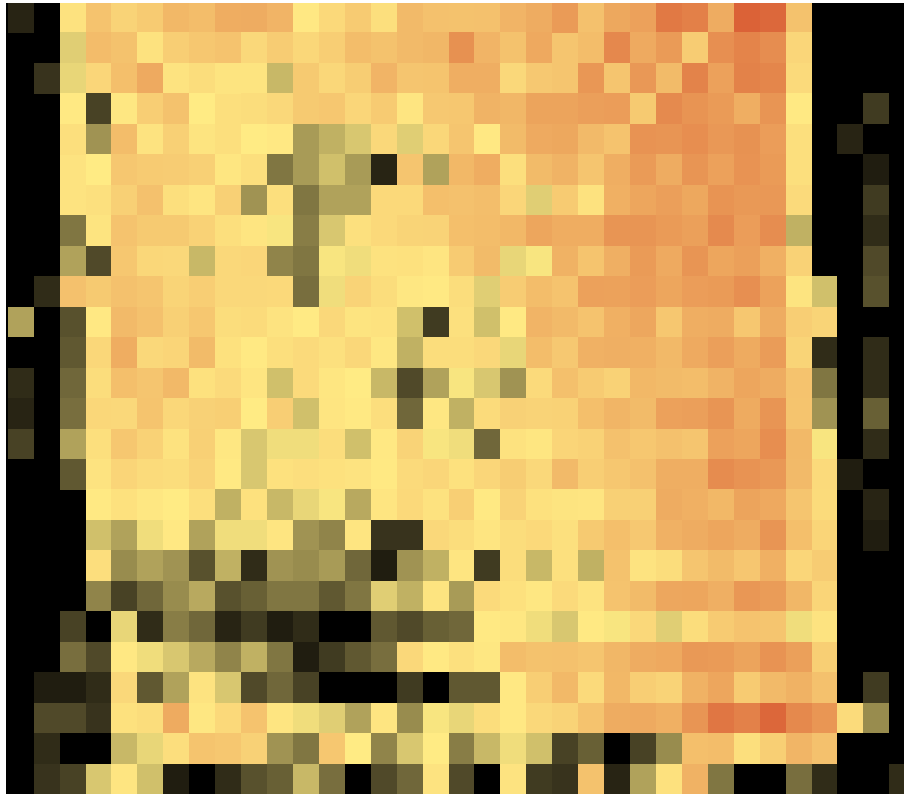
FIELD

Truck 1, Axle 1 of Locomotive	
Wheel Load, lbs	27,200
Rail Seat Load, lbs	11,300
% of Wheel Load Carried by Rail Seat	42
Maximum Pressure, psi	1,273
Average Pressure, psi	425
Contact Area, in^2	37.8
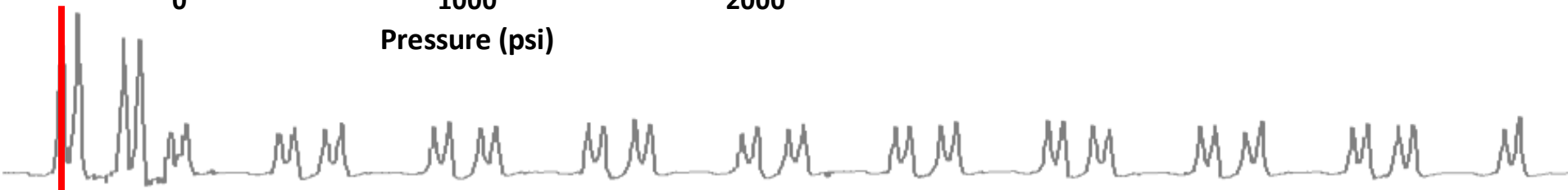
Pressure (psi)

0   1000   2000

RTT Passenger Consist - 50 mph
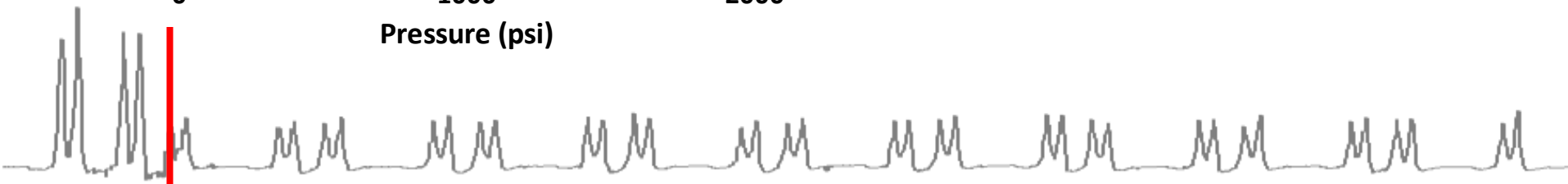
GAUGE

FIELD

Truck 1, Axle 1 of Passenger Car	
Wheel Load, lbs	9,900
Rail Seat Load, lbs	3,100
% of Wheel Load Carried by Rail Seat	31
Maximum Pressure, psi	941
Average Pressure, psi	229
Contact Area, in^2	34.3

Pressure (psi)
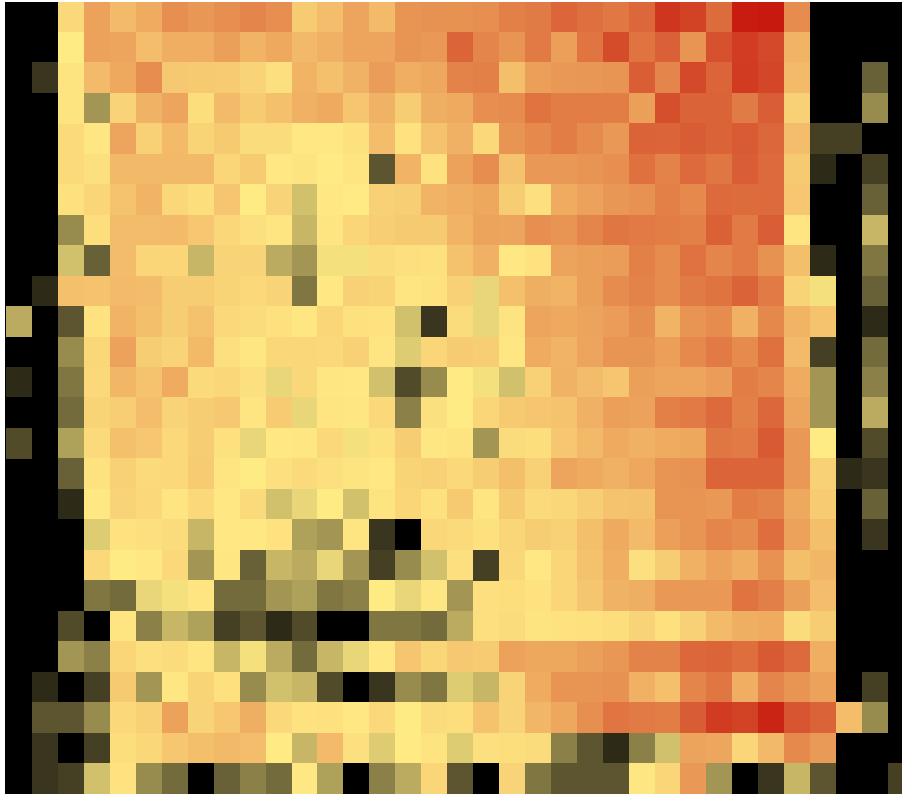
RTT Freight Consist - 15 mph
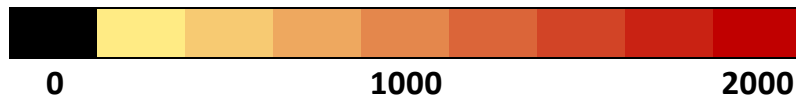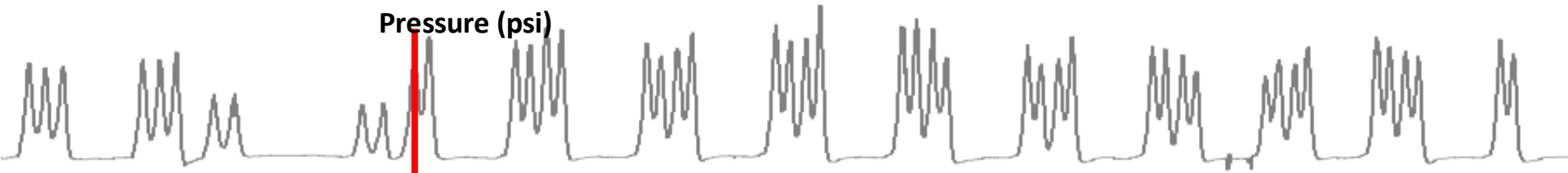
GAUGE

FIELD

Truck 1, Axle 1 of Freight Car	
Wheel Load, lbs	34,500
Rail Seat Load, lbs	16,700
% of Wheel Load Carried by Rail Seat	48
Maximum Pressure, psi	1,816
Average Pressure, psi	561
Contact Area, in^2	38.2

0   1000   2000

Pressure (psi)
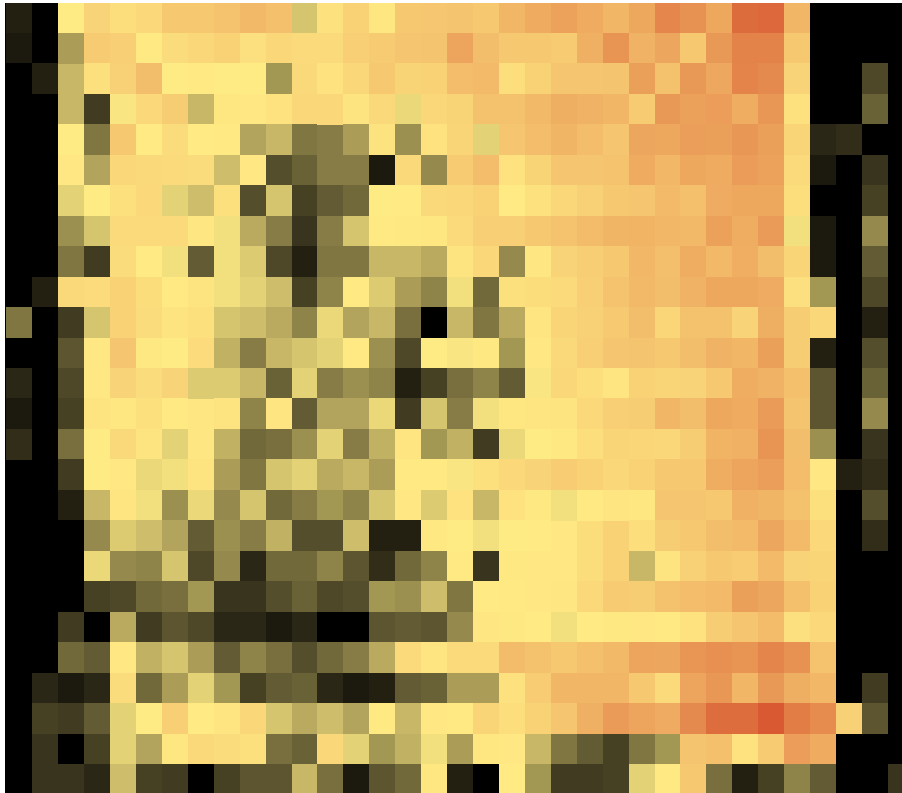
RTT Freight Consist - 60 mph
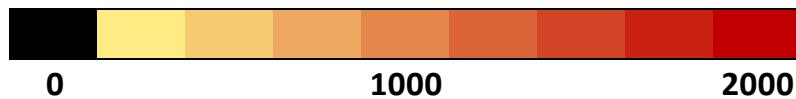
GAUGE

FIELD

Truck 1, Axle 1 of Locomotive	
Wheel Load, lbs	23,400
Rail Seat Load, lbs	8,700
% of Wheel Load Carried by Rail Seat	37
Maximum Pressure, psi	1,342
Average Pressure, psi	348
Contact Area, in^2	38.6
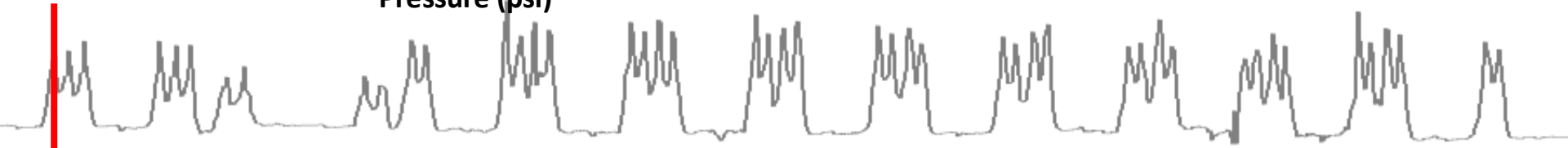
Pressure (psi)

0   1000   2000

RTT Freight Consist - 60 mph

GAUGE
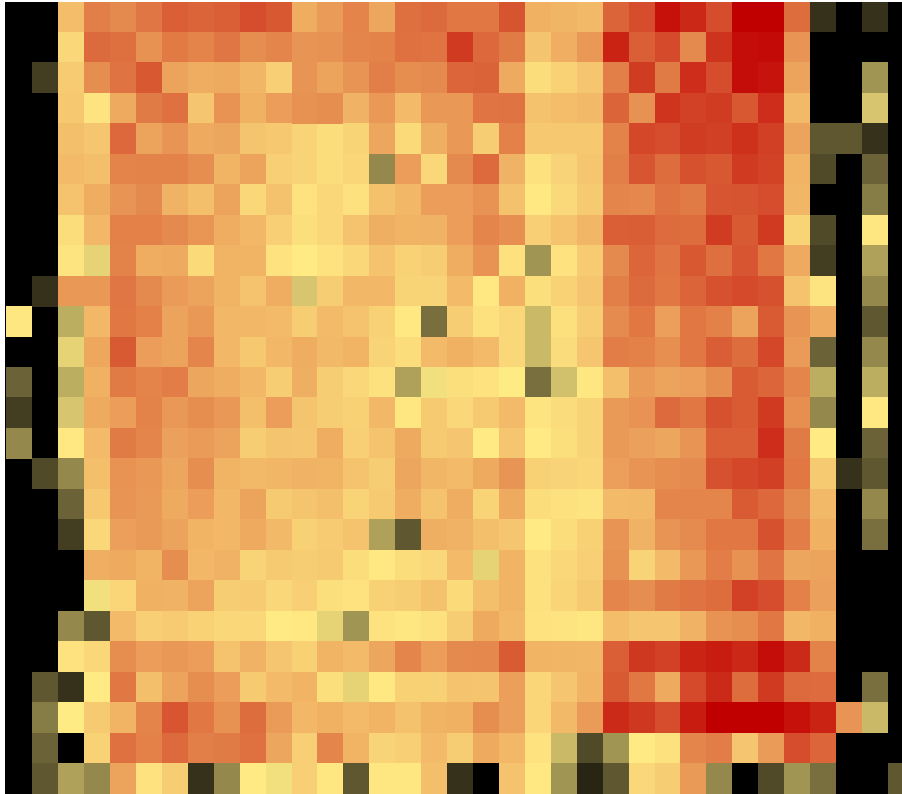
FIELD
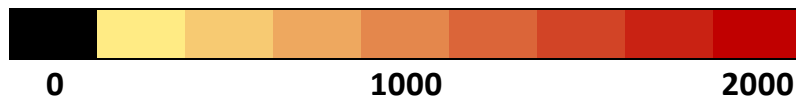
Truck 1, Axle 1 of Freight Car	
Wheel Load, lbs	39,100
Rail Seat Load, lbs	24,300
% of Wheel Load Carried by Rail Seat	62
Maximum Pressure, psi	2,486
Average Pressure, psi	746
Contact Area, in^2	39.0

Pressure (psi)

HTL TLV - Increasing L/V Ratios

Input Load
L/V Ratio

GAUGE
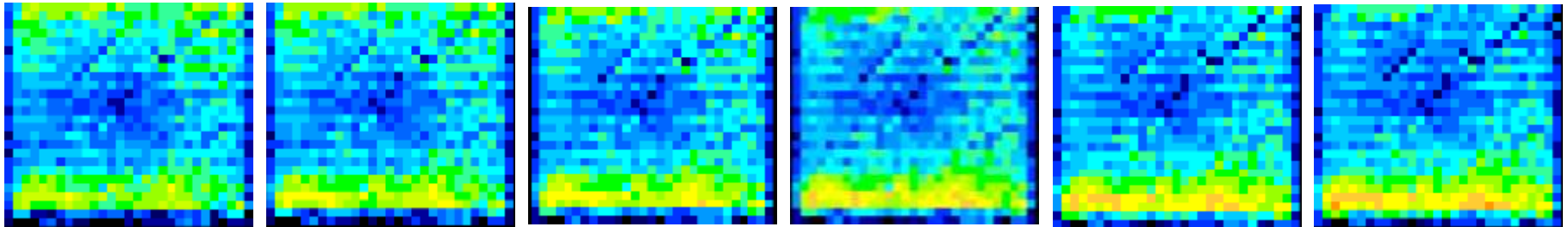
FIELD

40V	40V 2L	40V 4L	40V 6L	40V 8L	40V 10L
0	.05	.10	.15	.20	.25
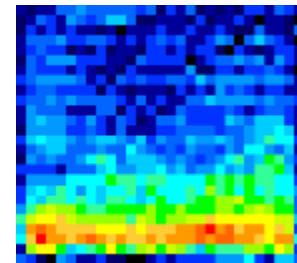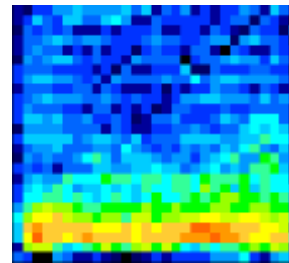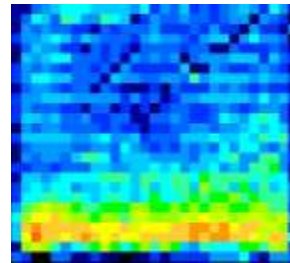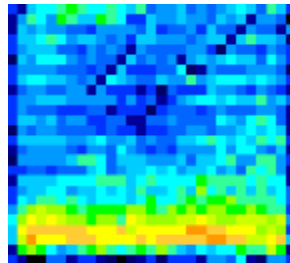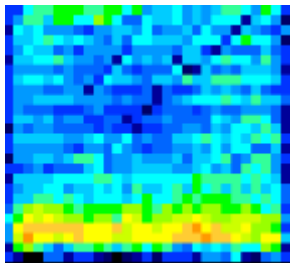
GAUGE

FIELD

40V 12L	40V 14L	40V 16L	40V 18L	40V 20L
.30	.35	.40	.45	.50

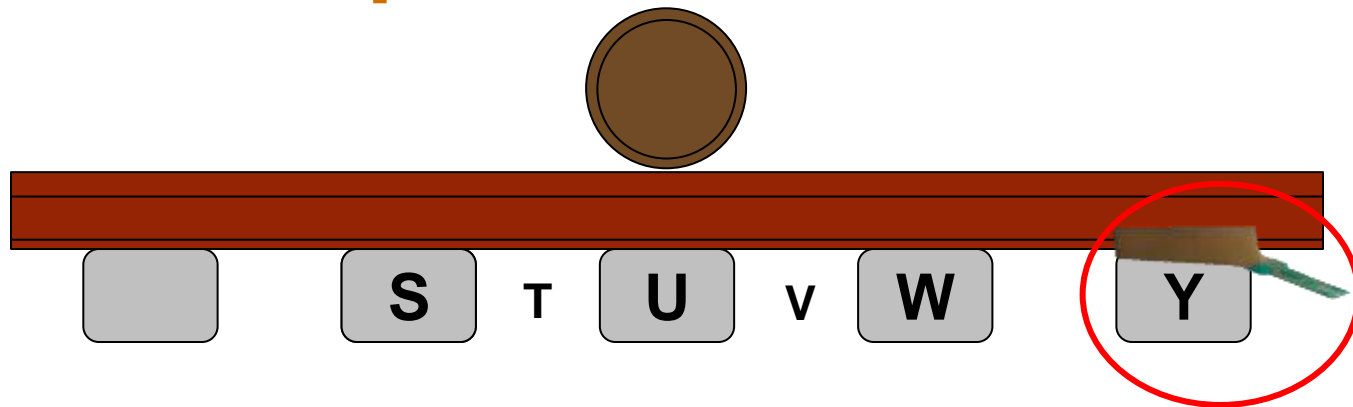# TLV 40 kip Vertical - HTL Low Rail
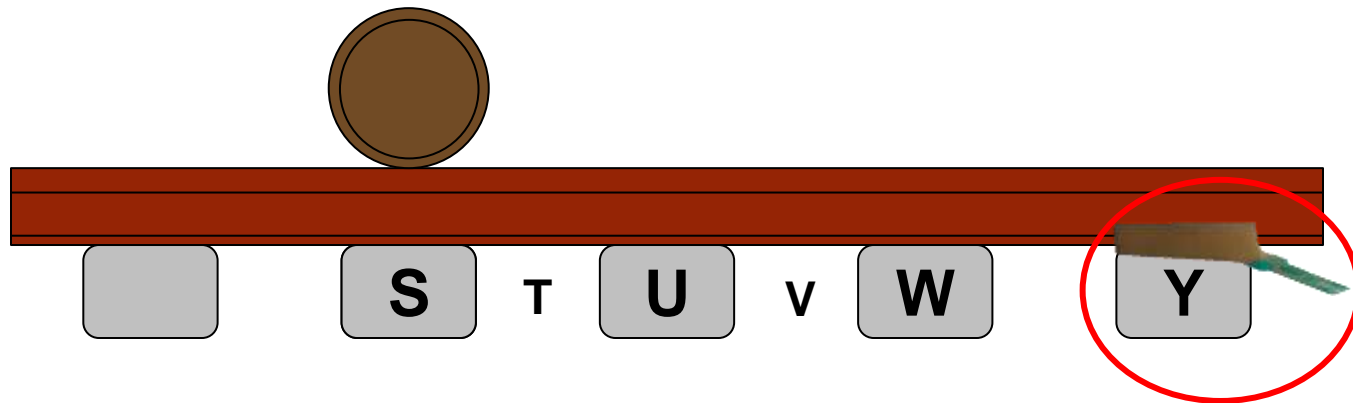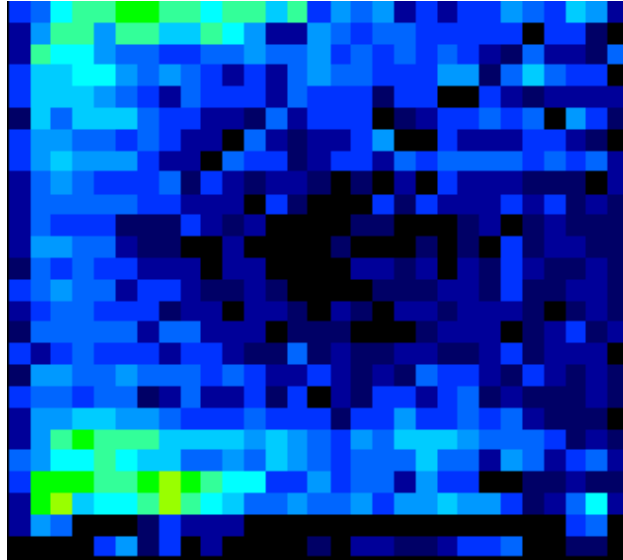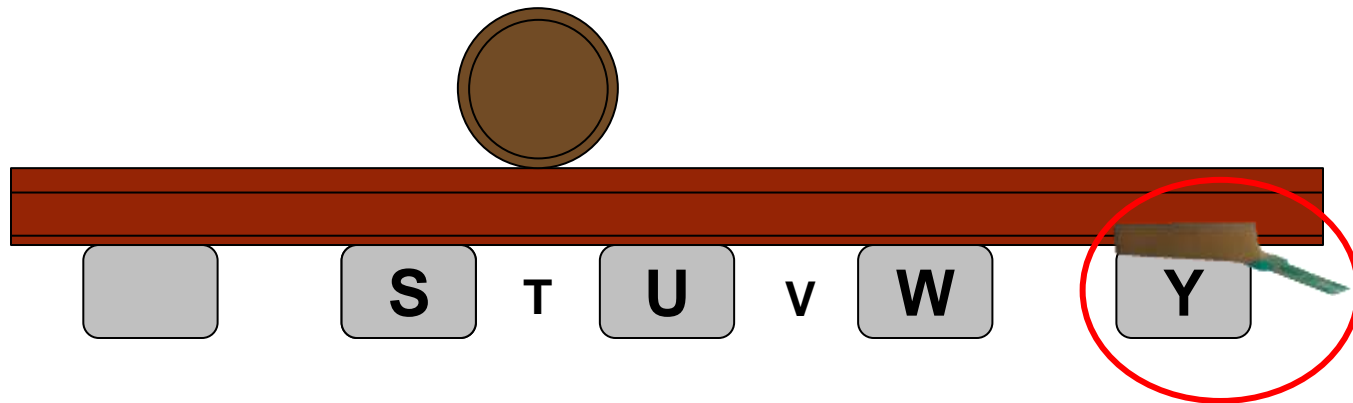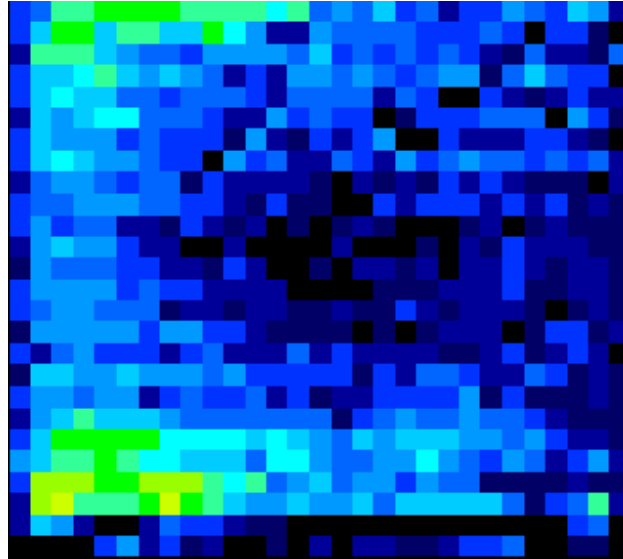
GAUGE

FIELD

TLV 40 kip Vertical - HTL Low Rail

GAUGE

FIELD

TLV 40 kip Vertical - HTL Low Rail

GAUGE

FIELD

TLV 40 kip Vertical - HTL Low Rail

GAUGE

FIELD

TLV 40 kip Vertical - HTL Low Rail

GAUGE
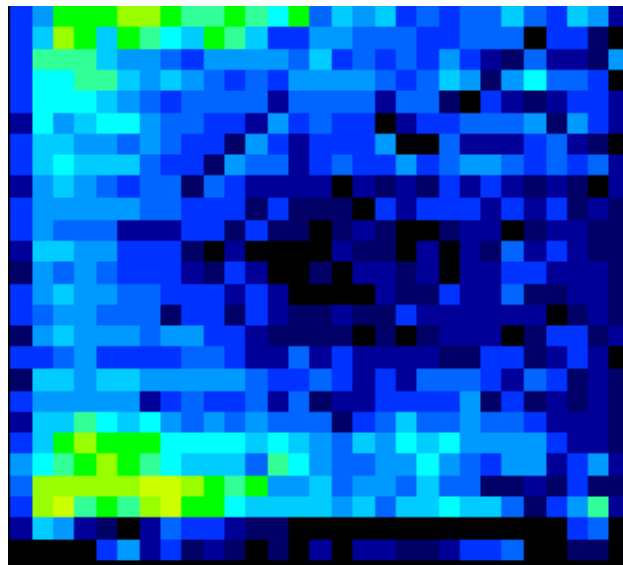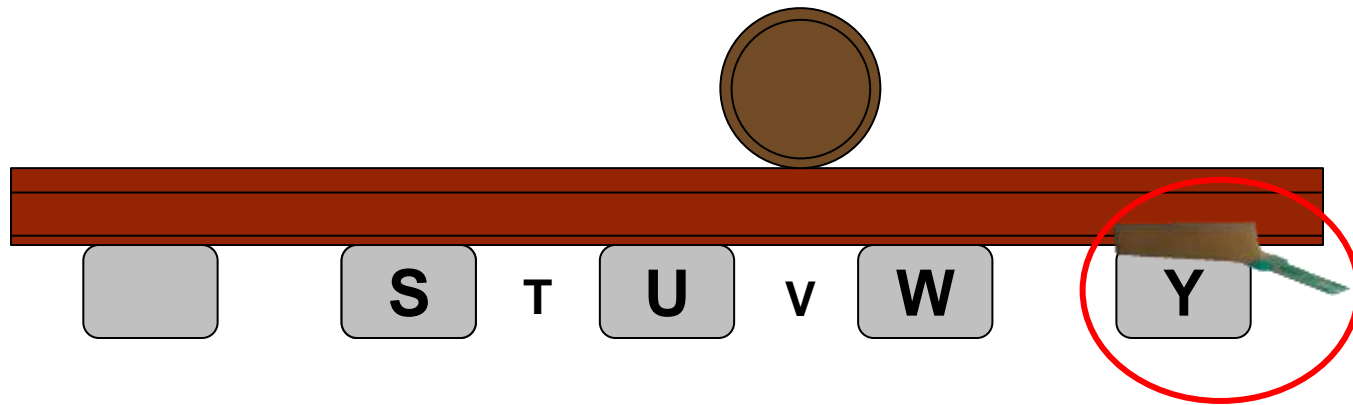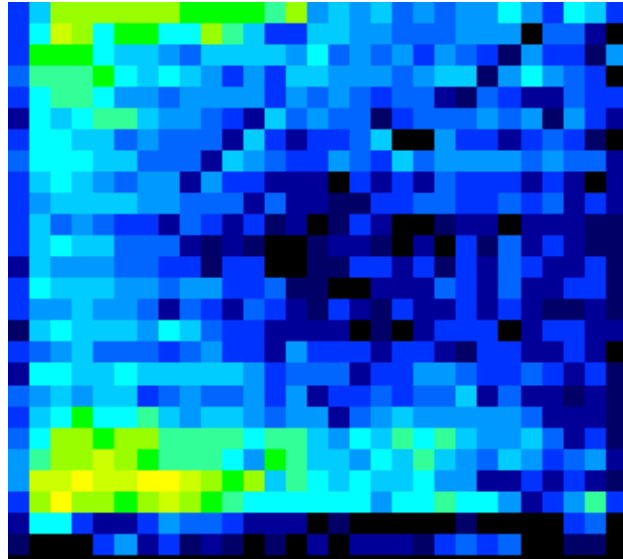

FIELD

TLV 40 kip Vertical - HTL Low Rail

GAUGE

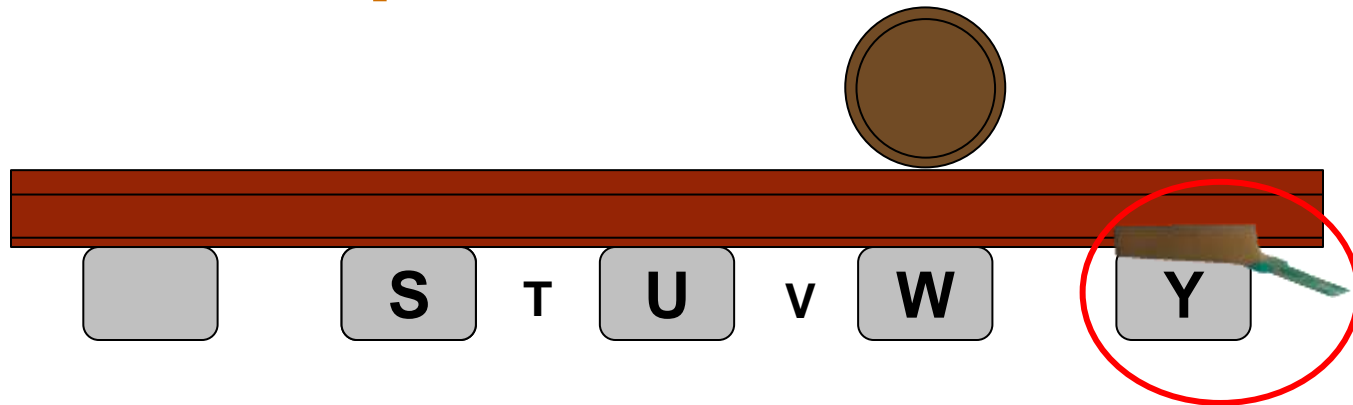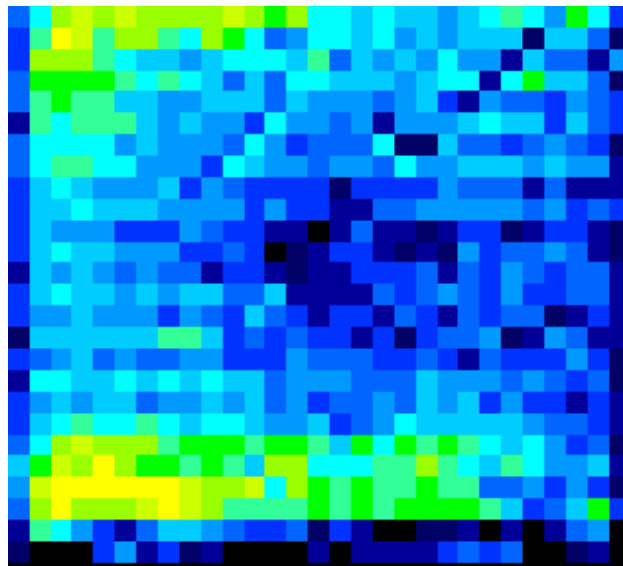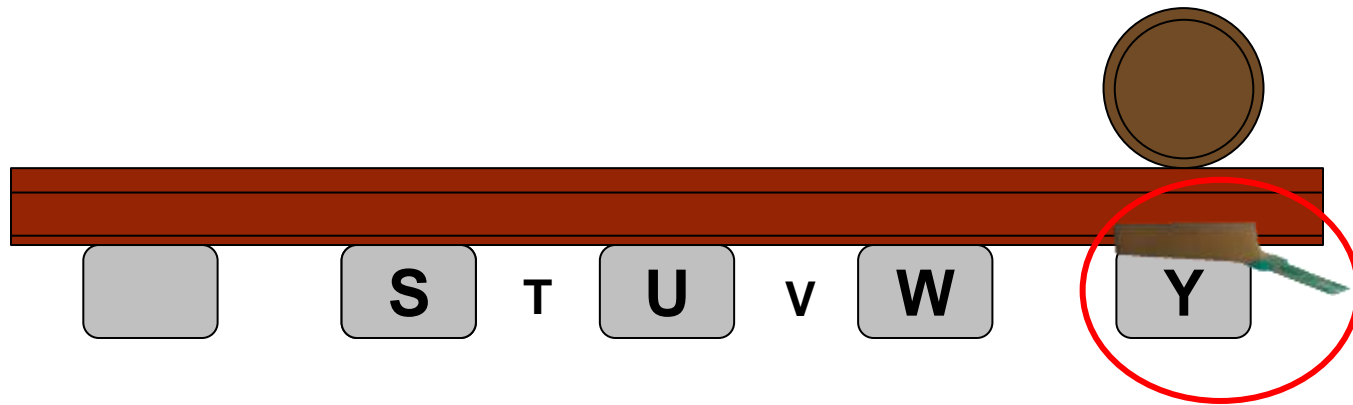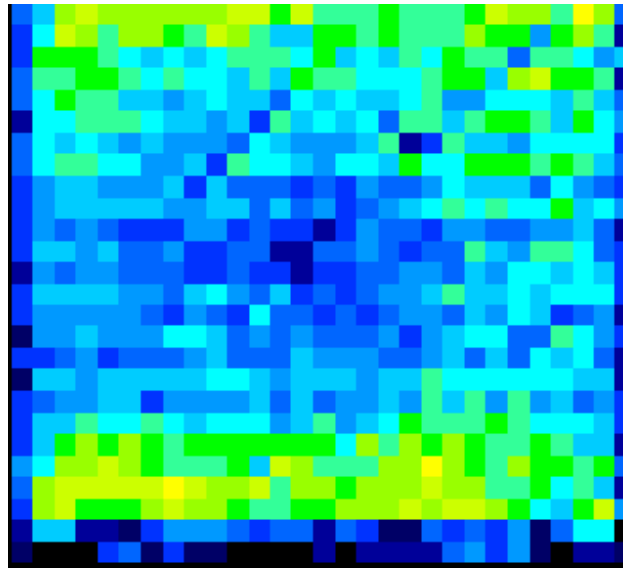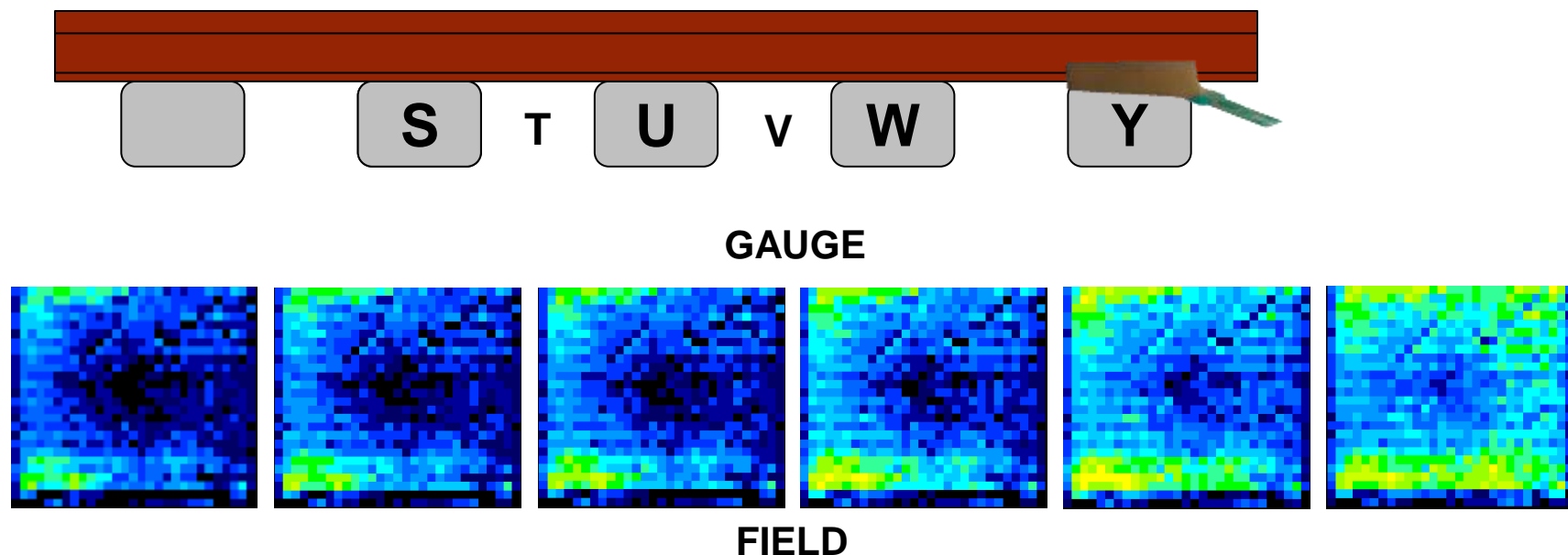FIELD

TLV 40 kip Vertical – HTL Low Rail

GAUGE

FIELD

Location of Load	Tie S	Crib T	Tie U	Crib V	Tie W	Tie Y
Raw Sum	13,390	18,082	20,574	27,875	37,529	49,490
% of Centered Load	27	37	42	56	76	-

Rail Pad Test

- **Objective:** gain understanding of effect of pad modulus on rail seat pressure distribution

- Bound the experiment by using low and high modulus pads

- Two rail pad types with same dimensions and geometry

  - Thermoplastic Vulcanizate (TPV - lower modulus)

  - Medium-Density Polyethylene (MDPE – higher modulus)

- Concrete rail seat and fastening system held constant

- Identical loading conditions

  - 32.5 kip vertical load

  - Lateral load varies based on respective L/V ratio

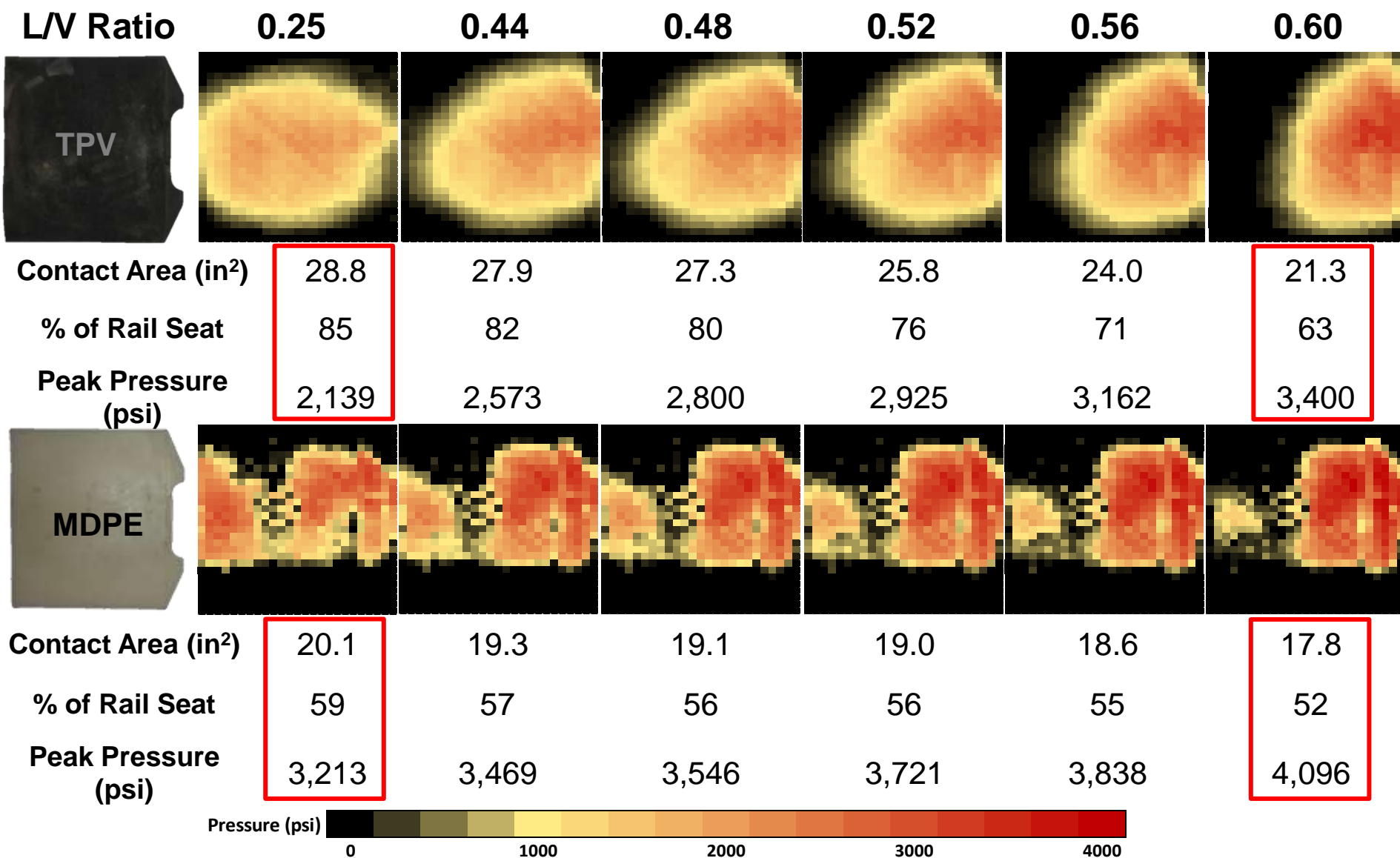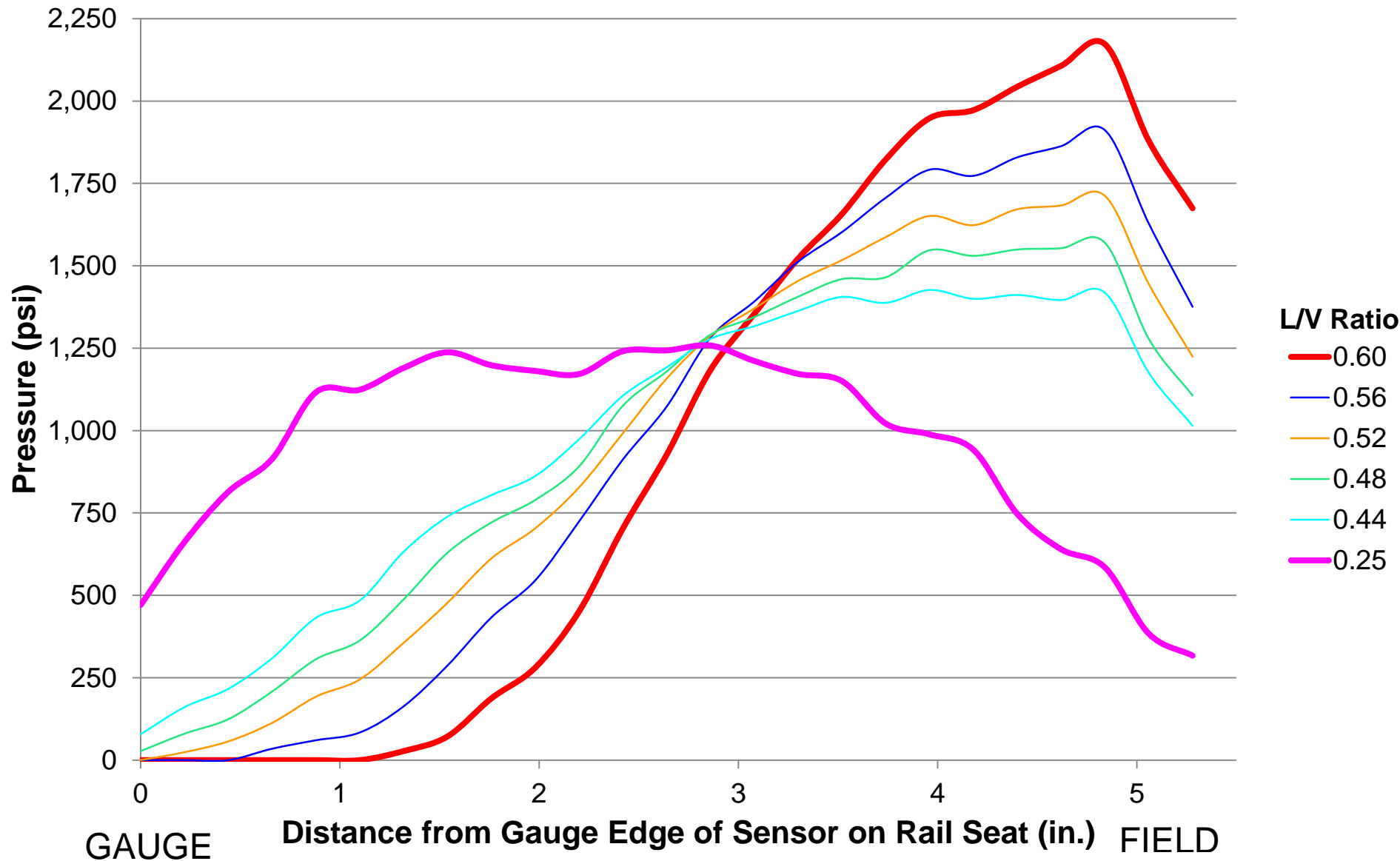|	TPV	MDPE
Shore Hardness	86 (A)	60 (D)
Flexural Modulus, psi	15,000*	120,000

*Approximate flexural modulus based on a TPV with a similar Shore Hardness of 87A

Rail Pad Test Results

L/V Ratio	0.25	0.44	0.48	0.52	0.56	0.60
TPV						
Contact Area (in²)	28.8	27.9	27.3	25.8	24.0	21.3
% of Rail Seat	85	82	80	76	71	63
Peak Pressure (psi)	2,139	2,573	2,800	2,925	3,162	3,400
MDPE						
Contact Area (in²)	20.1	19.3	19.1	19.0	18.6	17.8
% of Rail Seat	59	57	56	56	55	52
Peak Pressure (psi)	3,213	3,469	3,546	3,721	3,838	4,096

Pressure (psi)

0   1000   2000   3000   4000

Average Pressure Distribution for TPV Rail Pad

Average Pressure Distribution for MDPE Rail Pad
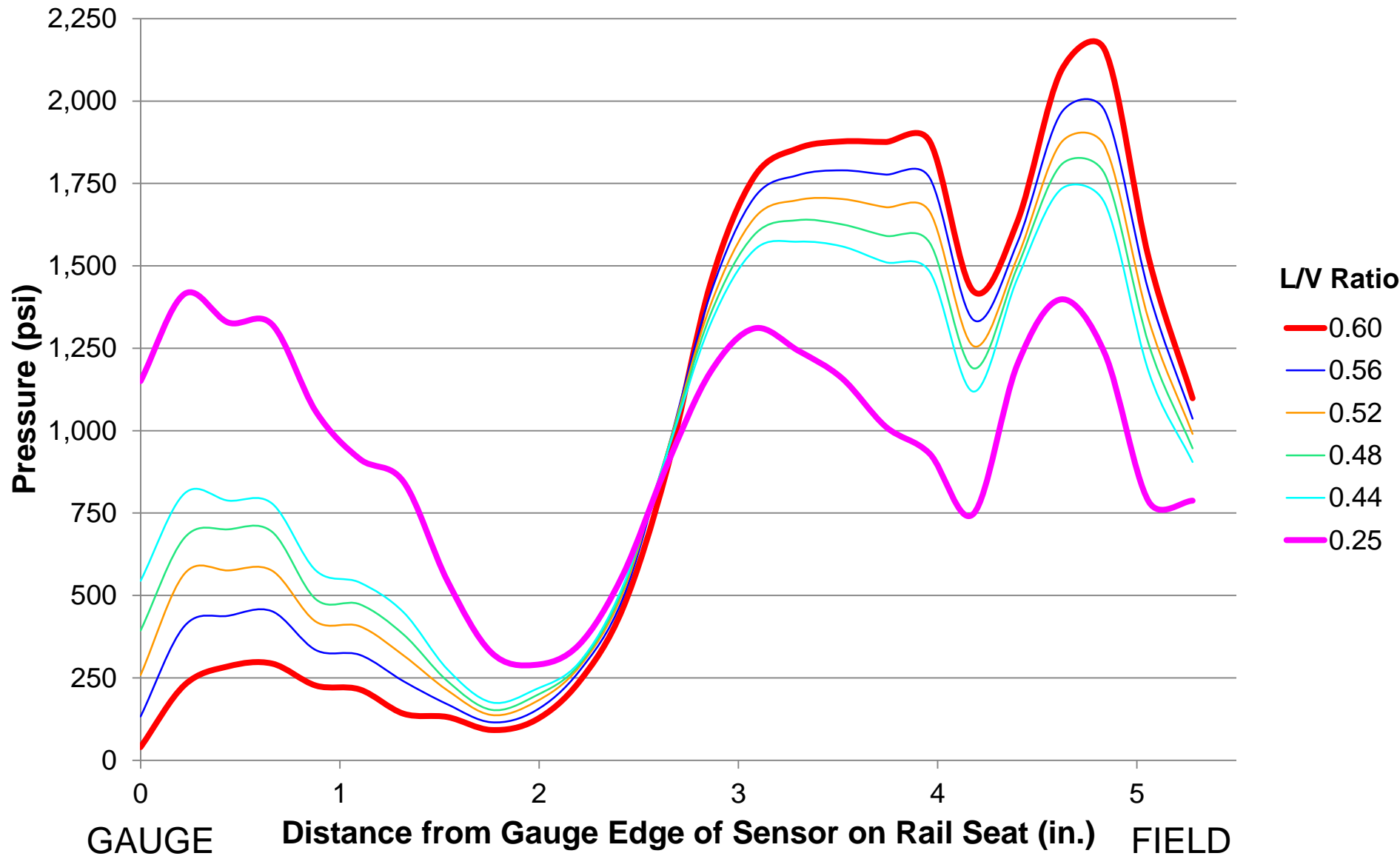
Rail Pad Test Results (cont.)

- **Two-Part Pad Assembly**
  - Poly Pad
  - Nylon 6-6 Abrasion Frame
- **32.5 kip vertical load**
- **Lateral load varies based on respective L/V ratio**

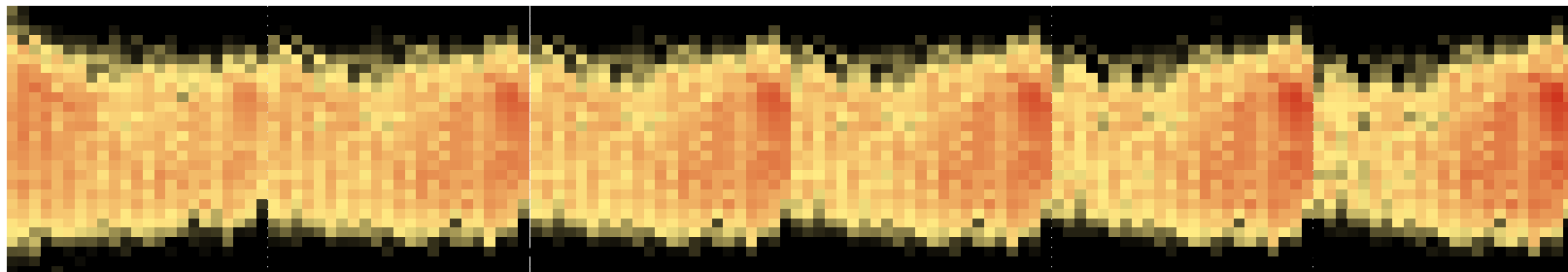← GAUGE   FIELD →

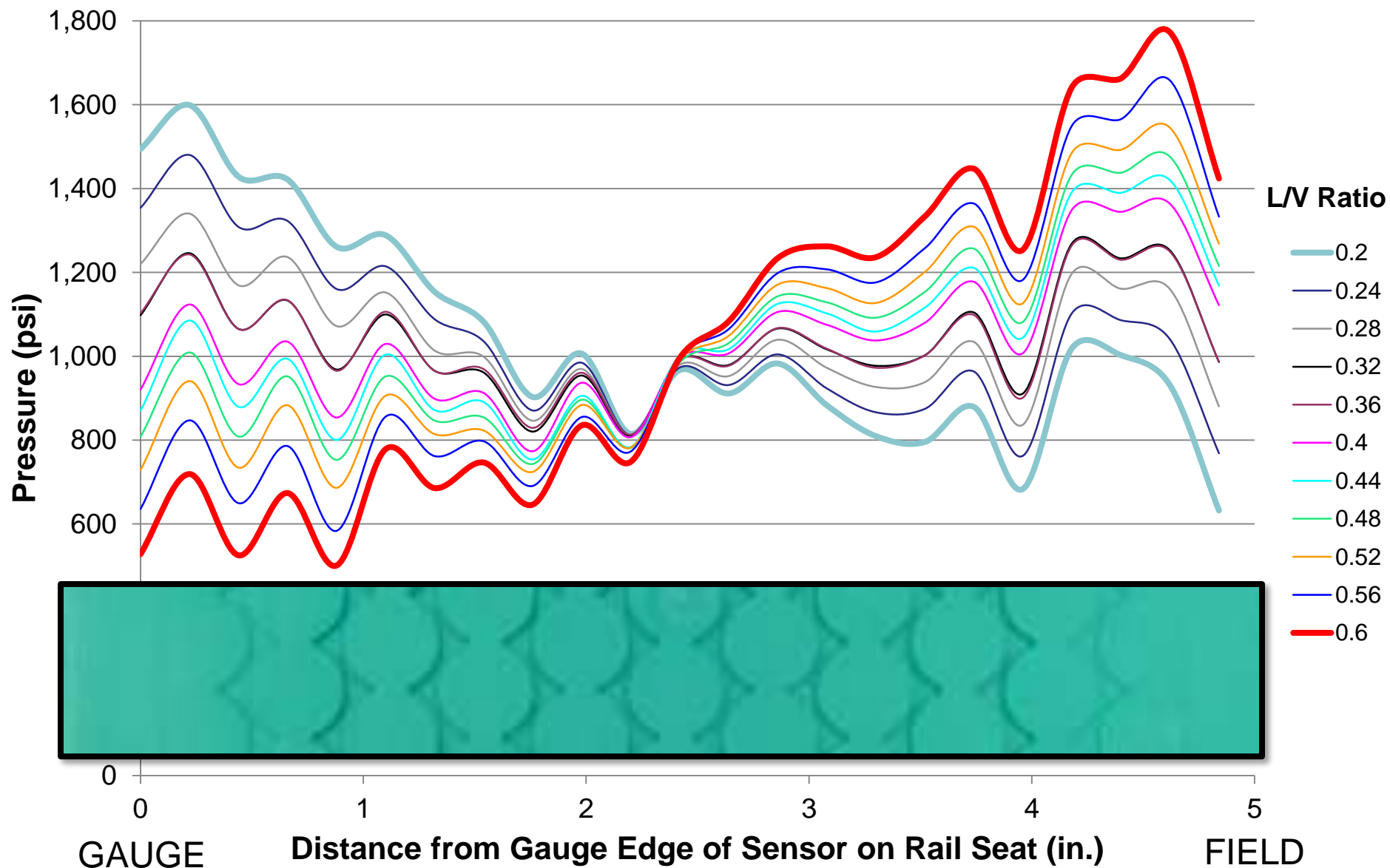| L/V Ratio	0.24	0.44	0.48	0.52	0.56	0.60
Two - Part Pad Assembly						
Contact Area (in²)	24.9	24.0	23.9	23.9	23.4	23.4
% of Rail Seat	80	77	77	77	75	75
Peak Pressure (psi)	2,550	2,821	2,877	2,990	3,201	3,325

Pressure (psi)

0   1000   2000   3000   4000

Average Pressure Distribution for Two-Part Pad Assembly

L/V Ratio
- 0.2
- 0.24
- 0.28
- 0.32
- 0.36
- 0.4
- 0.44
- 0.48
- 0.52
- 0.56
- 0.6

Rail Pad Comparison at 0.52 L/V

- Load Applied:
  - 32.5 kip vertical
  - 16.9 kip lateral

TPV　　MDPE　　**Two-Part Pad Assembly**

⟵ GAUGE　　　　FIELD ⟶
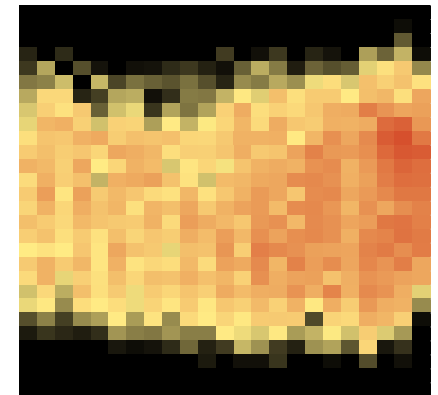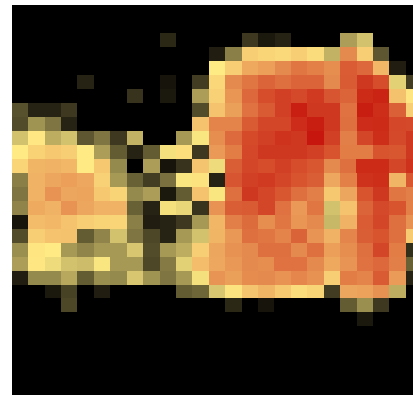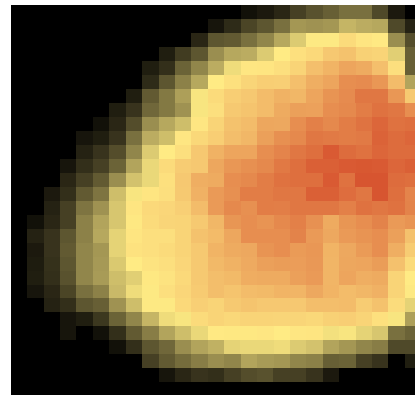
Contact Area (in^2)	25.8	19.0	23.9
Peak Pressure (psi)	2,925	3,721	2,990

Conclusions from Laboratory Testing

- **Effect of L/V Ratio**
  - Lower L/V ratios distribute the pressure over a larger contact area
  - Higher L/V ratios cause a concentration of pressure on the field side of the rail seat
    - Results in higher peak pressures
- **Rail Pad Test**
  - Lower modulus rail pads distribute rail seat loads over a larger contact area
    - Reduces peak pressure values
    - Mitigates highly concentrated loads at this interface
  - Higher modulus rail pads distribute rail seat loads in more highly concentrated areas
    - Possibly leads to localized crushing of the concrete surface
  - Two-Part Pad Assembly
    - Maintains relatively consistent contact area under increasing L/V ratios
    - Peak pressures similar to the lower modulus TPV pad
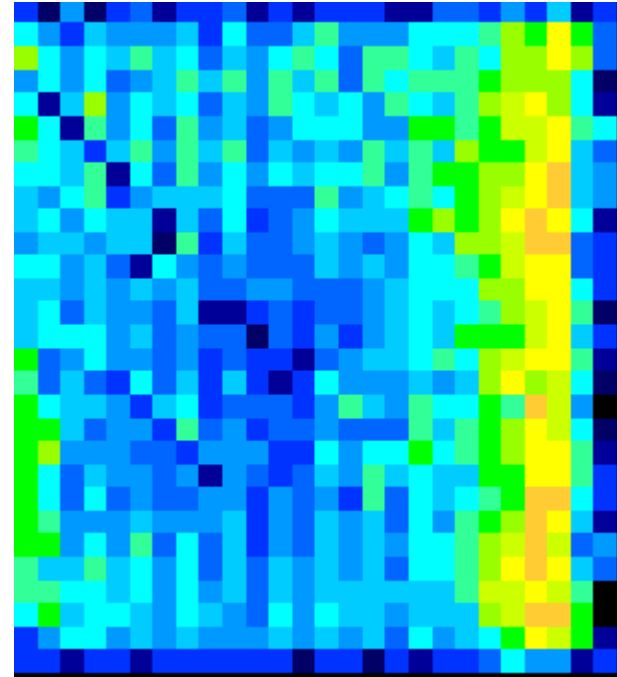
Lab vs. Field - L/V 0.40
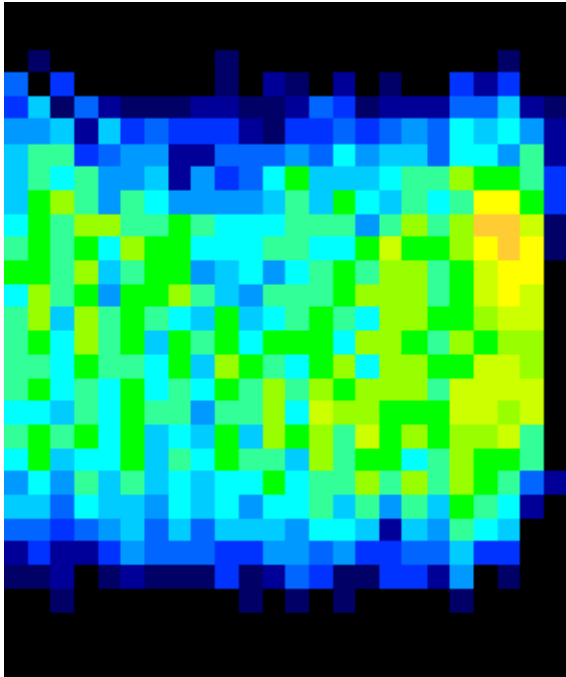
GAUGE · FIELD

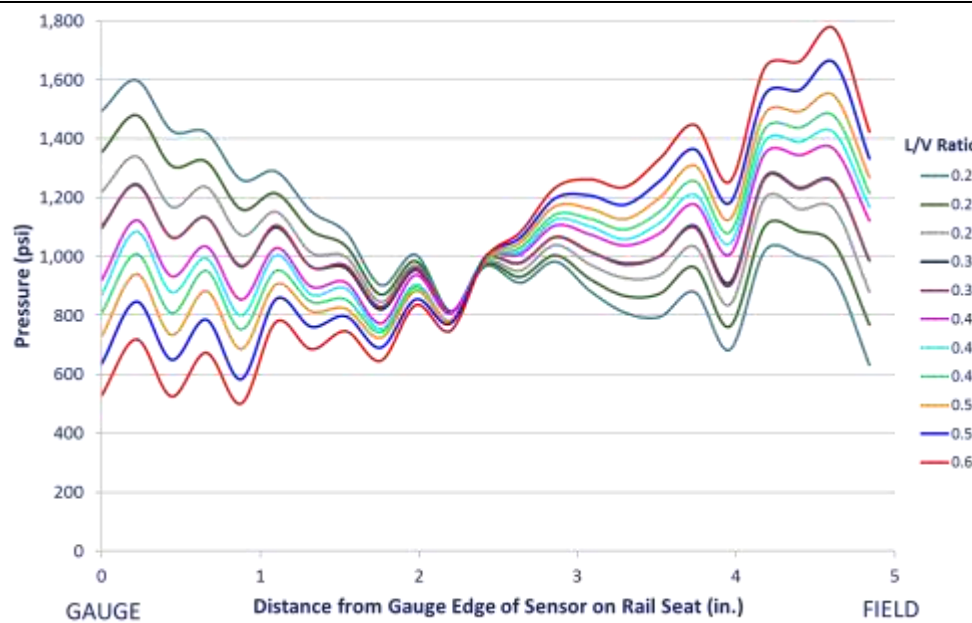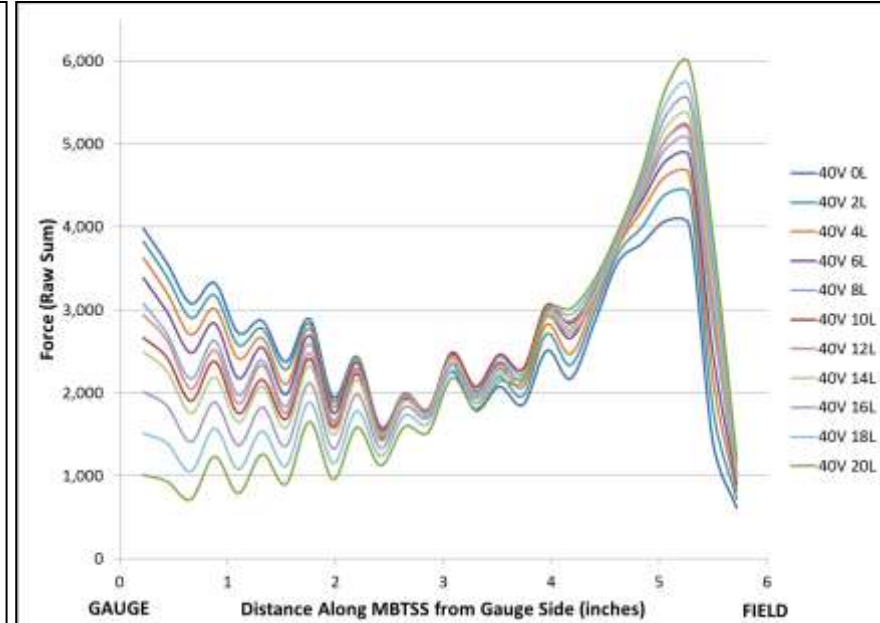**PLTM Test**
2-Part Pad Assembly
Contact Area: 24.44 in^2

GAUGE · FIELD

Field Test
2-Part Pad Assembly
Contact Area: 36.35 in^2

Lab vs. Field - Increasing L/V Ratios

PLTM Testing in Laboratory

Field Testing at TTC HTL