Measuring Concrete Crosstie Rail Seat Pressure Distribution with Matrix Based Tactile Surface Sensors (MBTSS)

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Outline

- Overview of FRA Concrete Crosstie and Fastening System BAA
- Current Objectives of Experimentation with MBTSS
- Pulsating Load Testing Machine (PLTM) at UIUC
- Sensor Layout and Data Representation
- Experimentation at UIUC
  - Rail Pad Test
  - Fastening Clip Test
- Conclusions
- Future Work
- Acknowledgements

FRA Concrete Crosstie and Fastening System BAA

- **Program Objectives**
  - Conduct comprehensive international literature review and state-of-the-art assessment for design and performance
  - Conduct experimental laboratory and field testing, leading to improved recommended practices for design
  - Provide mechanistic design recommendations for concrete crossties and fastening system design in the US
- **Select Program Deliverables**
  - Improved mechanistic design recommendations for concrete crossties and fastening systems in the US
  - Improved safety due to increased strength of critical infrastructure components
  - Centralized knowledge and document depository for concrete crossties and fastening systems

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FRA Tie and Fastener BAA Industry Partners:

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Hanson
LBFoster CXT Concrete Ties

FRA Tie and Fastener Program Structure

Inputs

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

Outputs/Deliverables

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

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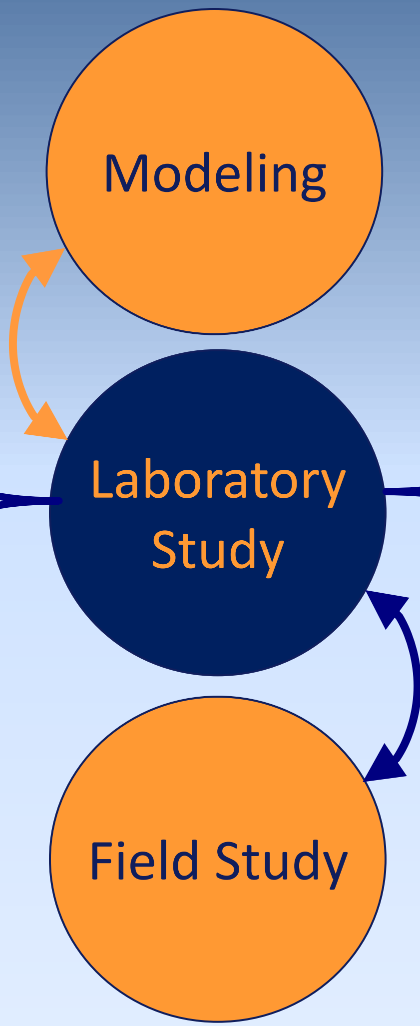
Rail Seat Load Calculation Methodologies

Involvement of Industry Experts



Outputs/Deliverables

Data Collection

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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

Current Objectives of Experimentation with MBTSS

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

Pulsating Load Testing Machine (PLTM)

- Housed at the Advanced Transportation and Research Engineering Laboratory (ATREL)
- Owned by Amsted RPS
- Used for Full Scale Concrete Tie and Fastening System Testing
- Following AREMA Test 6 – Wear and Abrasion
- Three 35,000 lb. actuators: two vertical and one horizontal
  - Ability to simulate various Lateral/Vertical (L/V) ratios

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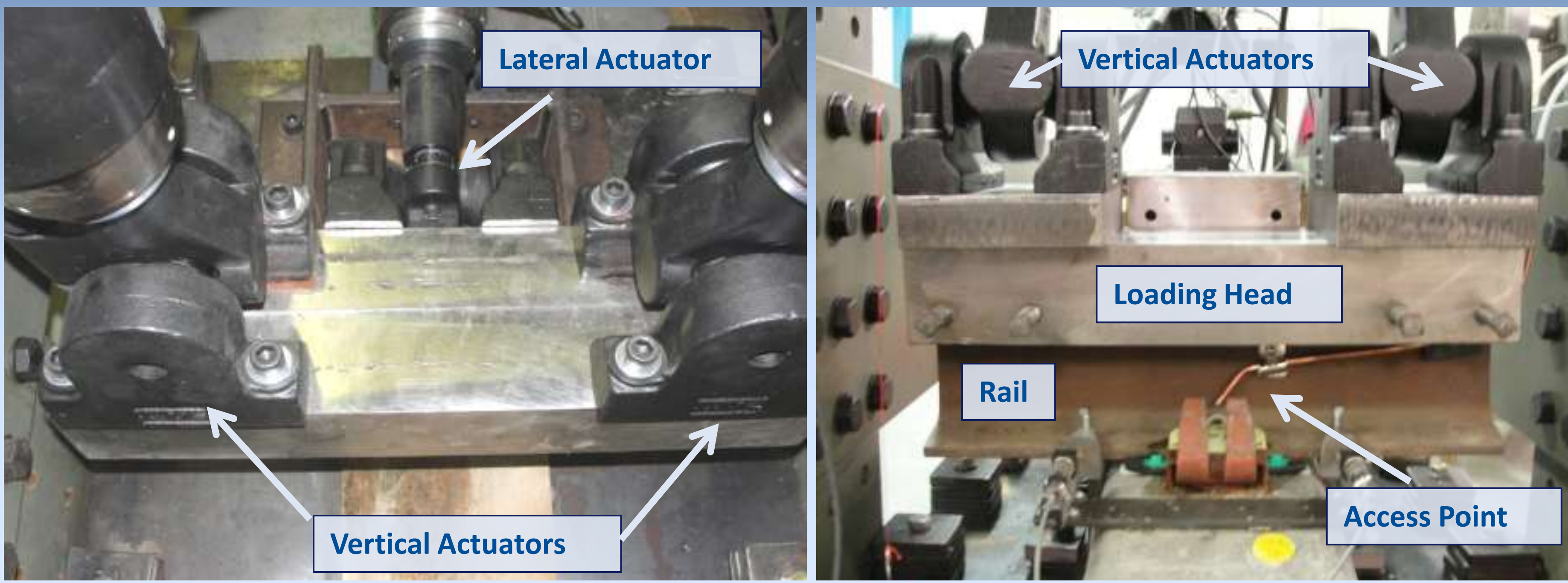
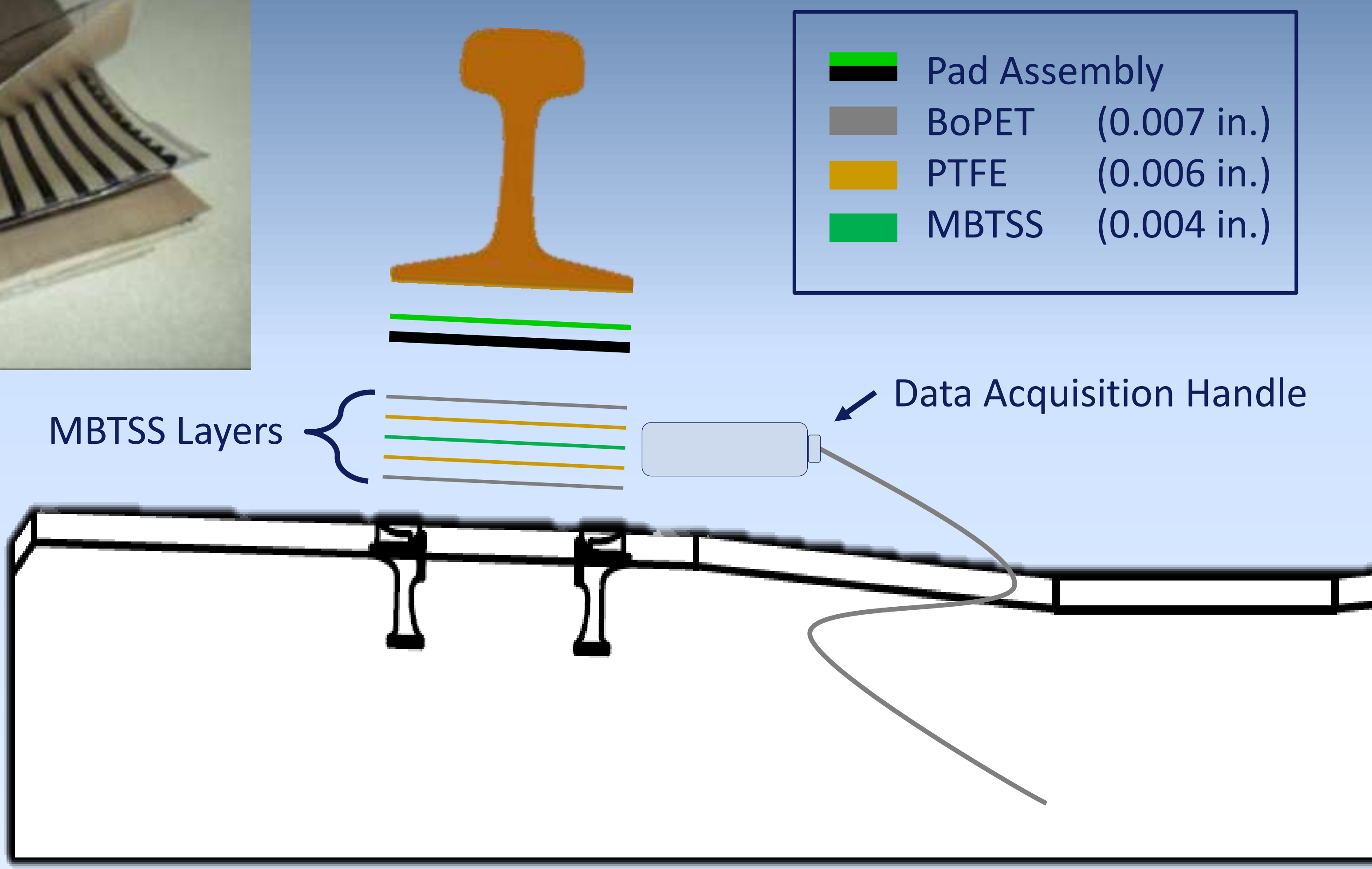
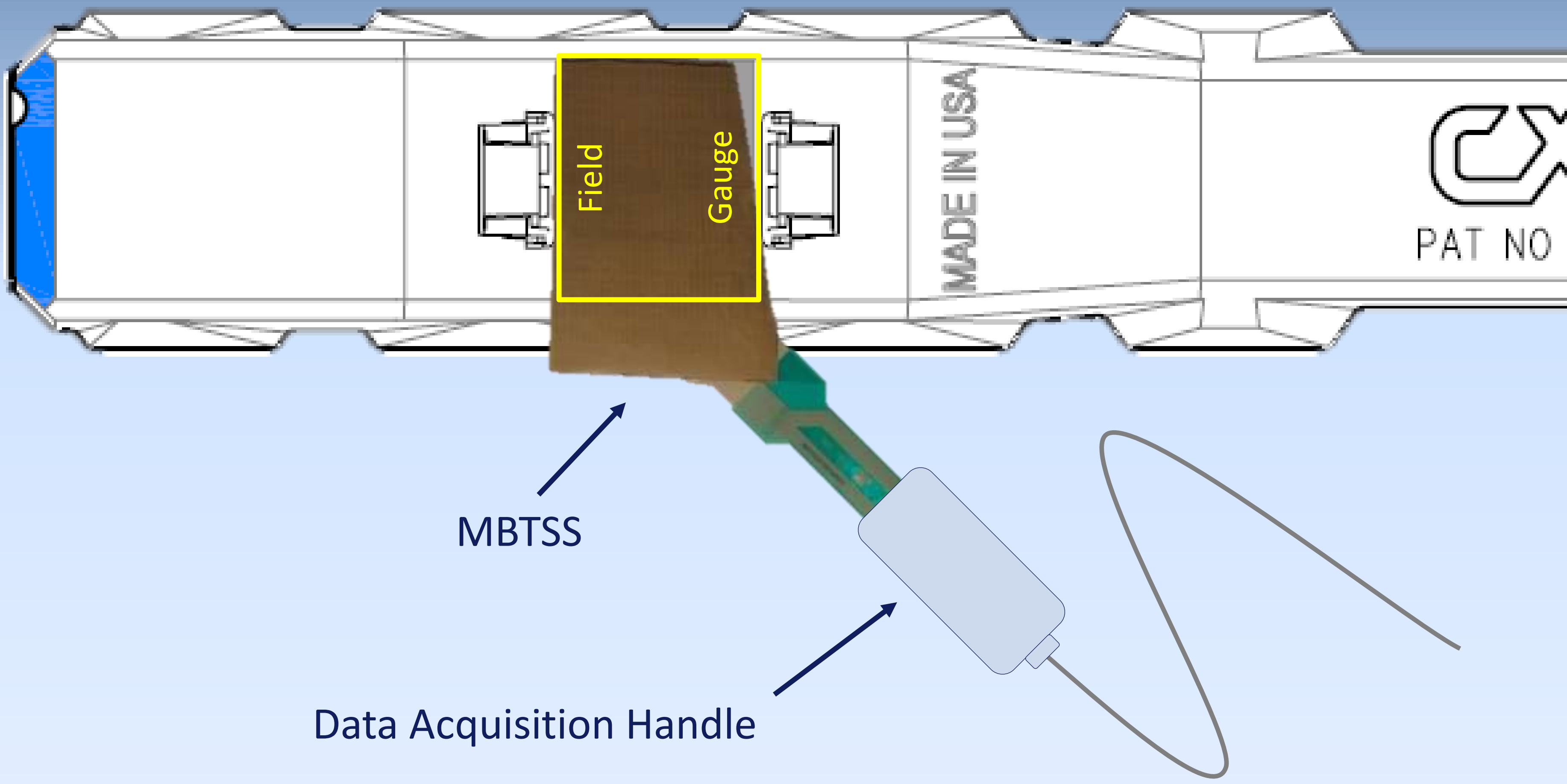
Pulsating Load Testing Machine (PLTM)



MBTSS Placement (Profile)

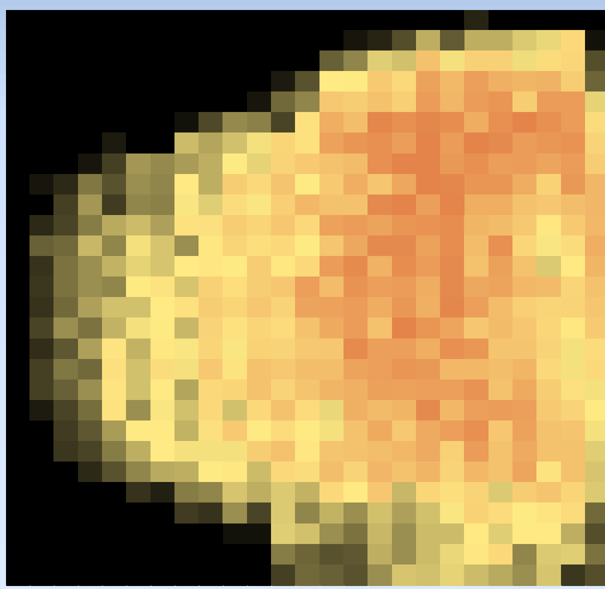


MBTSS Placement (Plan)

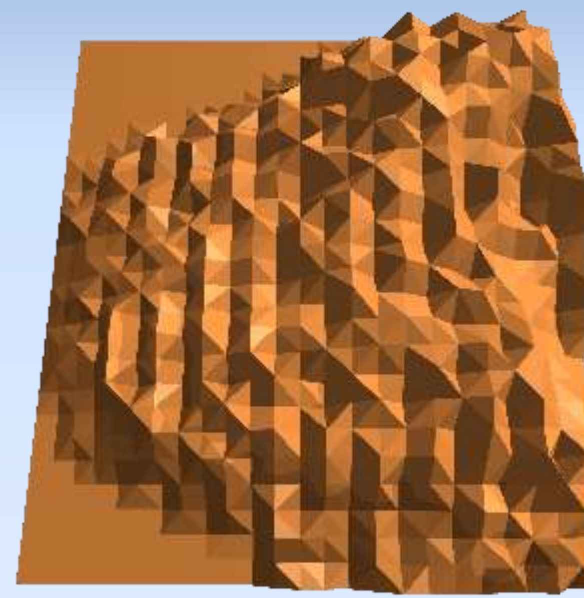


Visual Representation of Data

- Data visually displayed as color 2D or 3D images
- Force and pressure are calculated at each sensing point
- Standard color scale applied to all data



Sample 2D MBTSS Output



Sample 3D MBTSS Output

Pressure (psi)

0 1000 2000 3000 4000

GAUGE

FIELD

																		156					
													98	156	332	743	391	743	743	860	919	1232	78
												411	567	880	821	1545	958	1349	1349	938	1193	1271	332
										117	352	1017	997	1427	1232	1936	1642	1975	1760	1701	1740	1388	430
									98	450	567	1447	1388	1525	1369	2014	1681	2014	2092	1388	2014	2014	899
						78	313	587	547	293	1134	1779	1584	2288	2170	2288	2209	1799	2170	2327	2170	2014	1193
			117			802	704	821	958	1290	1134	1936	2092	2170	1994	2327	2014	2327	2248	2014	2072	2131	1310
		98	274	645	587	665	743	997	899	1310	1427	1545	1603	2170	2327	2327	2053	2170	1994	2014	1897	2014	1388
98	176	508	352	606	567	1036	743	1388	1232	1505	997	1427	1779	1486	1877	2327	2288	2092	2092	1799	1330	2053	1681
	274	645	254	567	547	978	880	1193	978	1369	1662	1545	1545	2248	2327	1975	2307	1779	1779	1545	1466	1584	1681
176	293	528	723	802	684	1134	1154	1388	1290	1466	1232	1936	2014	1916	2092	2131	2209	1701	1623	1447	1075	1427	1662
411	450	782	567	958	841	606	1075	1290	1173	1232	997	1486	1857	2248	2248	1936	2209	1603	2170	1271	978	1193	1779
215	489	606	763	899	841	1017	1056	997	1388	1075	1232	2014	2229	1740	2209	2014	2248	1545	1955	1525	860	1036	1701
235	489	606	567	997	1114	841	1349	1173	1388	1466	1975	1603	2131	1975	2014	1799	2248	1857	1916	1662	1623	1290	1545
215	450	684	821	821	1017	1134	1388	1290	1466	1310	1916	1936	2014	1799	2072	1760	2288	1975	1603	1369	1290	1310	1486
293	606	489	763	958	997	782	1310	1134	1290	1212	1525	1818	2014	1545	2327	2092	1897	1466	1623	1466	1271	1075	1427
196	371	684	1095	763	1075	978	1290	978	1330	1310	1447	1466	2229	1975	1975	1779	2170	2072	1505	1505	1310	958	1212
274	508	450	1154	821	1193	958	1447	1114	1545	1447	1584	1584	1916	1975	2092	2053	1662	1662	1584	1701	1232	958	1232
274	411	606	1095	821	1036	704	1232	1290	1545	1310	1505	1701	1760	1955	1936	1975	1975	2131	1525	1818	1388	1154	958
117	293	469	1114	606	978	821	1232	821	1232	1545	1212	919	1760	1623	1701	2248	1662	1975	2014	1975	1427	1310	997
	254	371	665	997	1036	763	1154	1427	1036	1212	1036	958	1525	1818	1447	1838	1975	2170	1466	1936	1525	1505	958
	235	293	528	743	1017	958	958	958	1388	1545	1056	1505	1545	1584	1662	1838	1349	2014	1545	1838	1545	1545	880
		176	352	567	723	743	997	1075	802	1232	1193	1584	1310	1681	1525	1701	1310	1662	1545	1897	1114	1545	841
				215	137	528	567	841	743	860	763	1232	1036	1466	782	1271	1173	1310	860	1388	1505	1290	860
						254	215	606	293	860	567	763	606	821	684	821	978	1330	1212	997	1095	1212	450
								78	78	880	821	606	489	782	606	802	802	1036	880	1036	1036	743	332
										528	430	352	371	743	606	802	919	1056	1232	567	860	880	489
										274	450	411	352	606	841	821	899	802	723	606	841	235	332

Pressure (psi): 0, 1000, 2000, 3000, 4000

0.22 in.

1545

0.22 in.

Area = 0.0484 in^2

~21 per 1 in^2

Experimentation at UIUC

- Laboratory experimentation to measure effect of L/V ratio on pressure distribution in the rail seat varying:
  - Rail pad assembly
  - Fastening clip
- Attempt to simulate range of field loading inputs in the laboratory using the PLTM

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

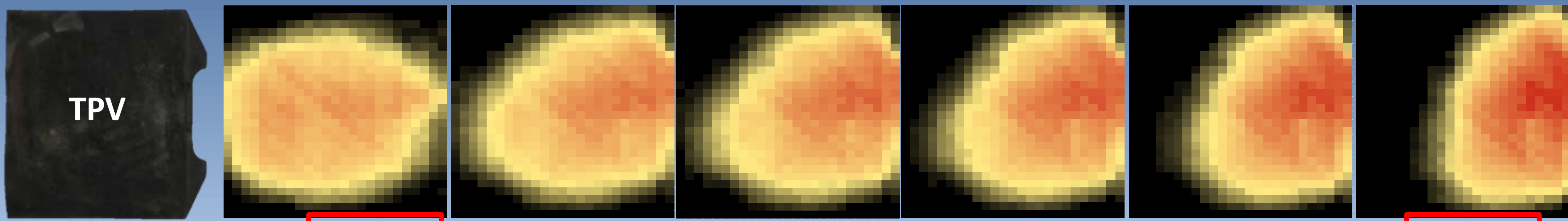
	TPV	MDPE
Shore Hardness	86 (A)	60 (D)
Flexural Modulus, psi	15,000*	120,000

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

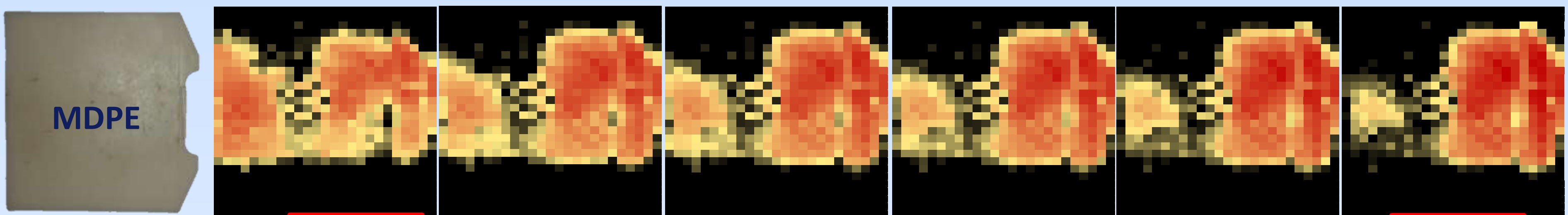
Rail Pad Test Results

← GAUGE FIELD →

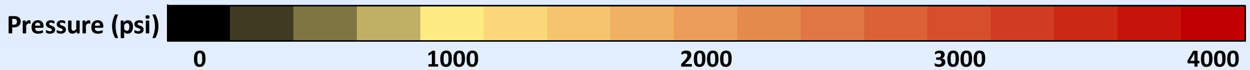
L/V Ratio	0.25	0.44	0.48	0.52	0.56	0.60



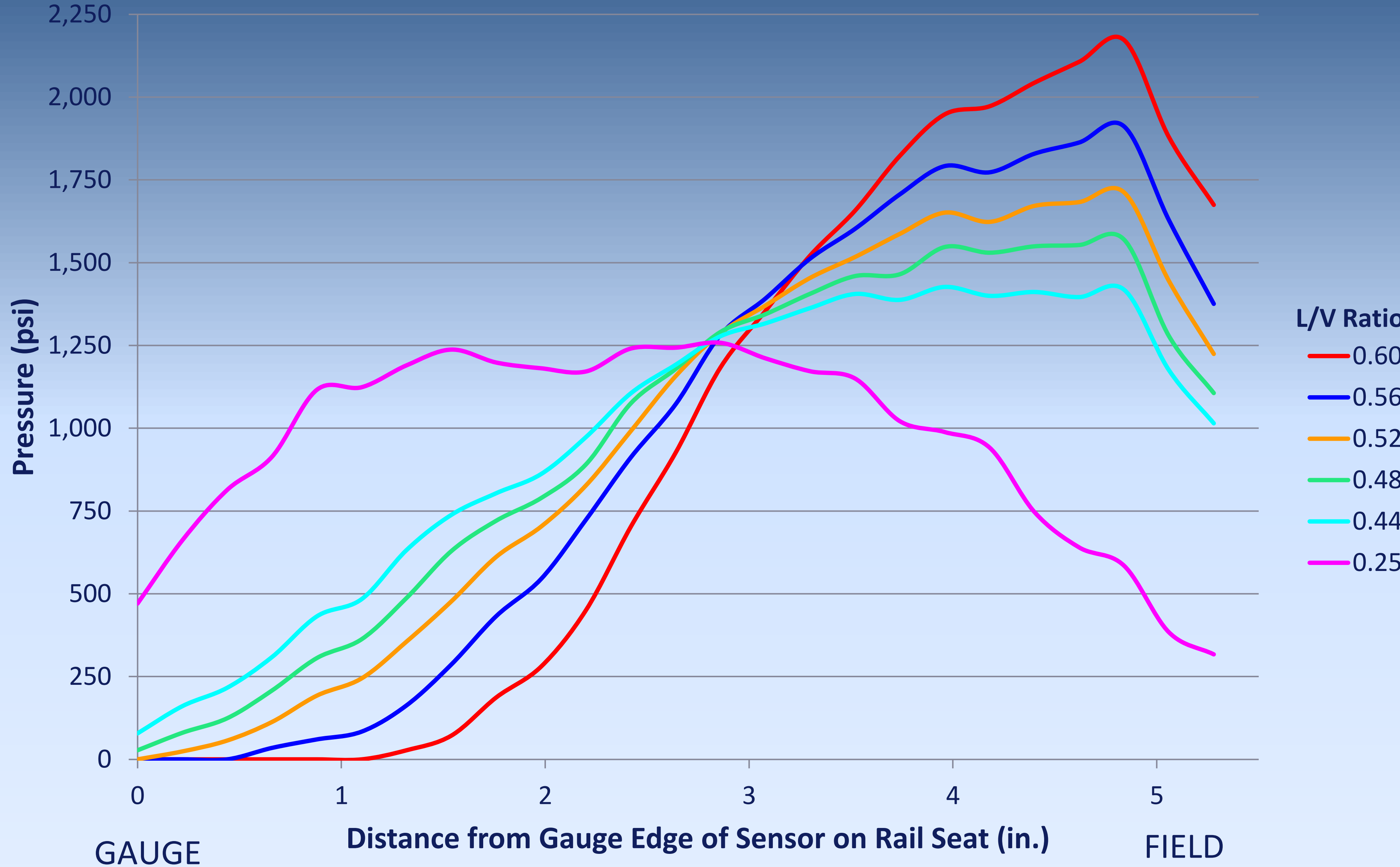
Contact Area (in²)	28.8	27.9	27.3	25.8	24.0	21.3
% of Rail Seat	85	82	80	76	71	63
Peak Pressure (psi)	2,139	2,573	2,800	2,925	3,162	3,400



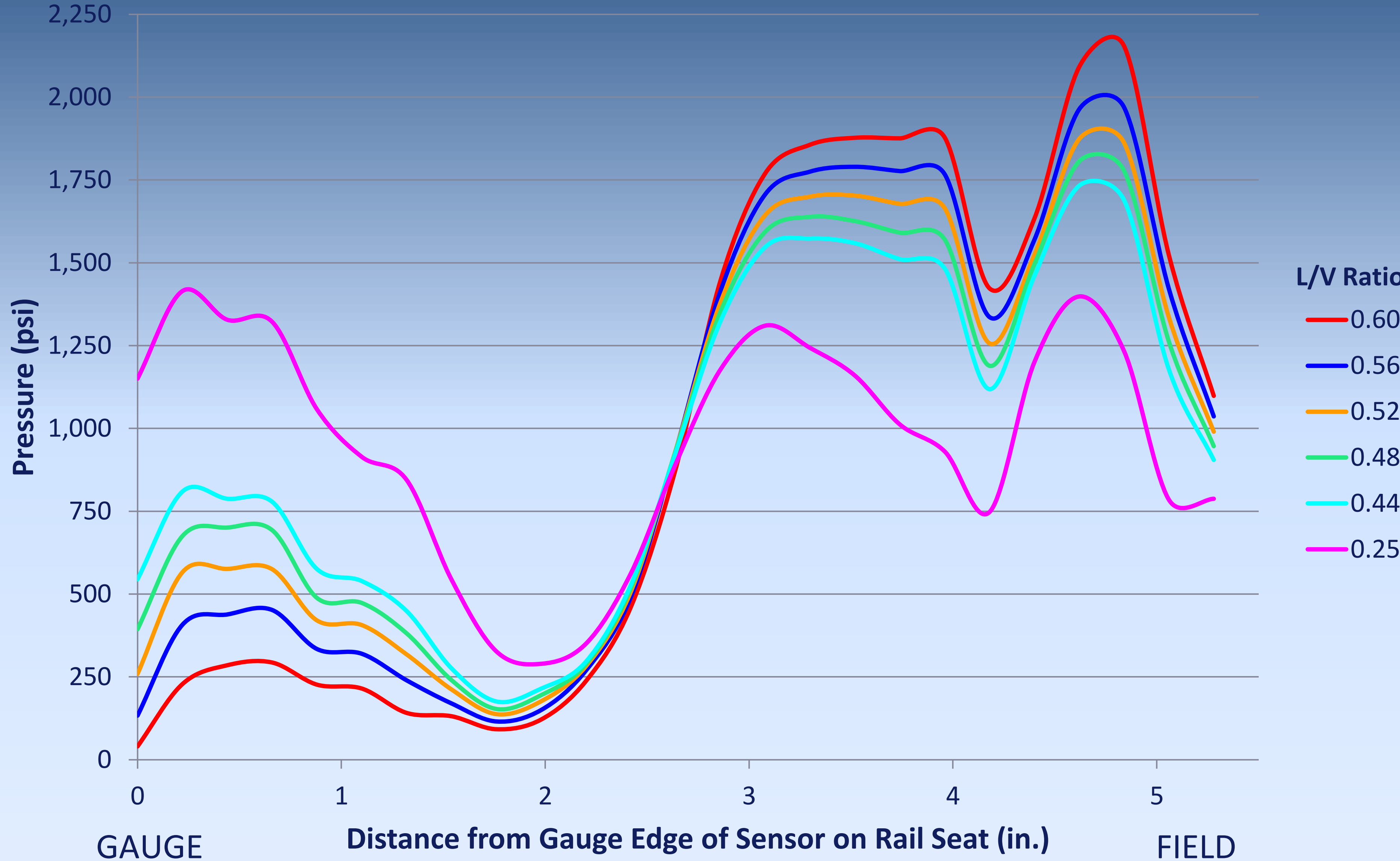
Contact Area (in²)	20.1	19.3	19.1	19.0	18.6	17.8
% of Rail Seat	59	57	56	56	55	52
Peak Pressure (psi)	3,213	3,469	3,546	3,721	3,838	4,096



Average Pressure Distribution for TPV Rail Pad

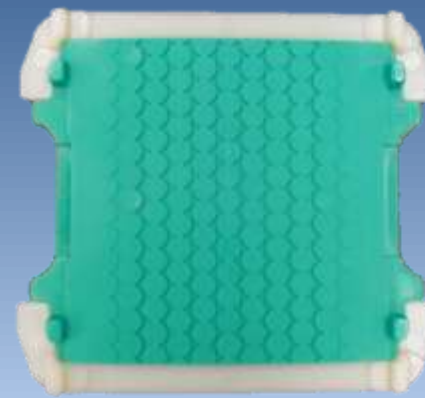


Average Pressure Distribution for MDPE Rail Pad



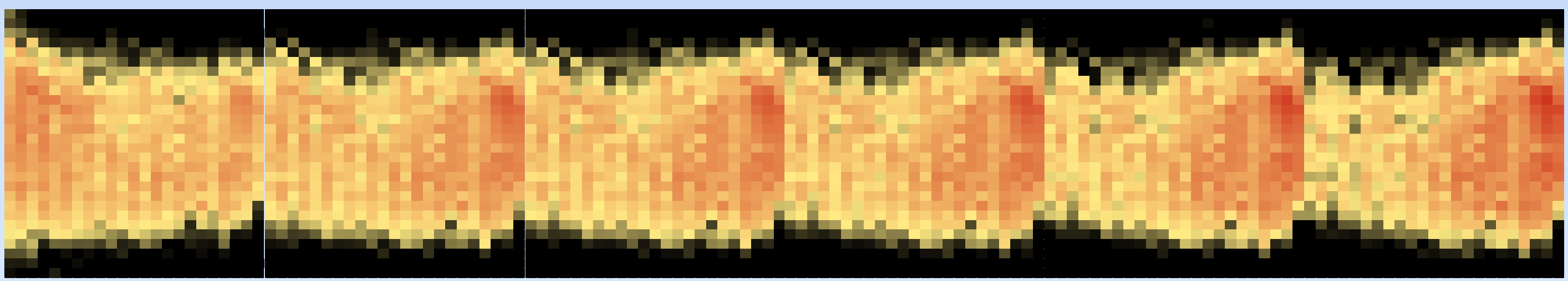
Rail Pad Test Results (cont.)

- 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

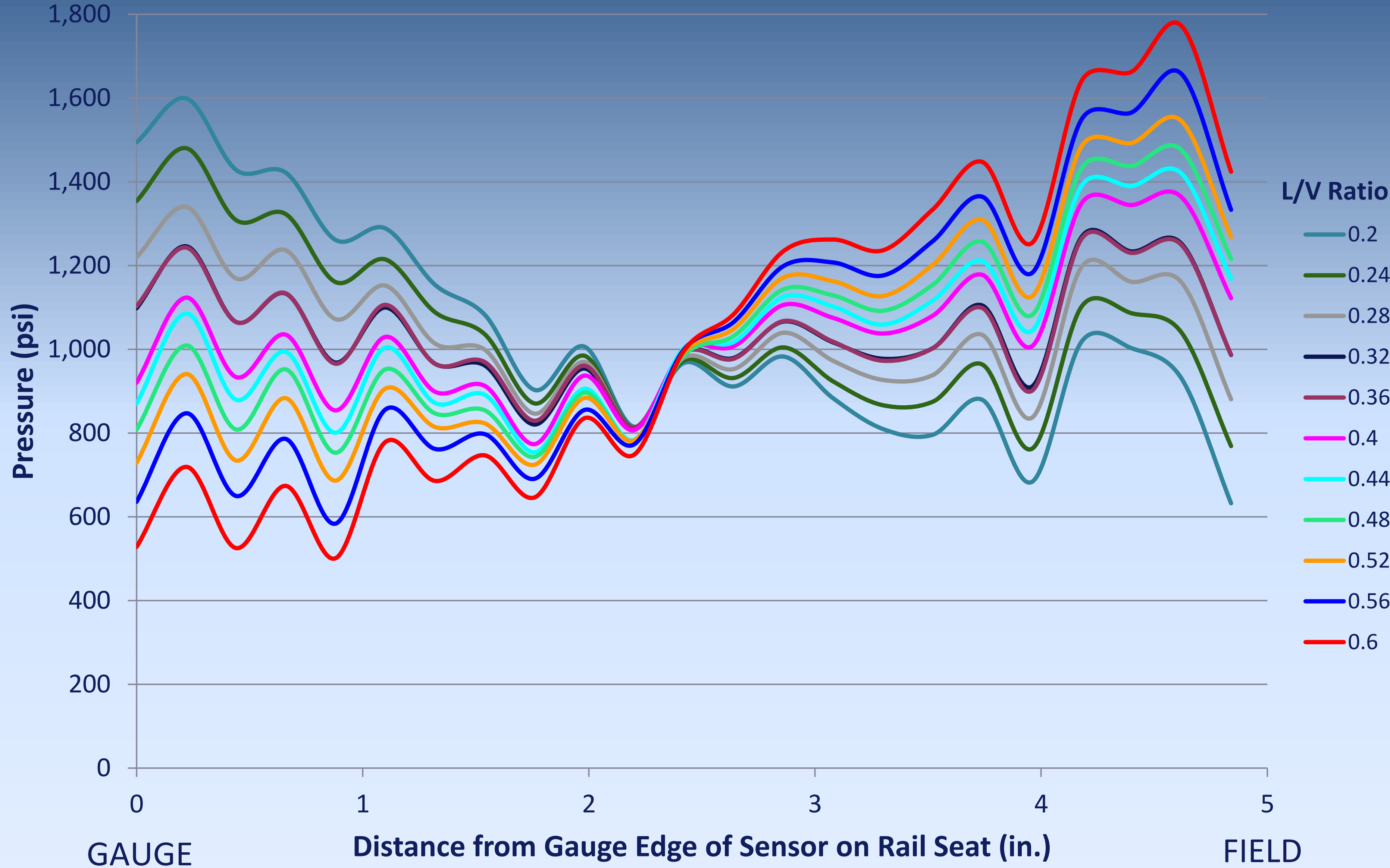


Two - Part Pad Assembly

	0.24	0.44	0.48	0.52	0.56	0.60
Contact Area (in^2)	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

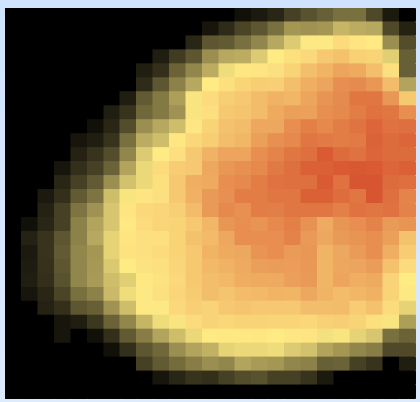
Average Pressure Distribution for Two-Part Pad Assembly

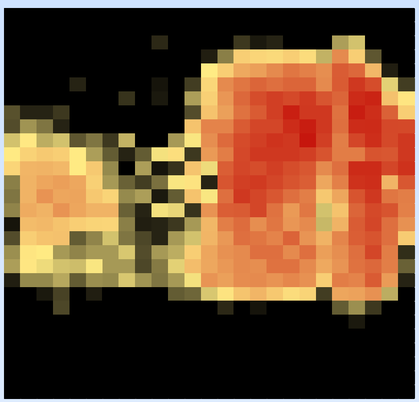


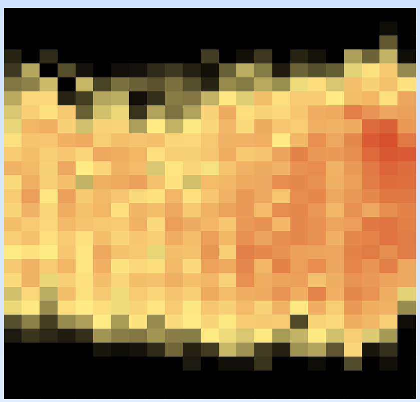
Rail Pad Comparison at 0.52 L/V

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

← GAUGE FIELD →







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

Clip Test

- **Objective:** gain preliminary understanding of effect of clip geometry on pressure distribution
- Rail pad material held constant
- Identical loading conditions
  - 32.5 kip vertical load
  - Lateral load varies based on respective L/V ratio

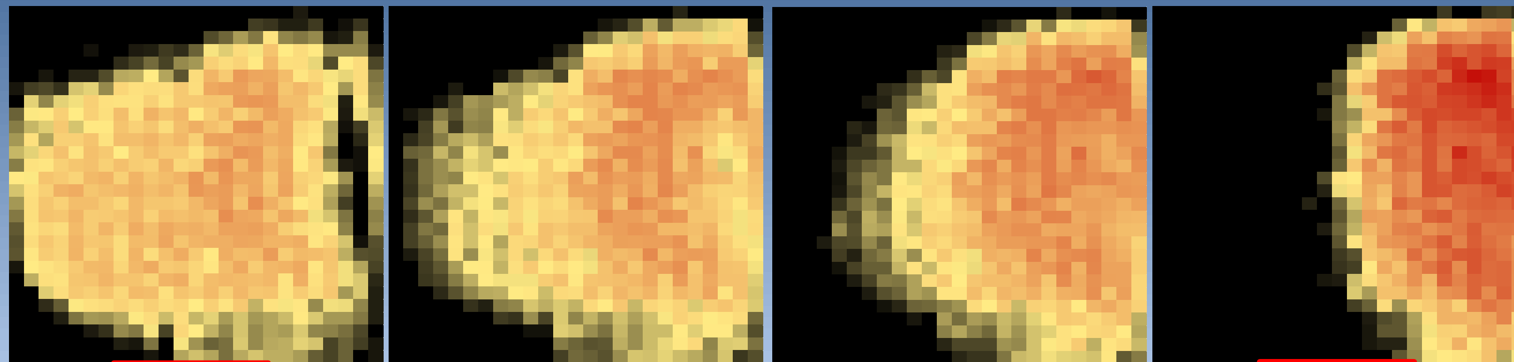
	Clip A	Clip B
Design Toe Load, lbs	4,750	5,500
Spring Rate*, lb/in	8,223	6,286

*Value based on manufacturer's design toe load at a given deflection

Clip Test Results

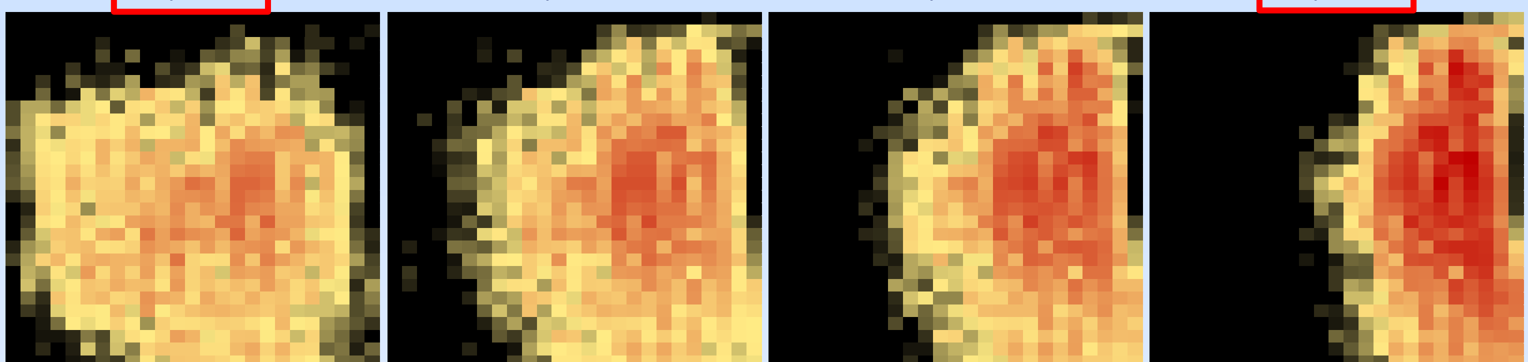
← GAUGE FIELD →

L/V Ratio	0.25	0.44	0.52	0.60



Clip A

	0.25	0.44	0.52	0.60
Contact Area (in²)	28.4	26.6	23.6	16.6
% of Rail Seat	84	78	70	49
Peak Pressure (psi)	2,188	2,327	2,872	3,809



Clip B

	0.25	0.44	0.52	0.60
Contact Area (in²)	27.6	24.5	21.0	17.2
% of Rail Seat	81	72	62	51
Peak Pressure (psi)	2,744	3,067	3,385	4,083

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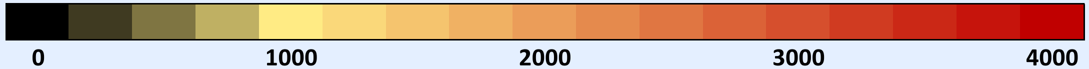
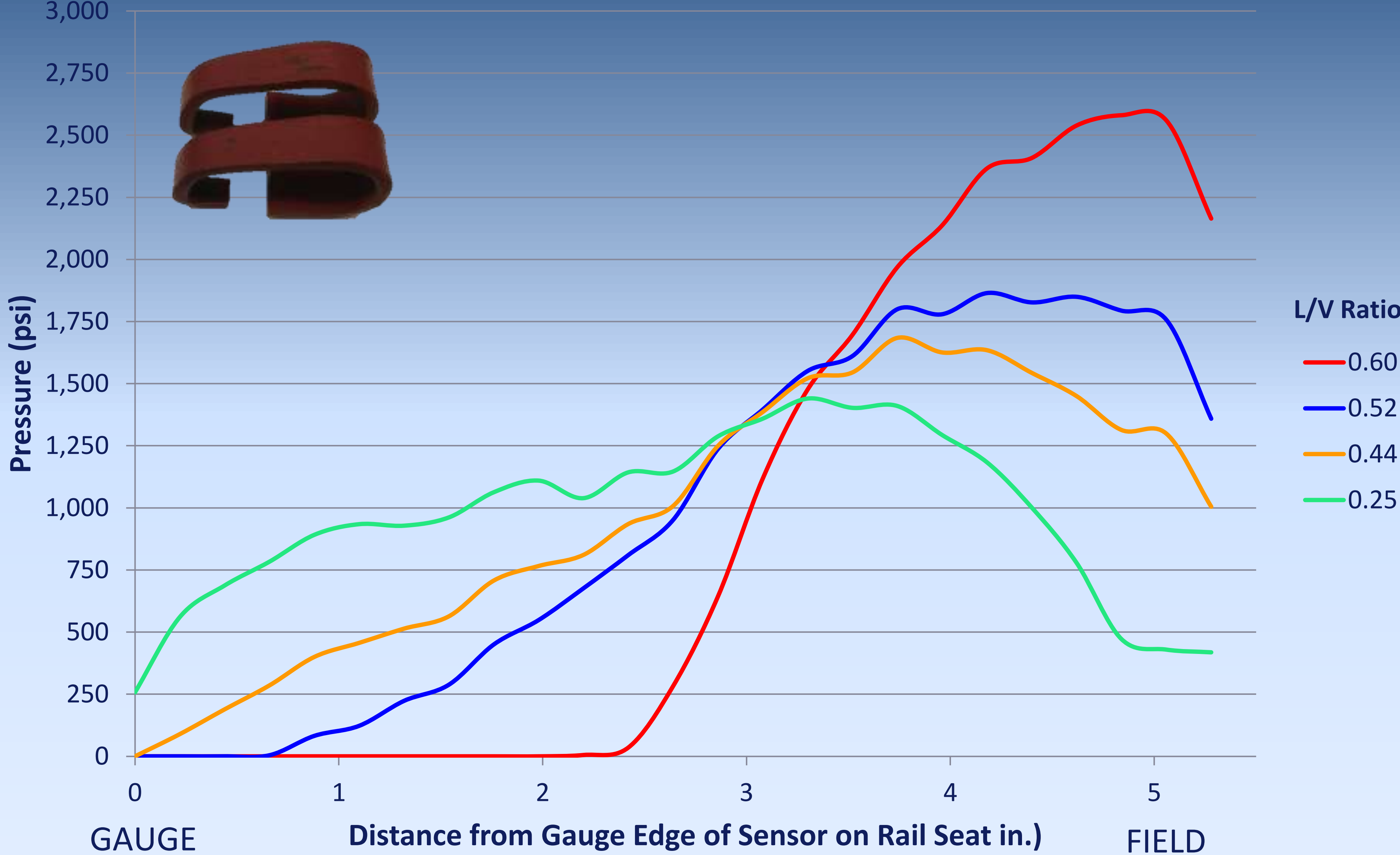
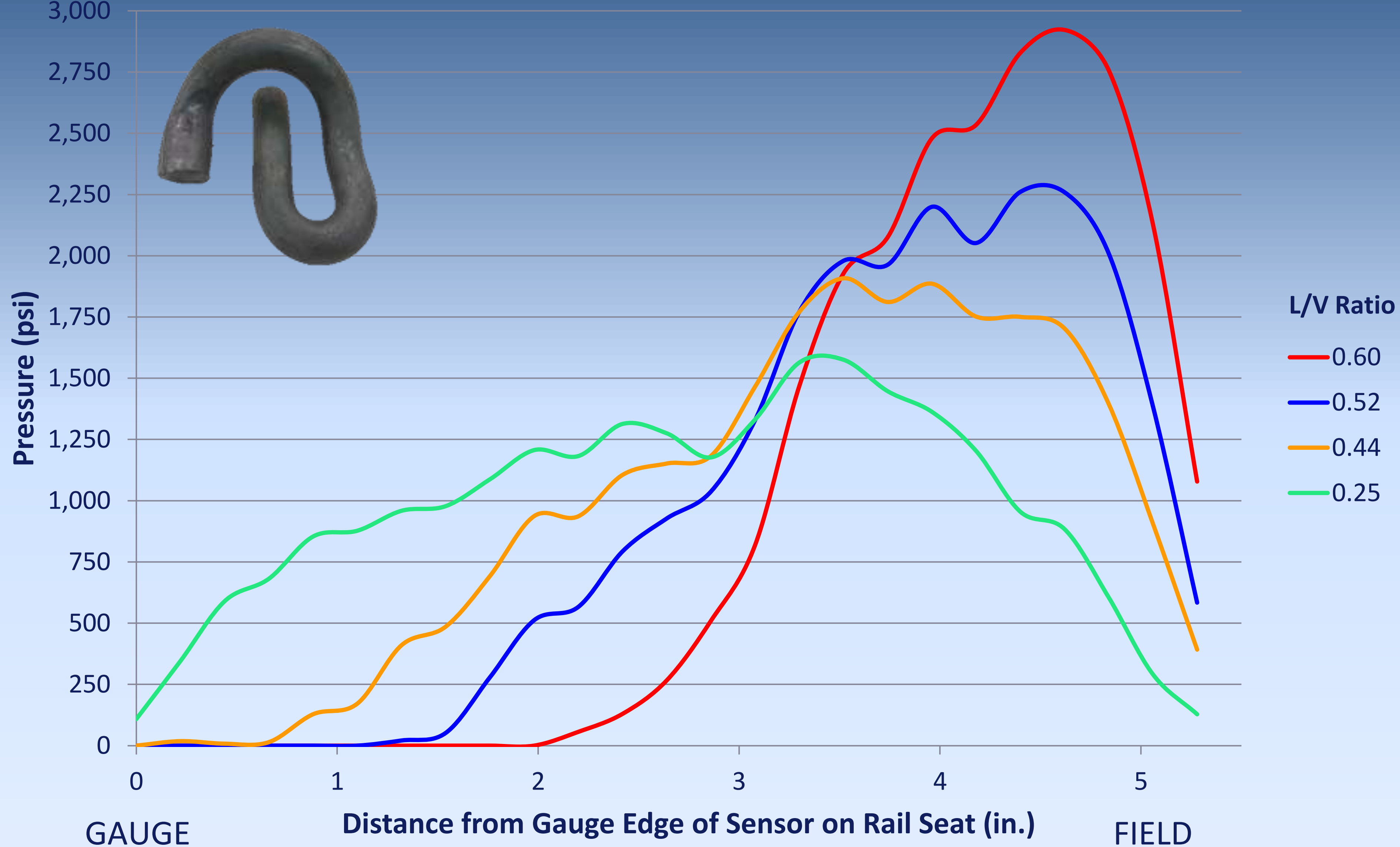
Pressure (psi)



Average Pressure Distribution for Clip A



Average Pressure Distribution for Clip B



Conclusions from 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

Conclusions from Testing (cont.)

- **Fastening Clip Test**
  - Design of the clip component of the fastening system affects the shape of the pressure distribution on the rail seat
  - Minimal differences in peak pressures and contact areas of pressure distribution between the two clips tested in the experiment

Future Work with MBTSS

- 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 pad modulus testing within bounded experiments
- Continue testing common North American fastening systems

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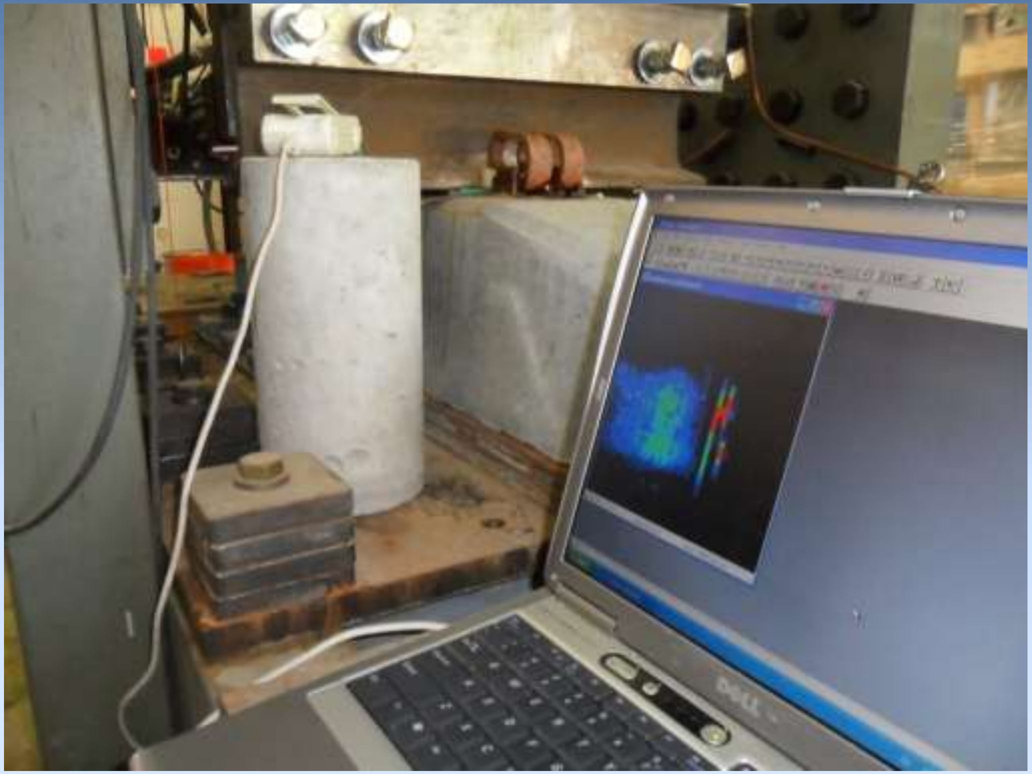
Questions / Comments



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