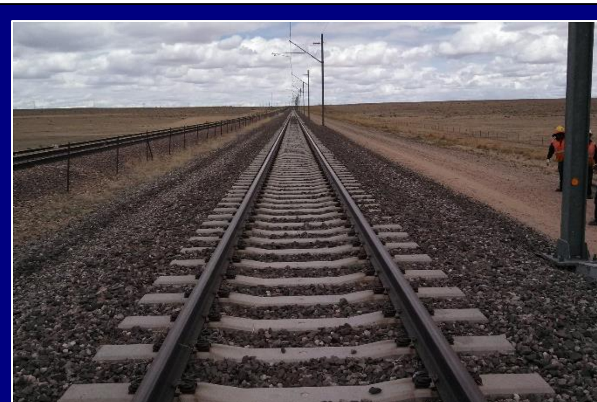
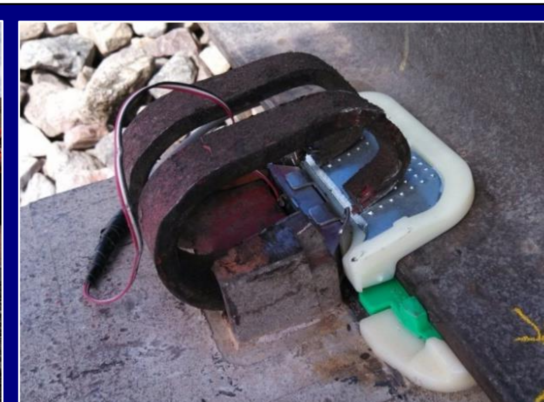
Analysis of the Lateral Load Path in Concrete Crosstie Fastening Systems





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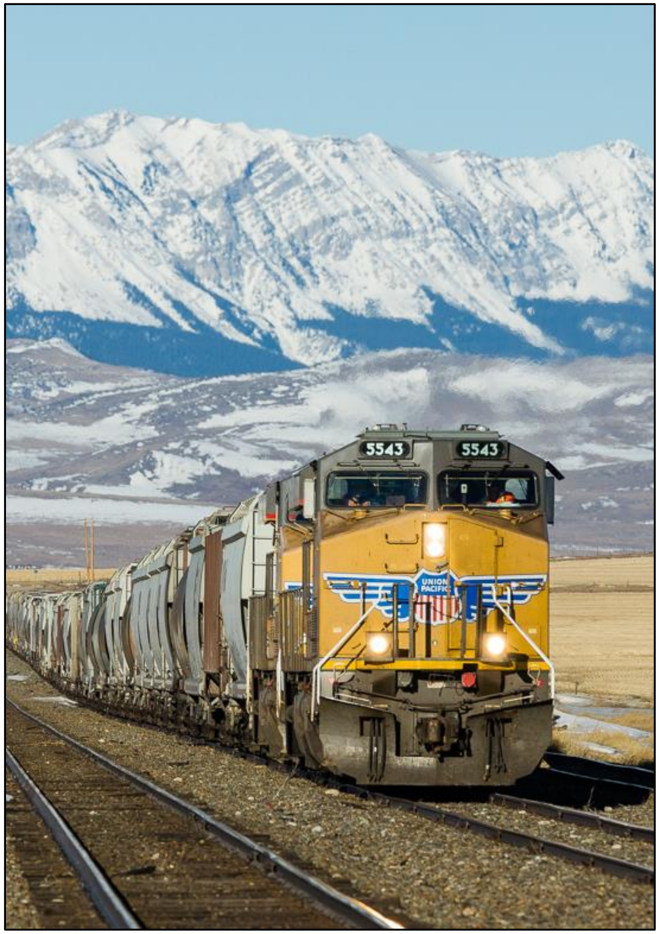
U.S. Department of Transportation
Federal Railroad Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

ASSOCIATION OF AMERICAN RAILROADS

Outline

- Background
- Purpose of lateral force measurement
- Lateral force measurement technology
- Crosstie-to-crosstie distribution
- Dynamic forces during train runs
- Results and conclusions
- Future work



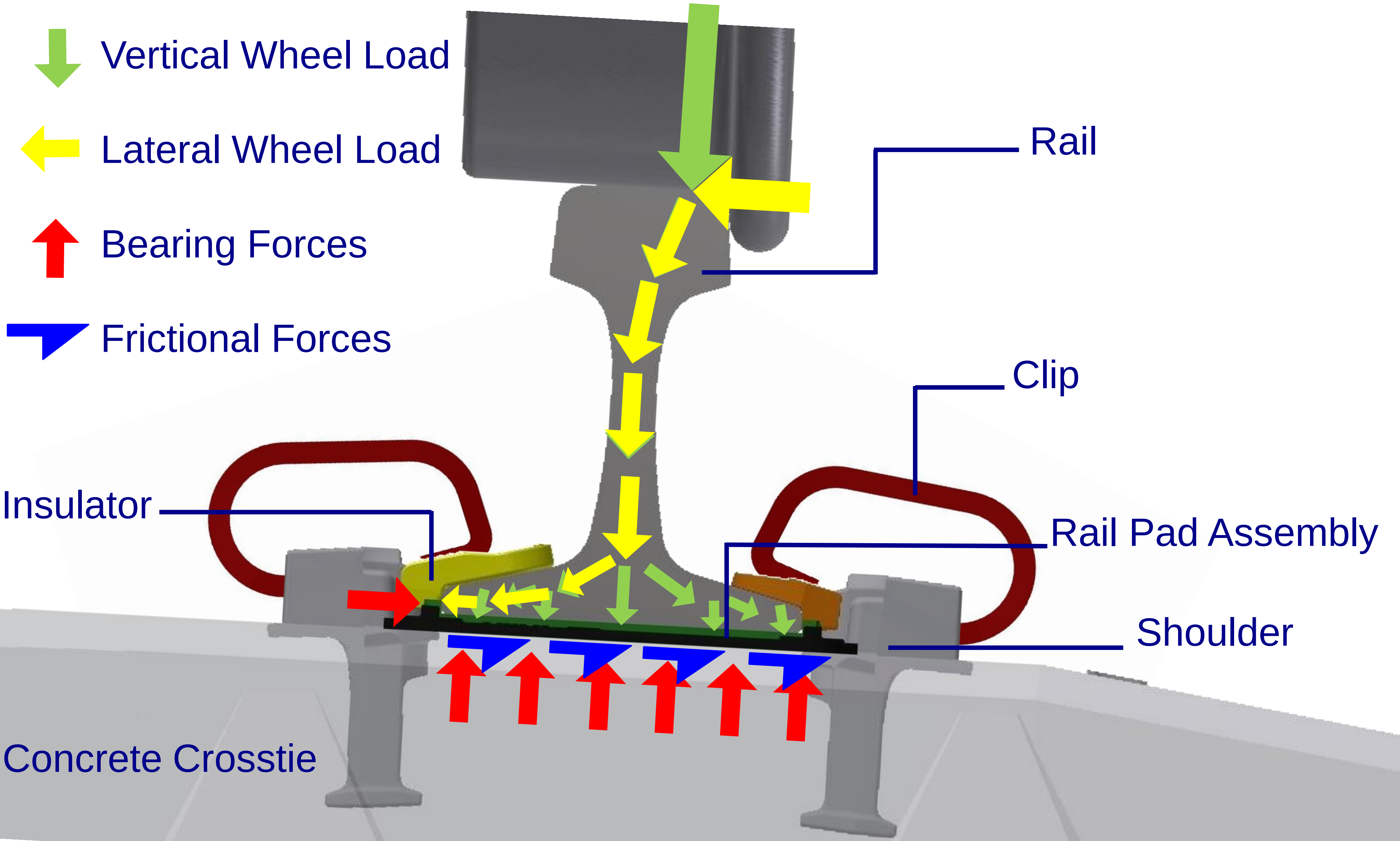
Background

- 25 million concrete crossties are in use on North American heavy haul freight railroads
- **Industry trends**:
  - Many variations in fastening system design and performance
  - Fastening system components are failing earlier than their design life
    - Crushing, abrasion, fracturing
  - Increasing heavy axle loads (HAL) and traffic volumes
  - Shared infrastructure with both HAL and high speed rail (HSR)
- **Industry need**:
  - Fastening systems that economically withstand increasingly demanding loading conditions
    - Minimizing maintenance procedures allows for increased operating efficiency and capacity

Purpose of Lateral Force Measurement

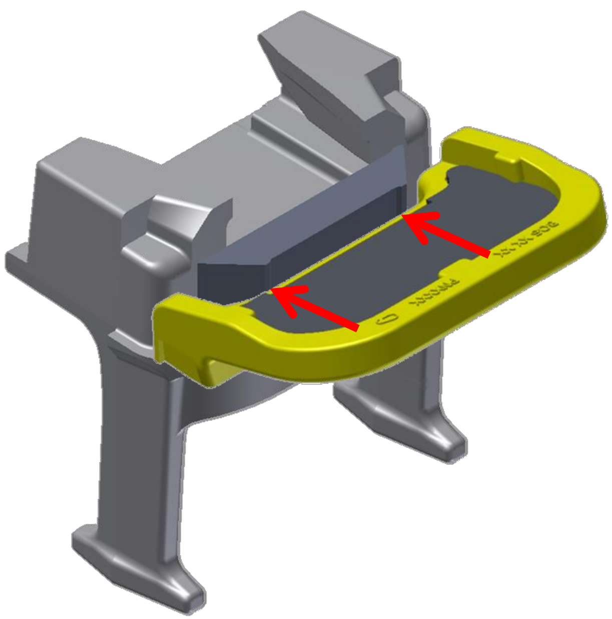
- **Quantify lateral loading conditions to aid in the mechanistic design of fastening systems**
- Understand demands on fastening system components under loading conditions known to generate failures
- Gain understanding of the lateral load path by:
  - Quantifying forces and stresses acting on the insulator and shoulder
  - Quantifying the distribution of lateral forces in fastening system
    - e.g. Bearing on shoulder, frictional resistance from rail pad assembly or clip, etc.
  - Understanding the causes of variation on lateral load distribution among adjacent crossties

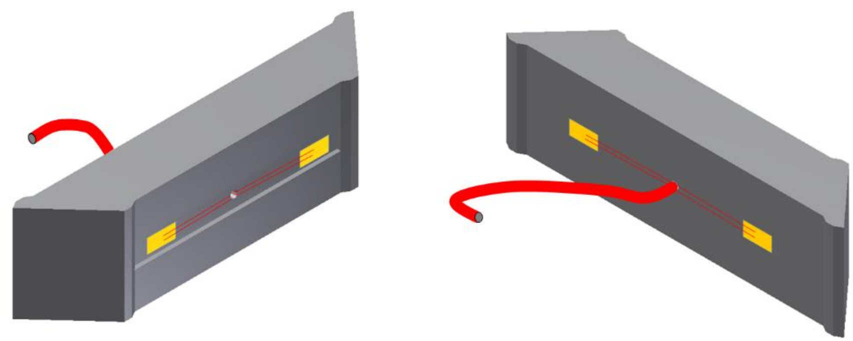
Defining the Lateral Load Path



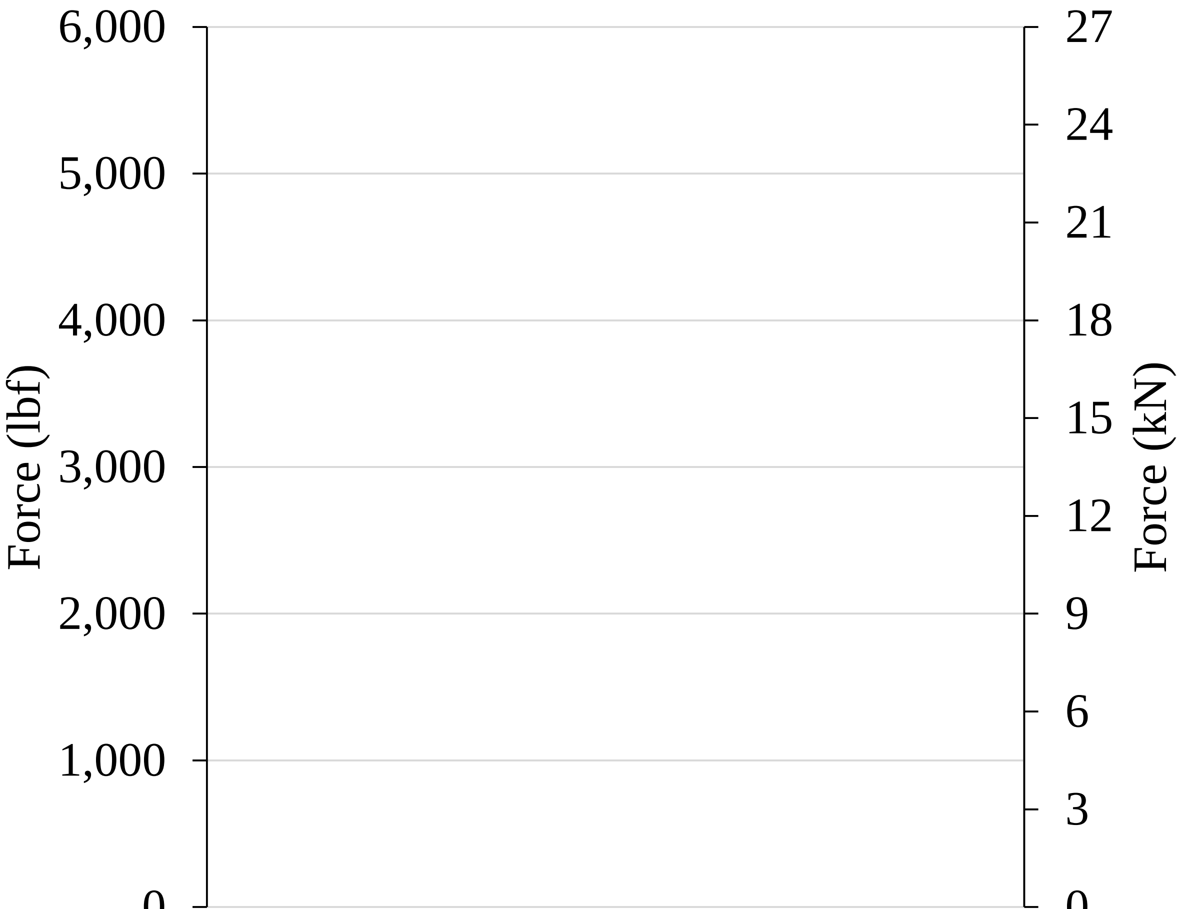
Lateral Force Measurement Methodology

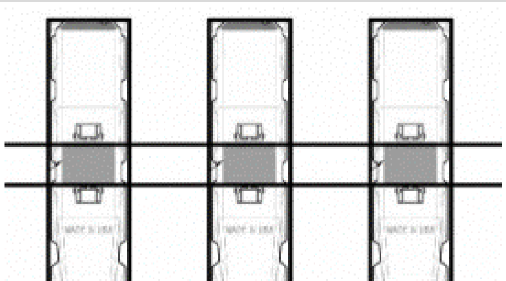
- Lateral Load Evaluation Device (LLED)
  - Original shoulder face is removed
  - Insert designed as a beam and optimized to replace removed section and maintains original geometry
  - Measures bending strain of beam under 4-point bending
    - Measuring bending strain is a proven technique

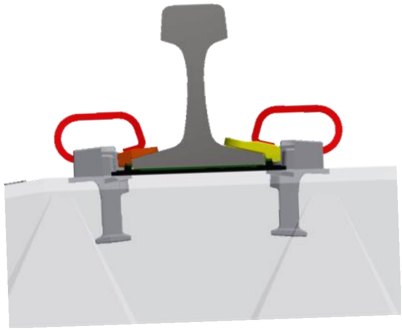




Tie-to-Tie Lateral Load Distribution







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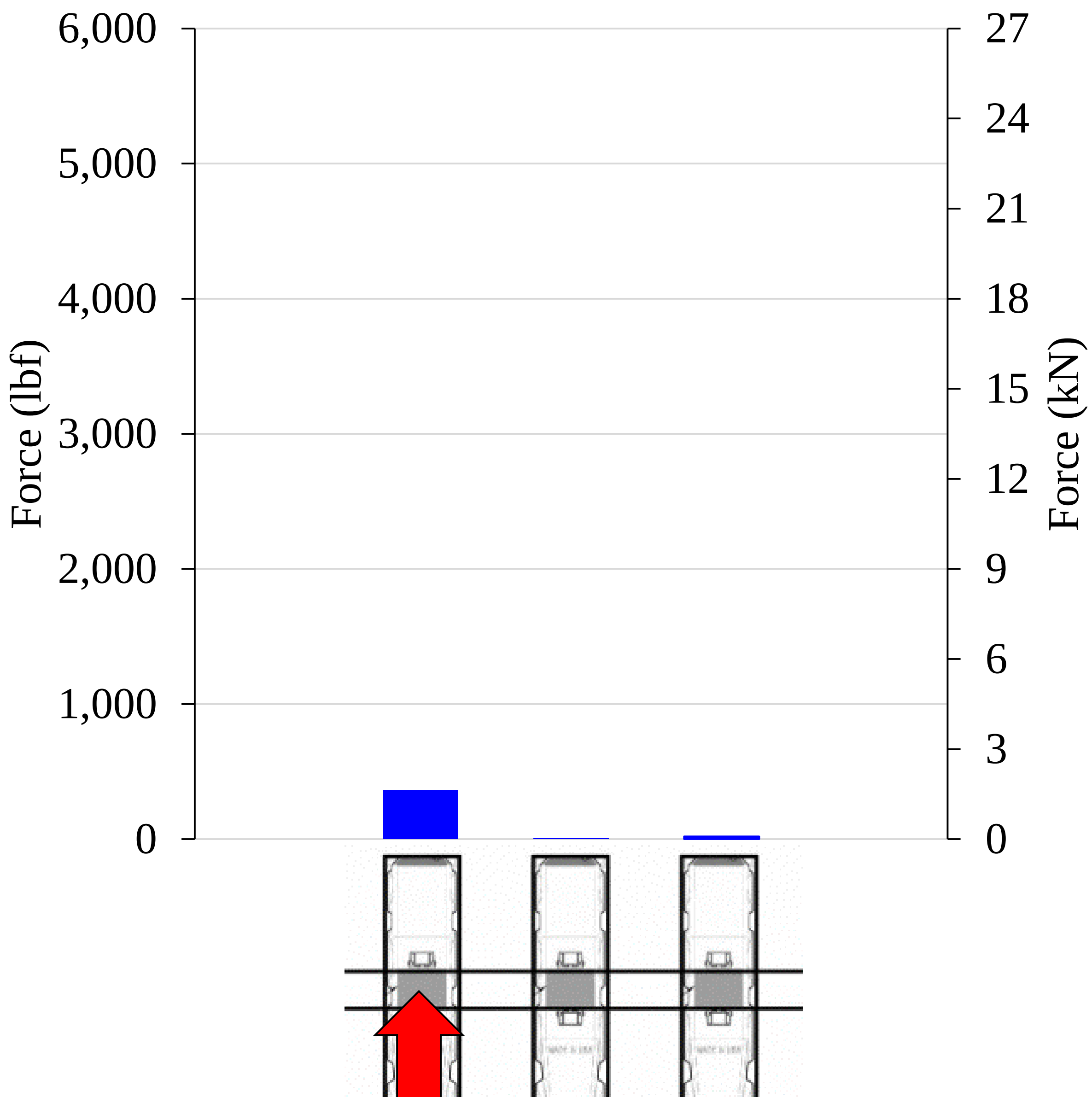

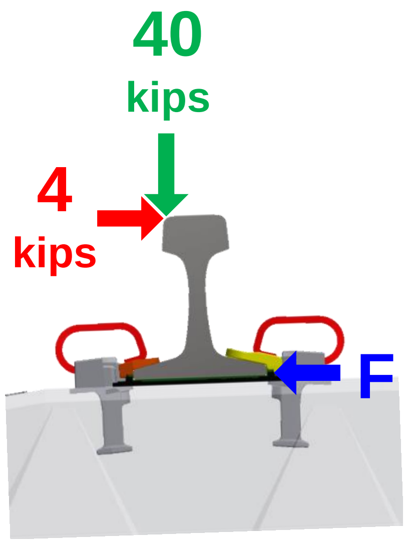

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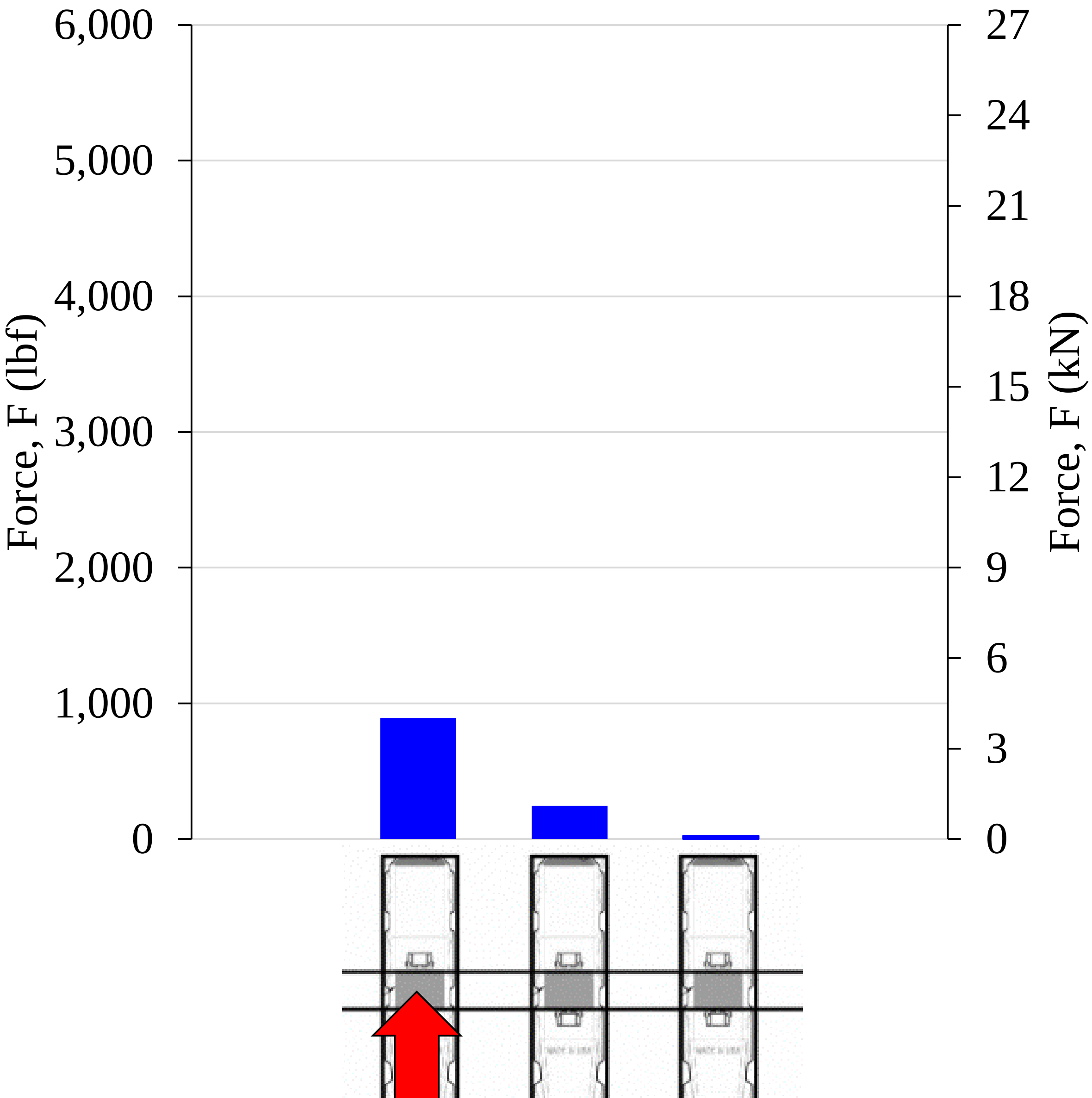

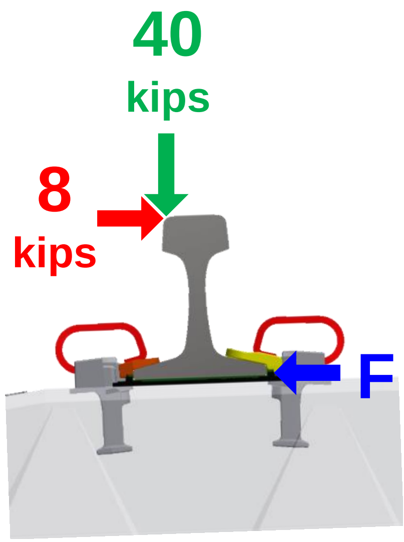

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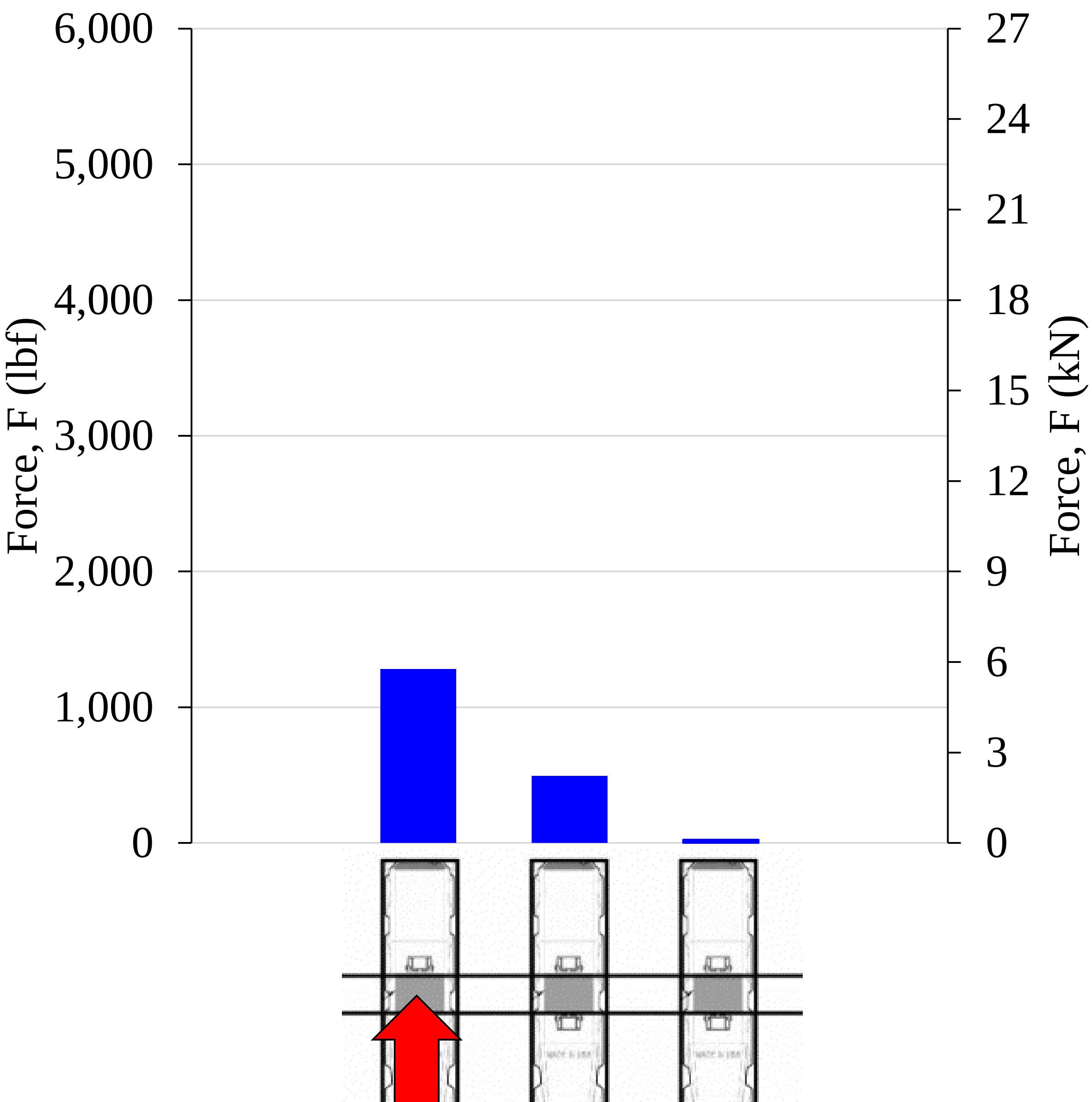

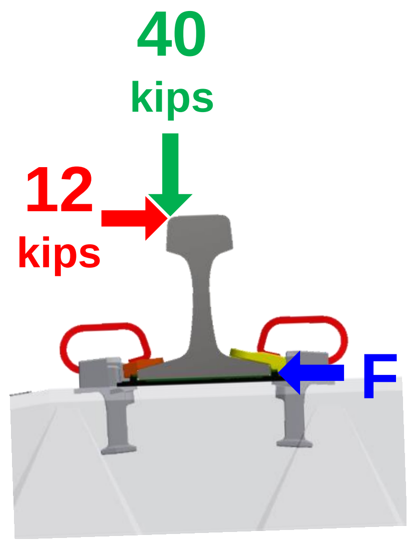

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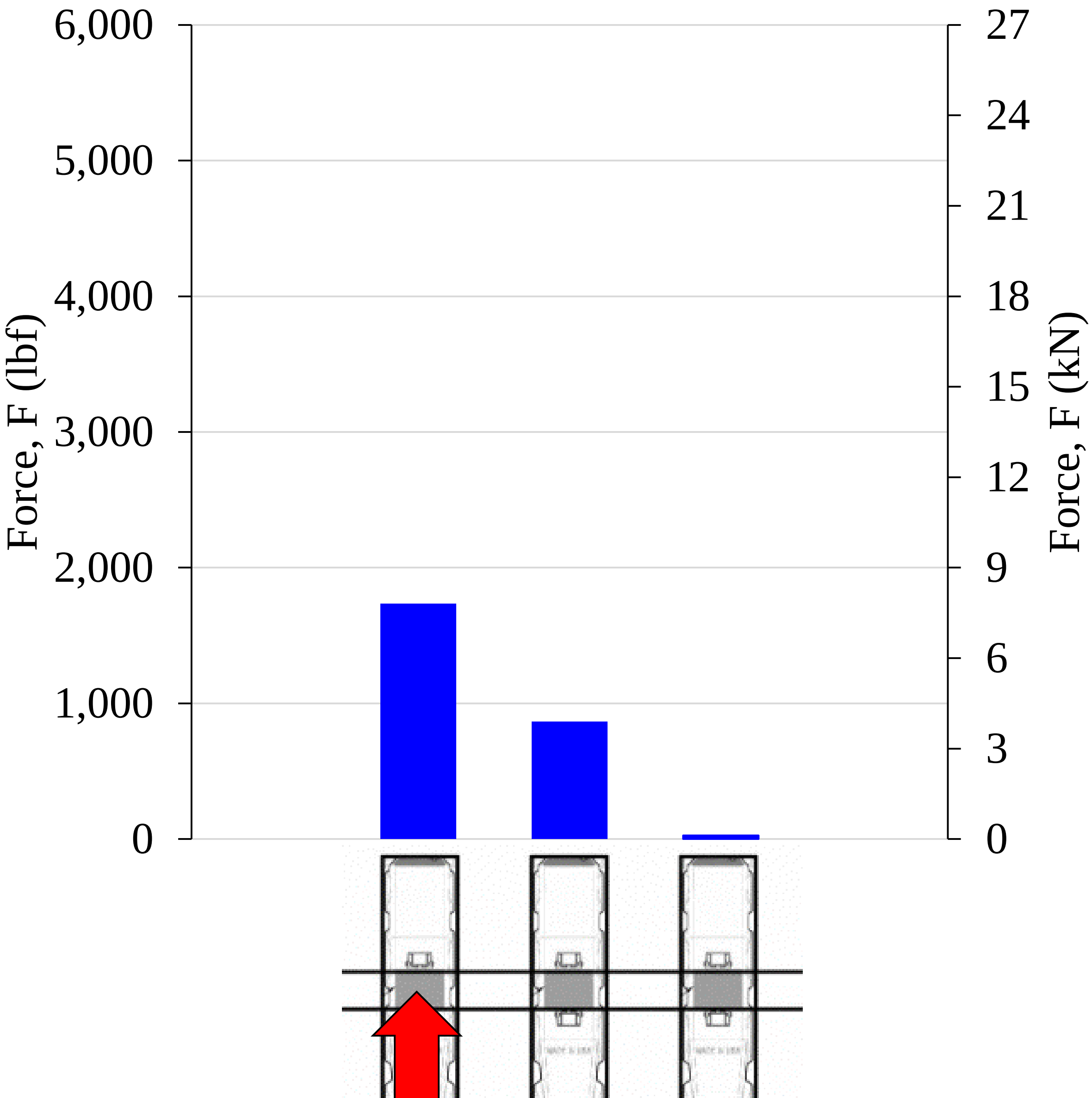

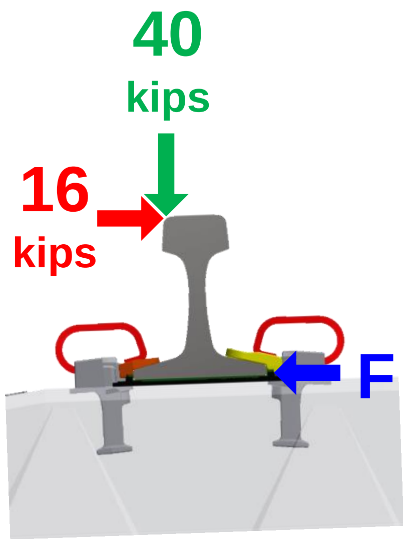

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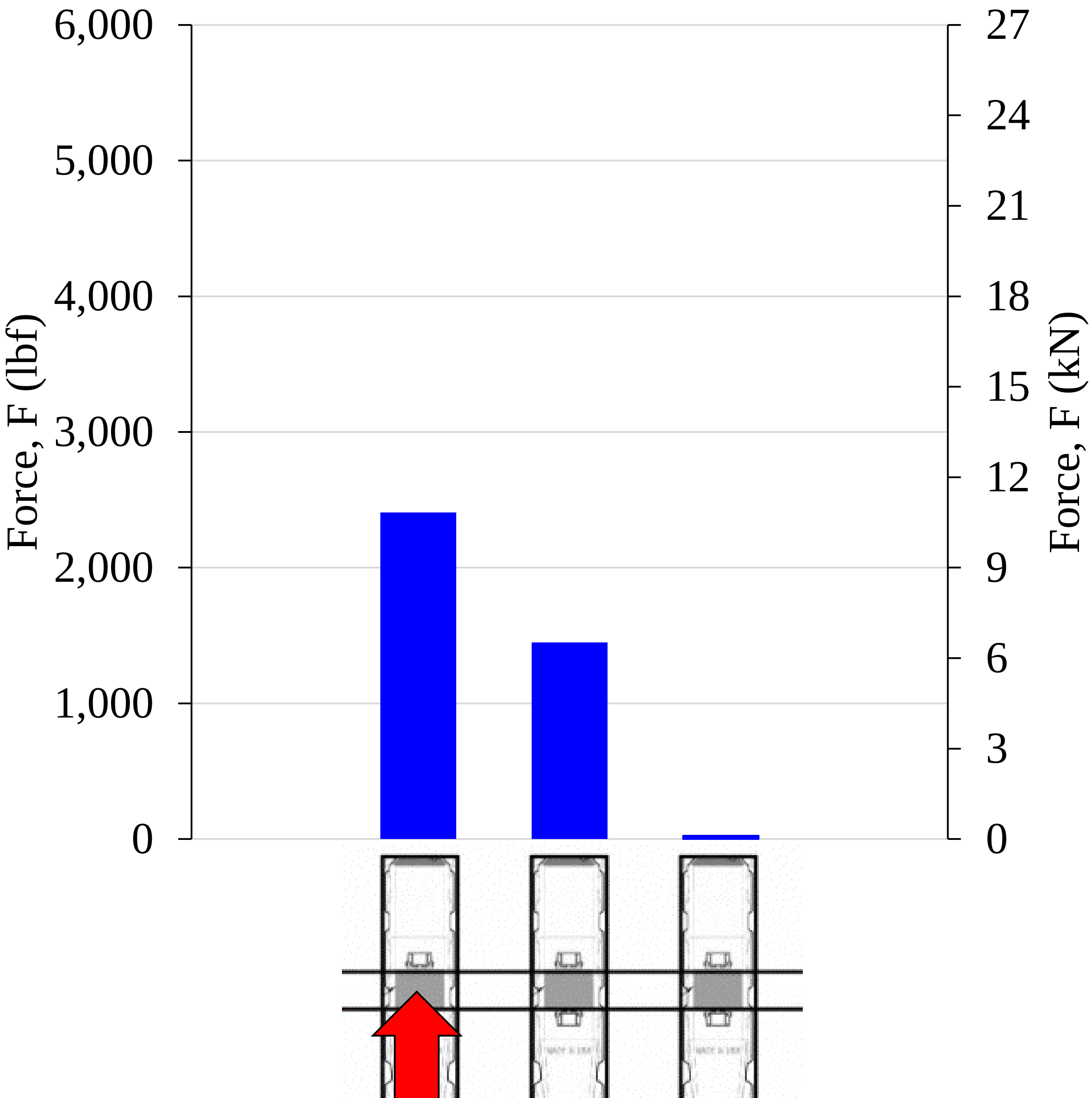

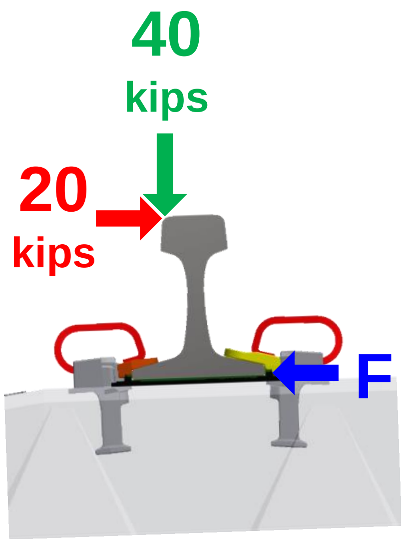

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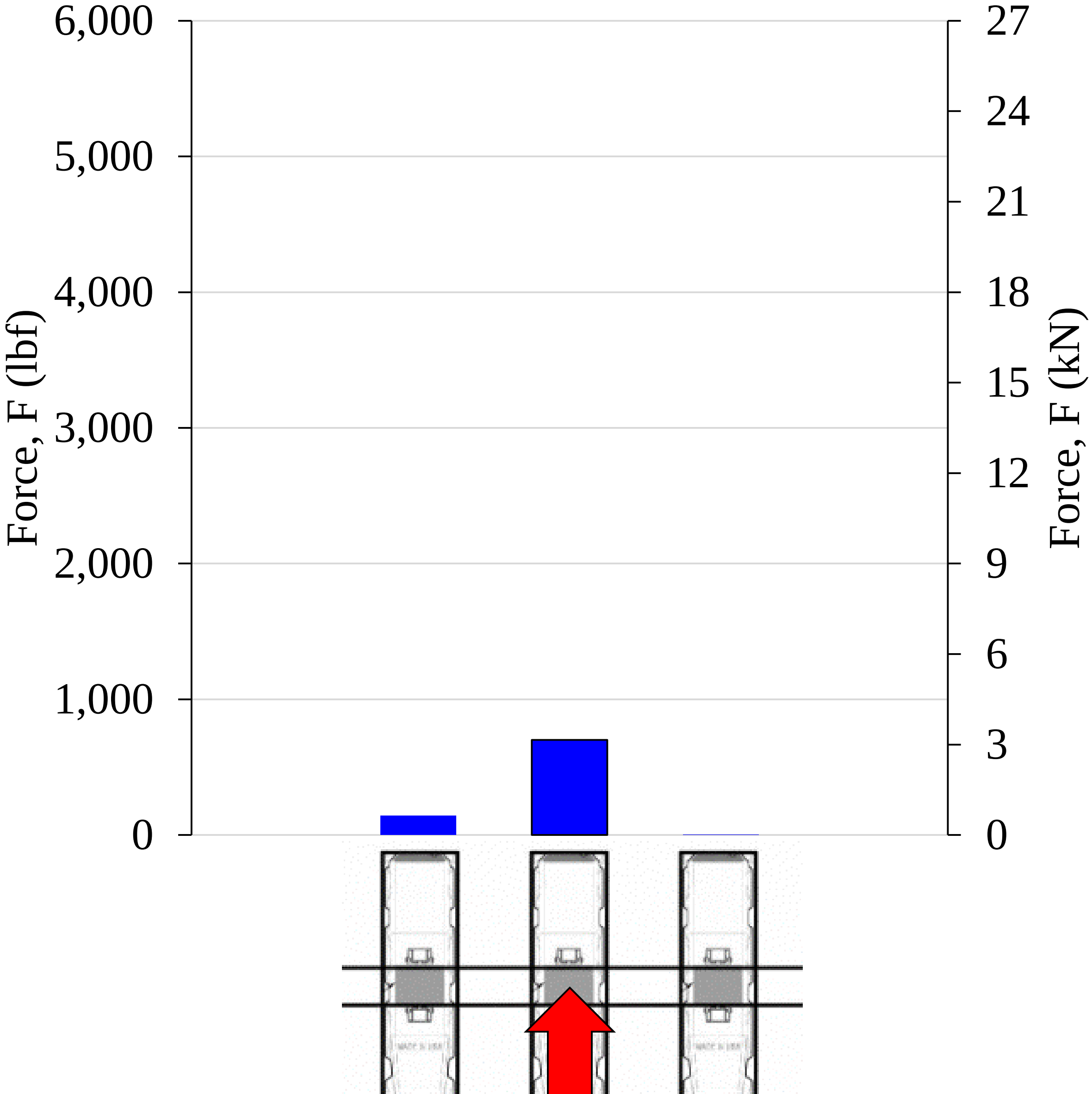

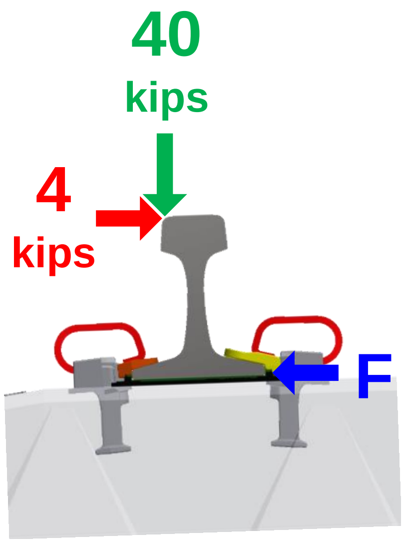

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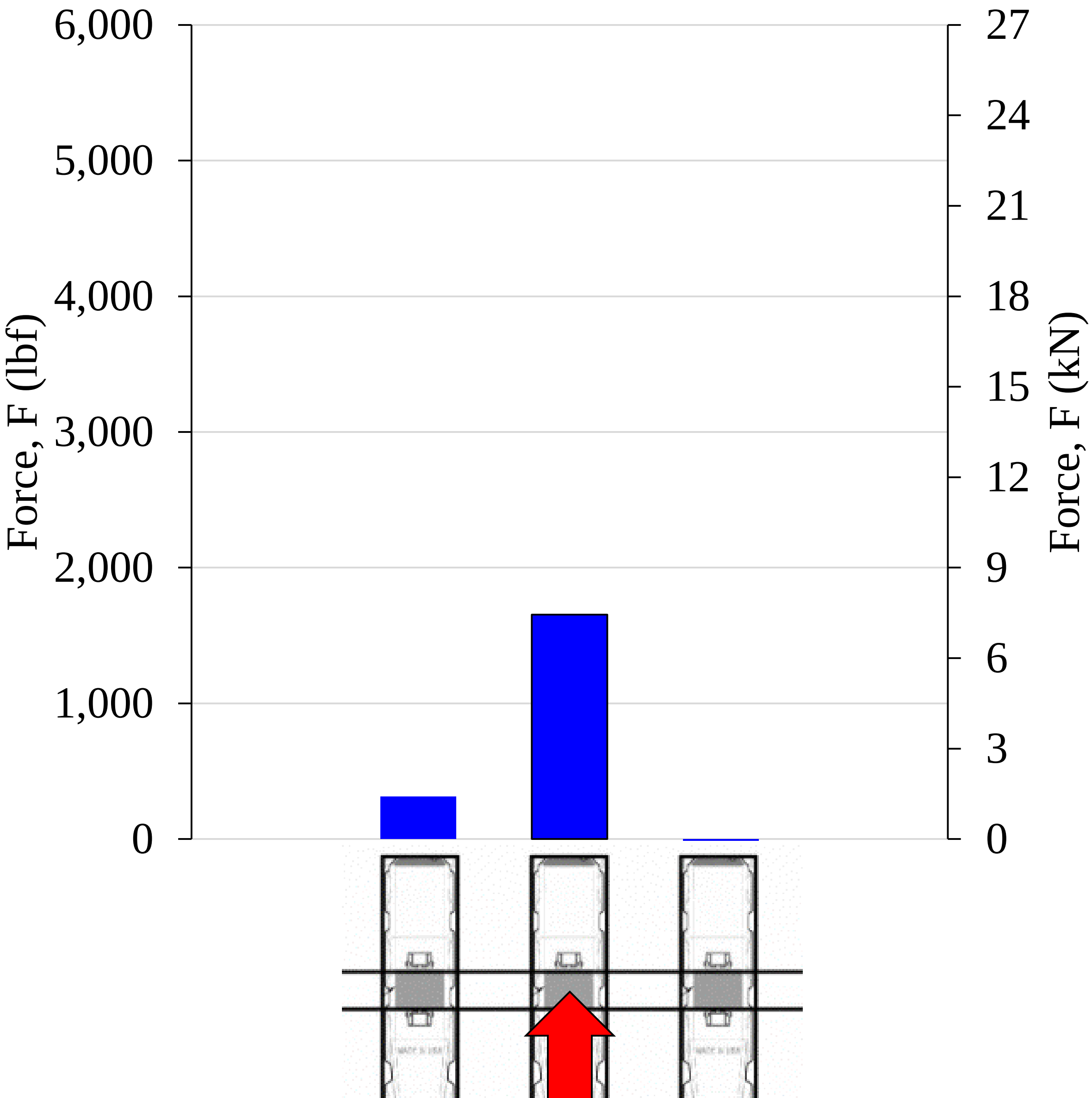

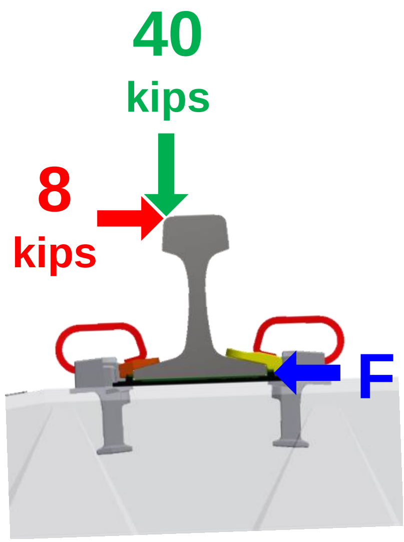

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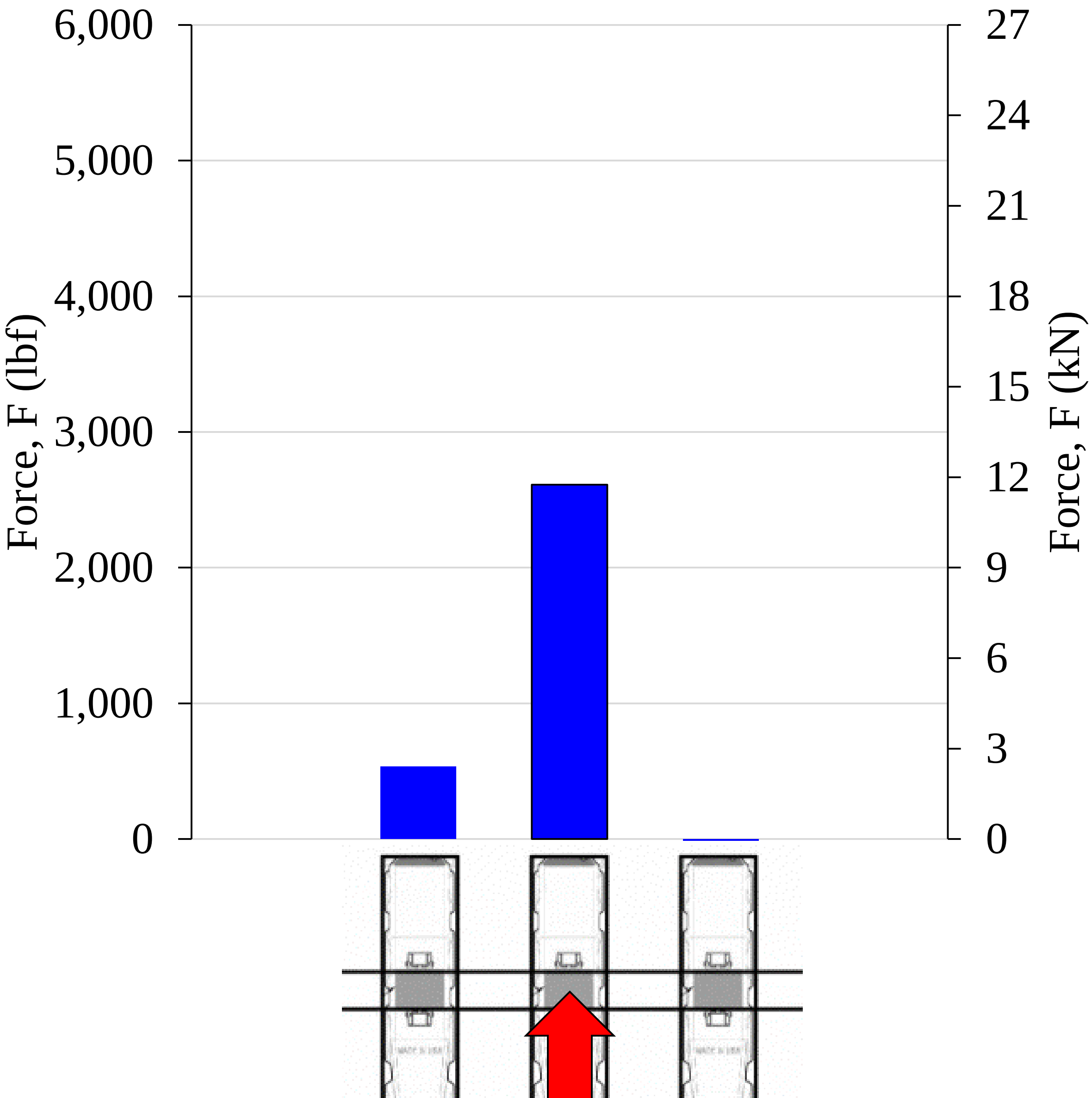

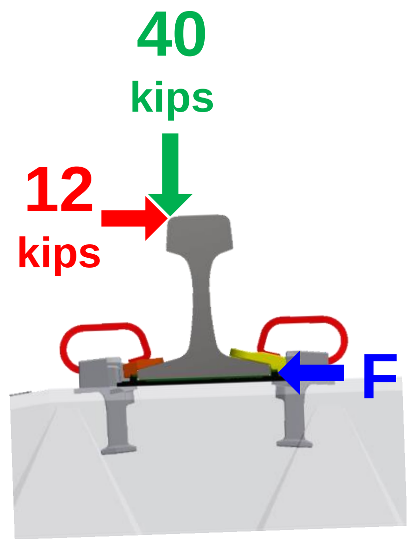

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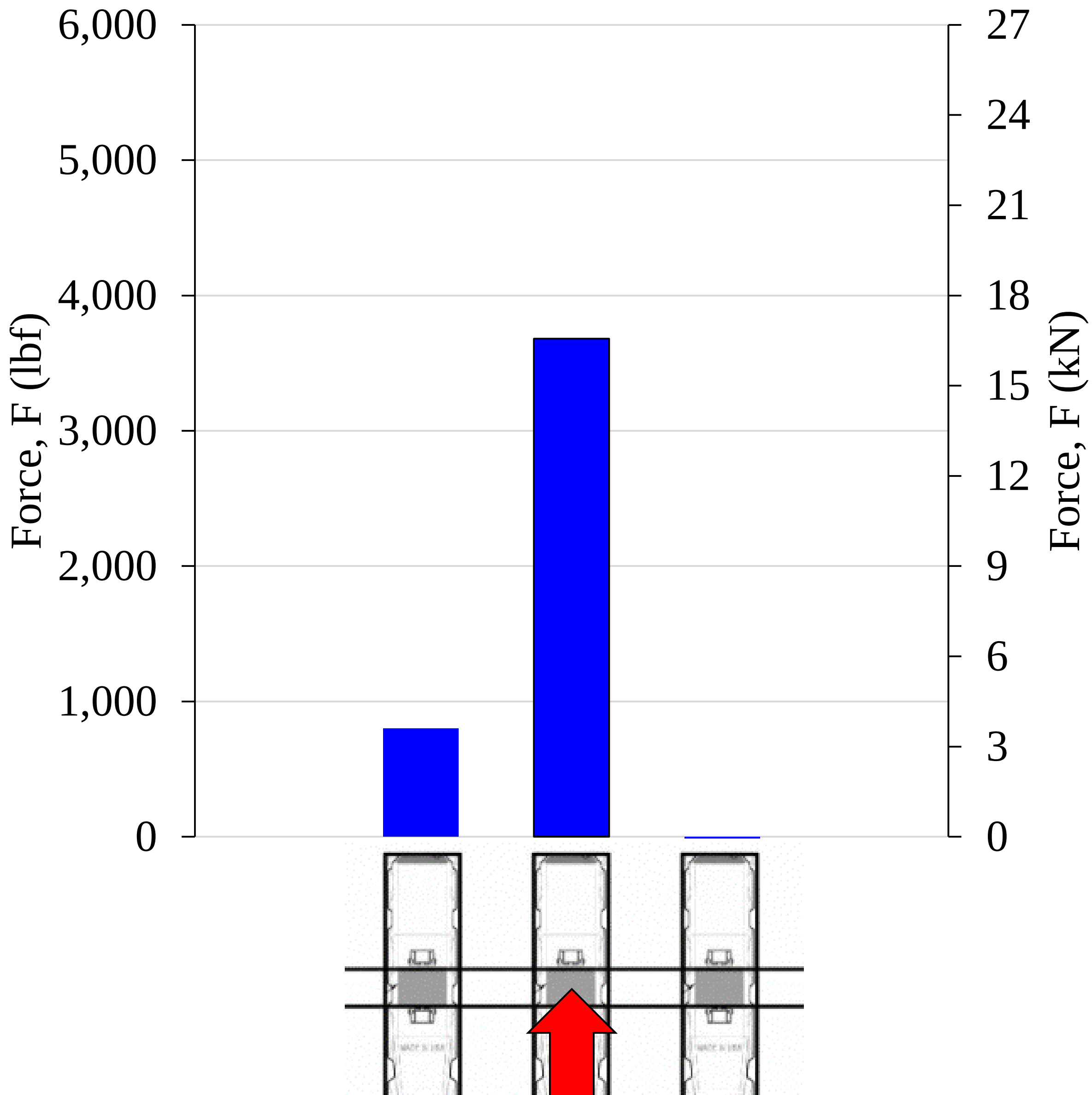

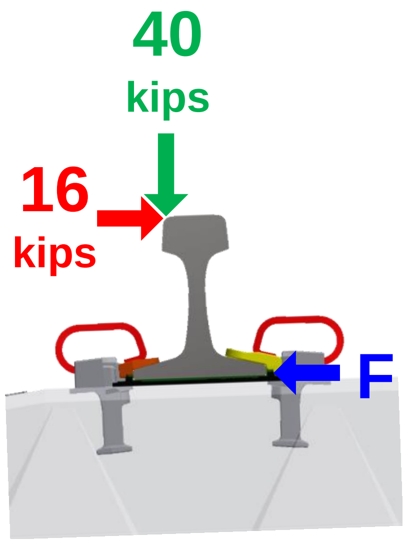

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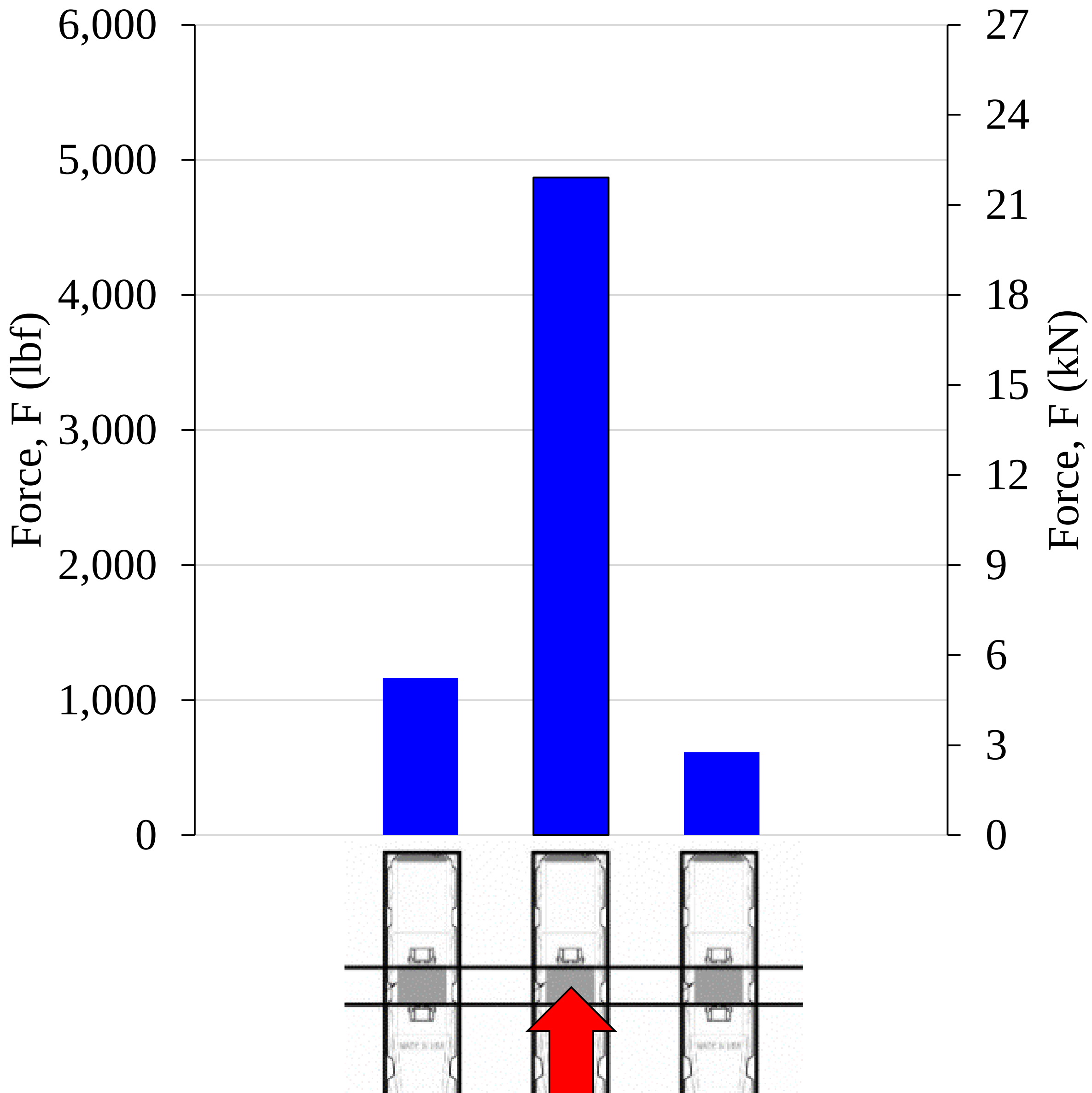

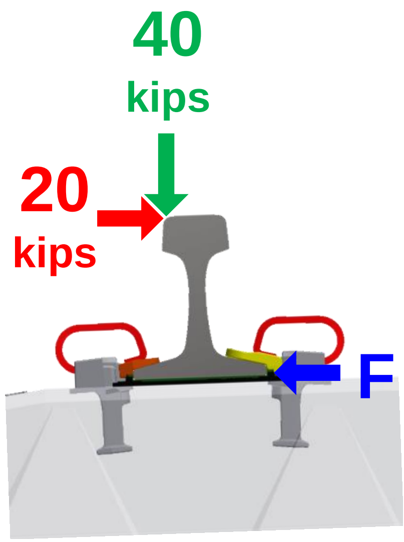

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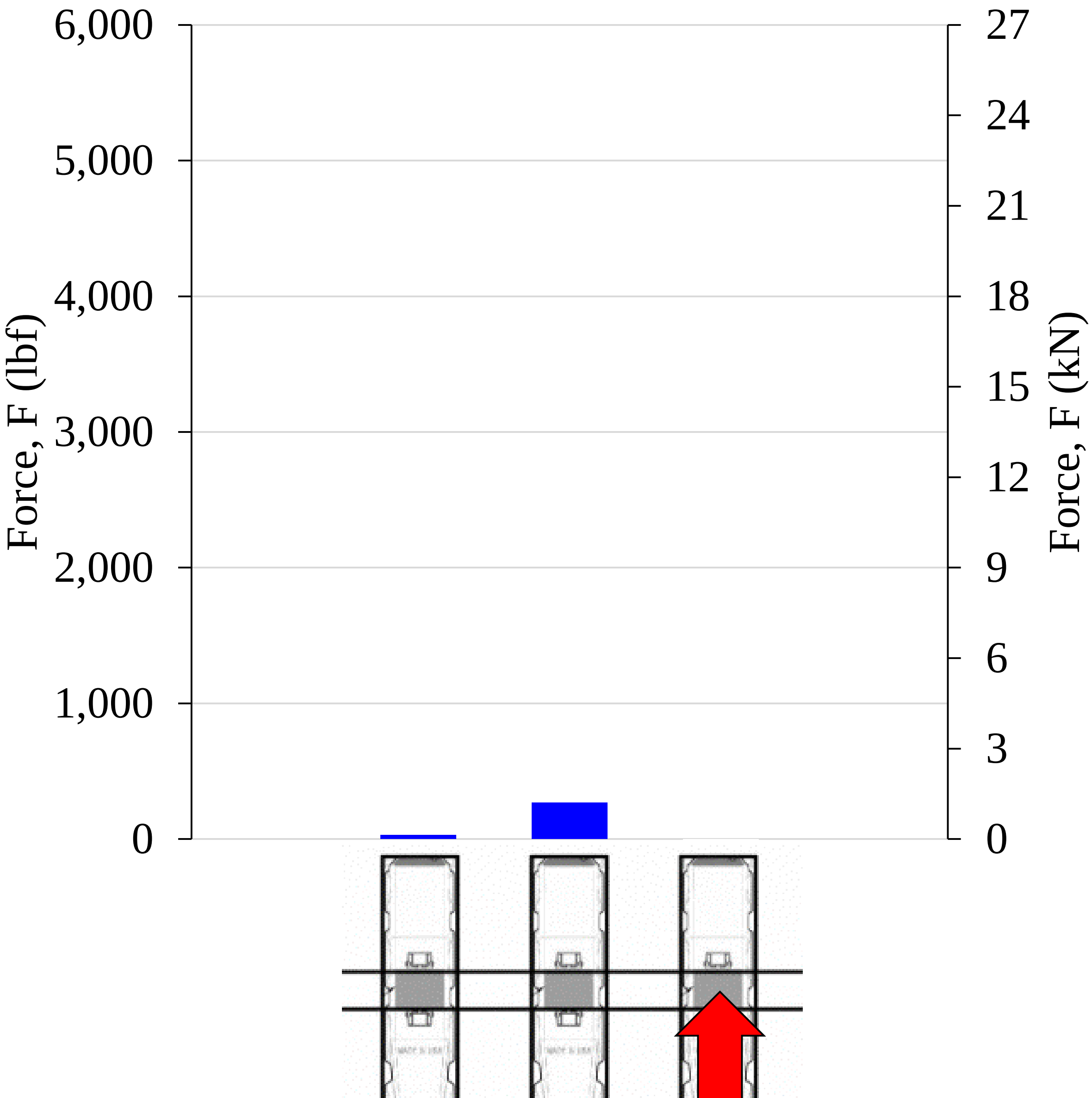

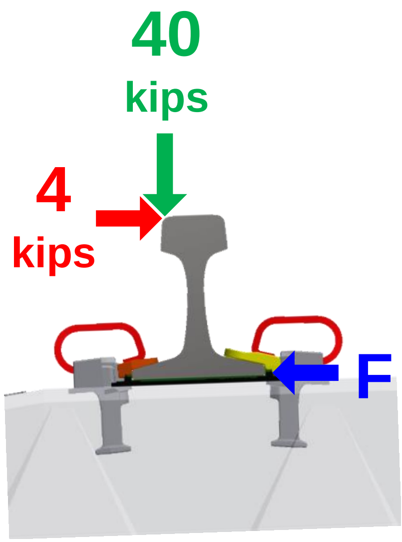

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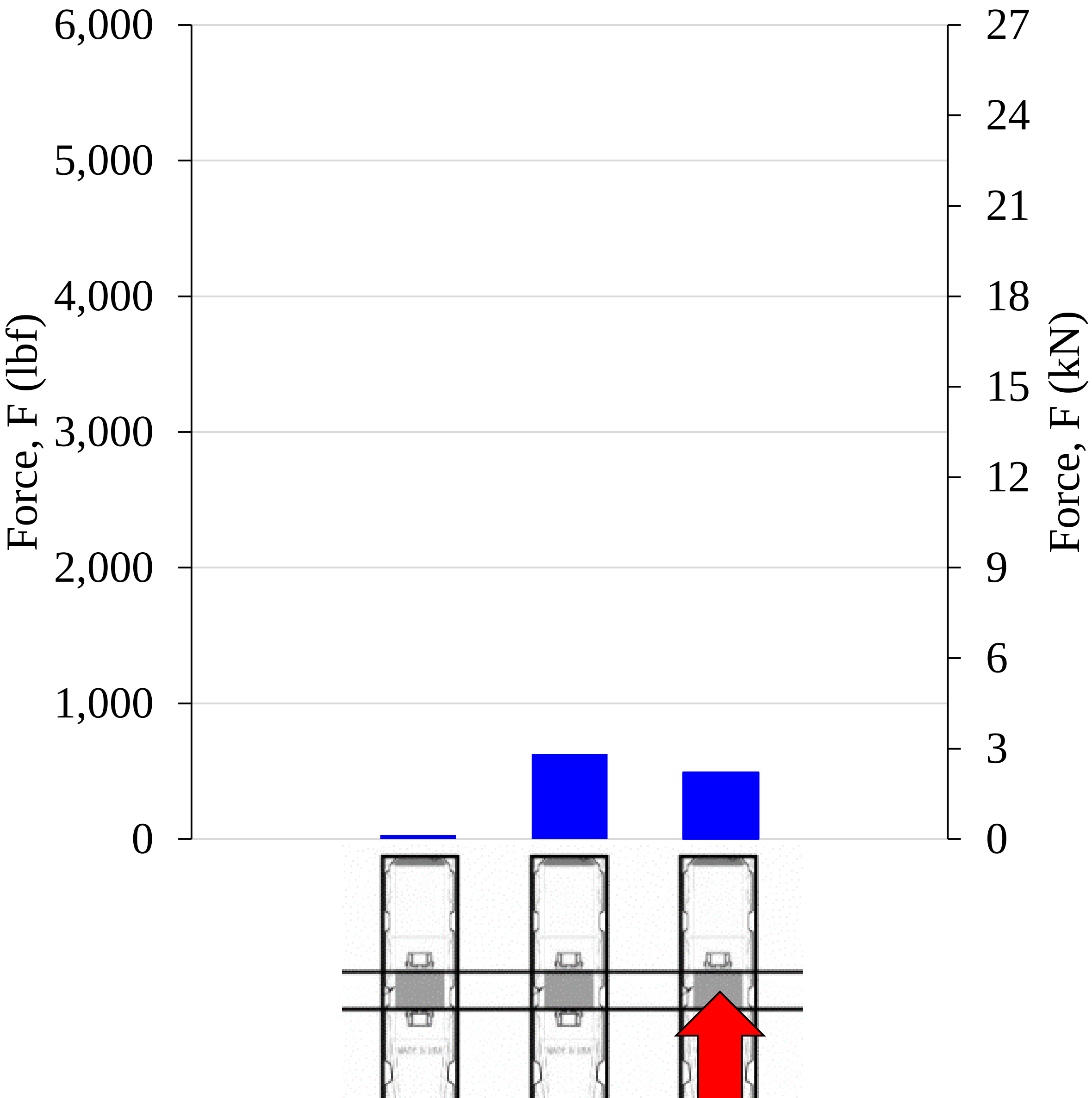

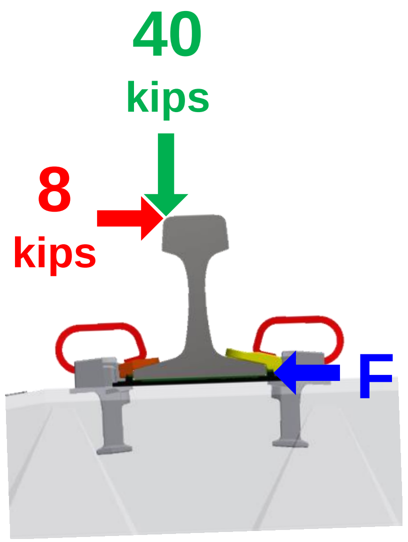

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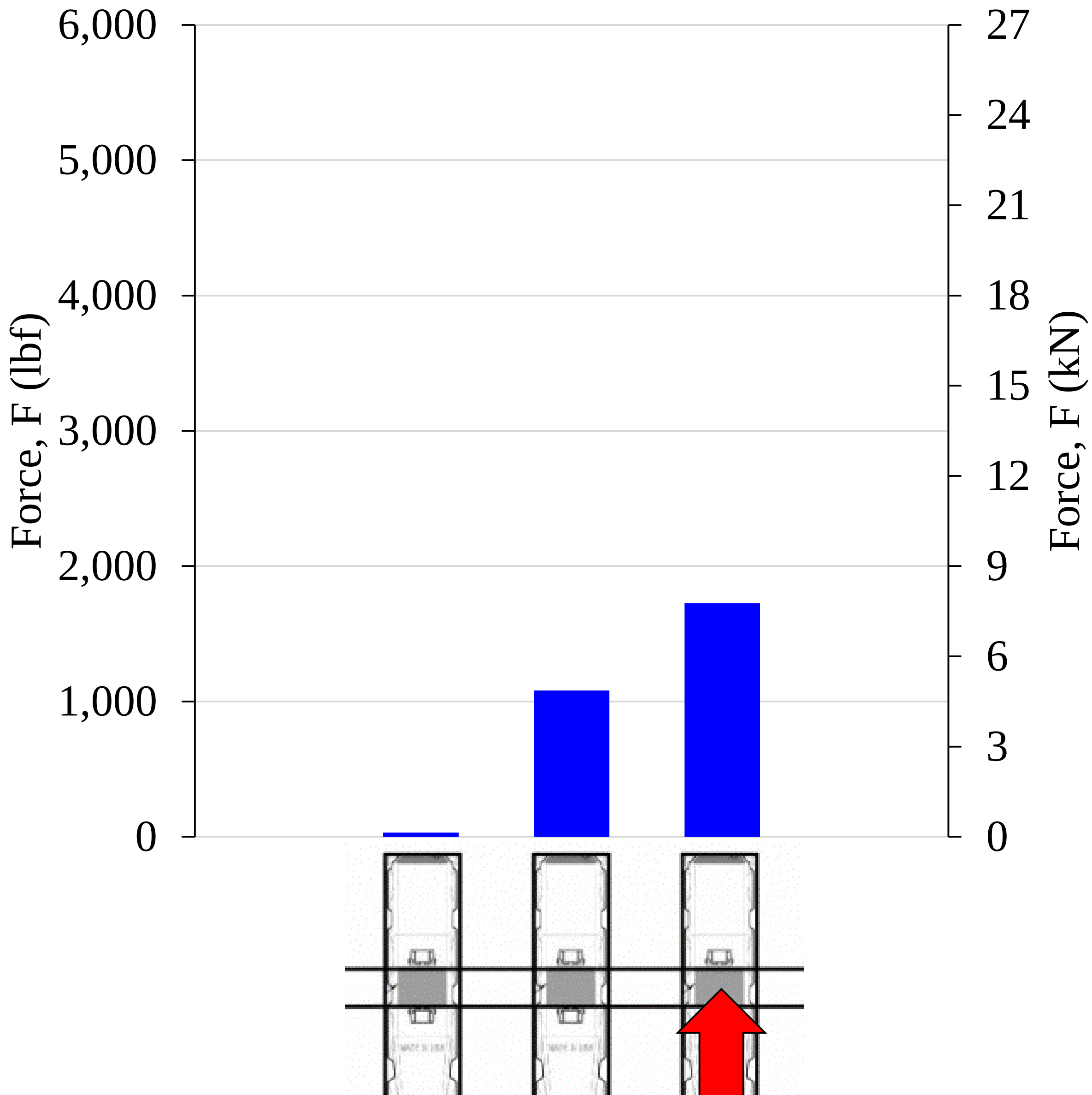

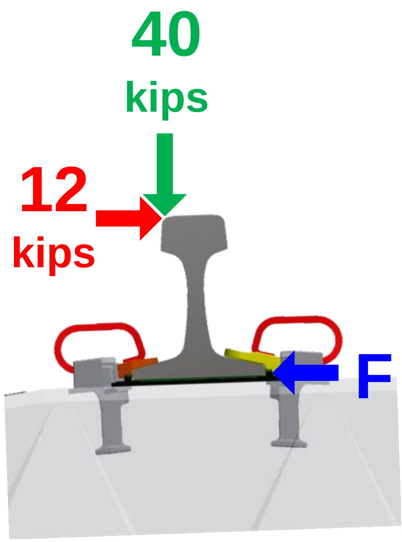

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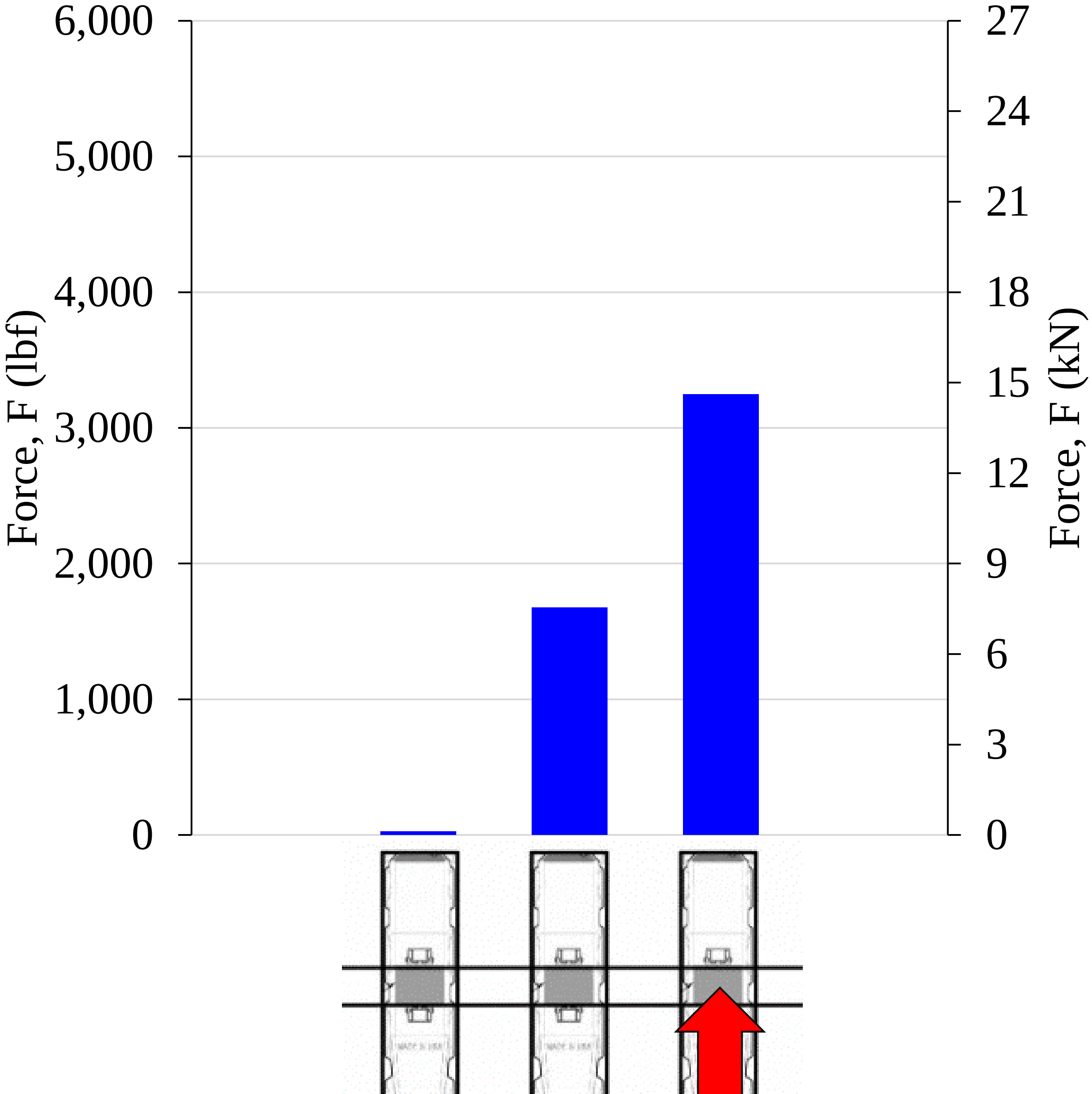

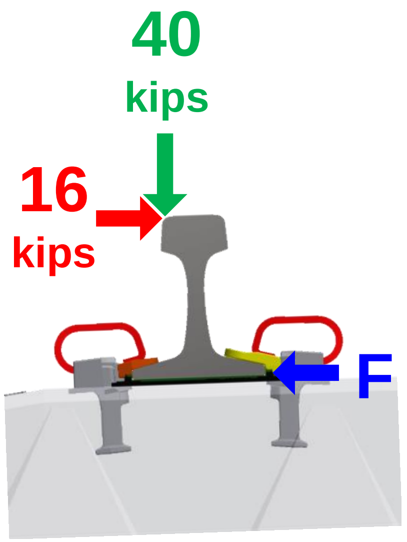

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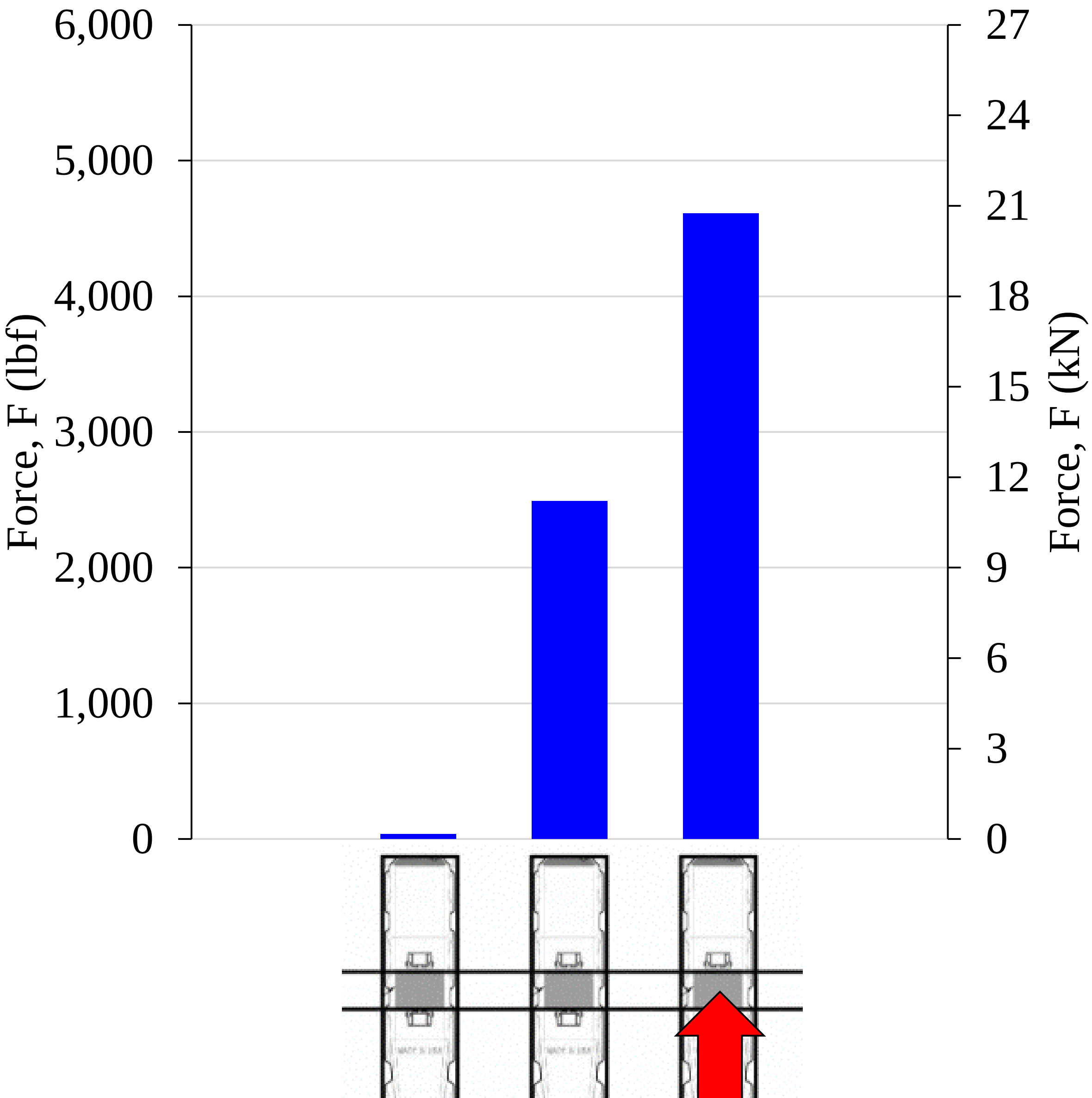
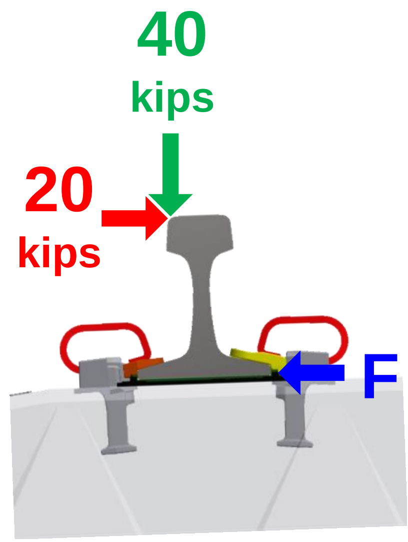
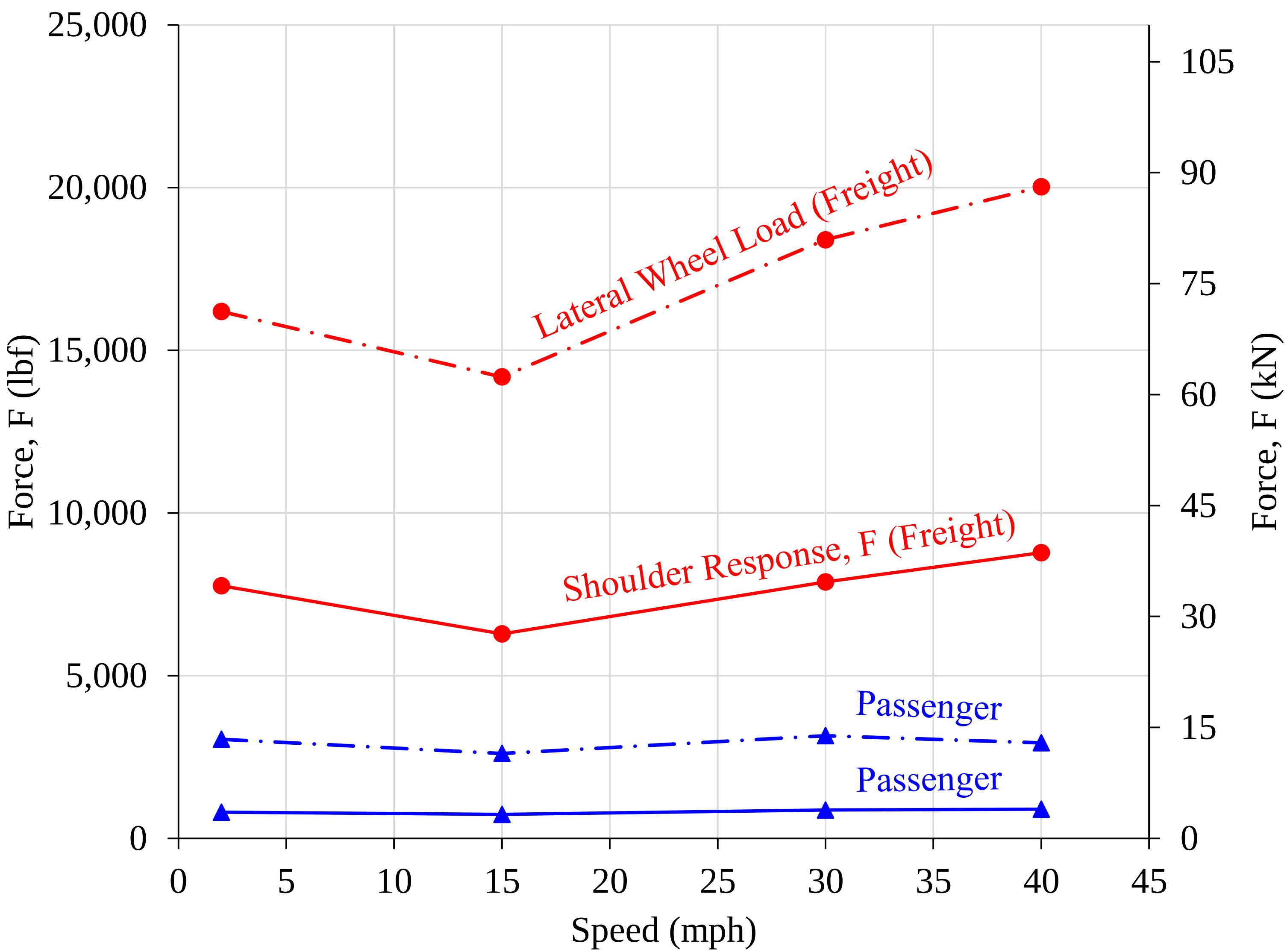




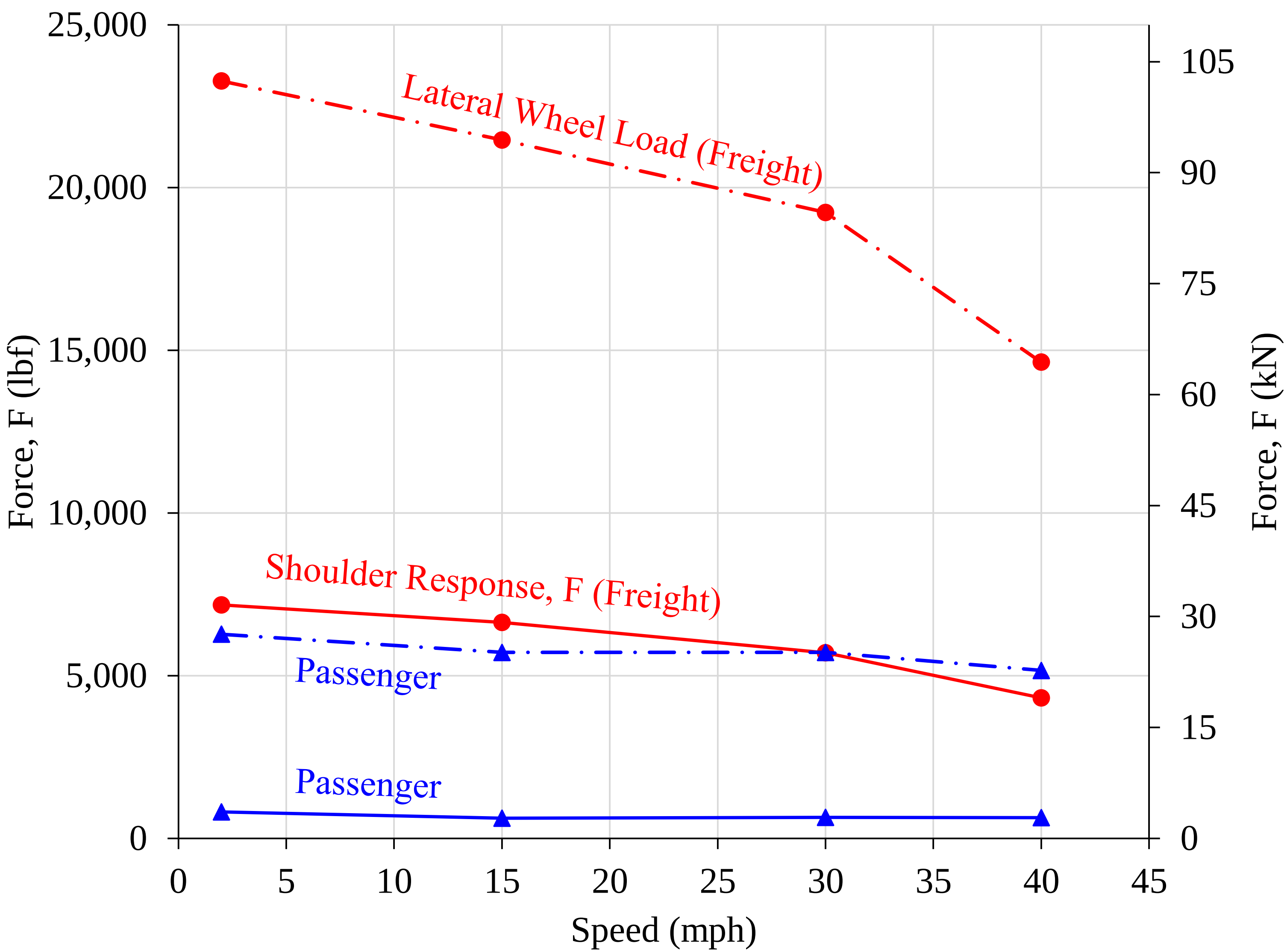
Lateral Loads Within Fastening System

Curved Track (High Rail), Passenger and Freight Peak Loads



Lateral Loads Within Fastening System

Curved Track (Low Rail), Passenger and Freight Peak Loads

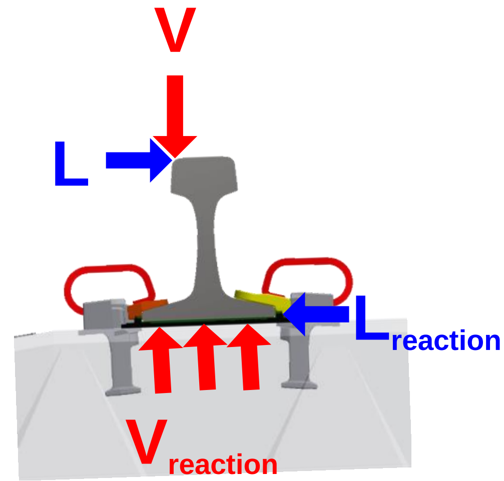


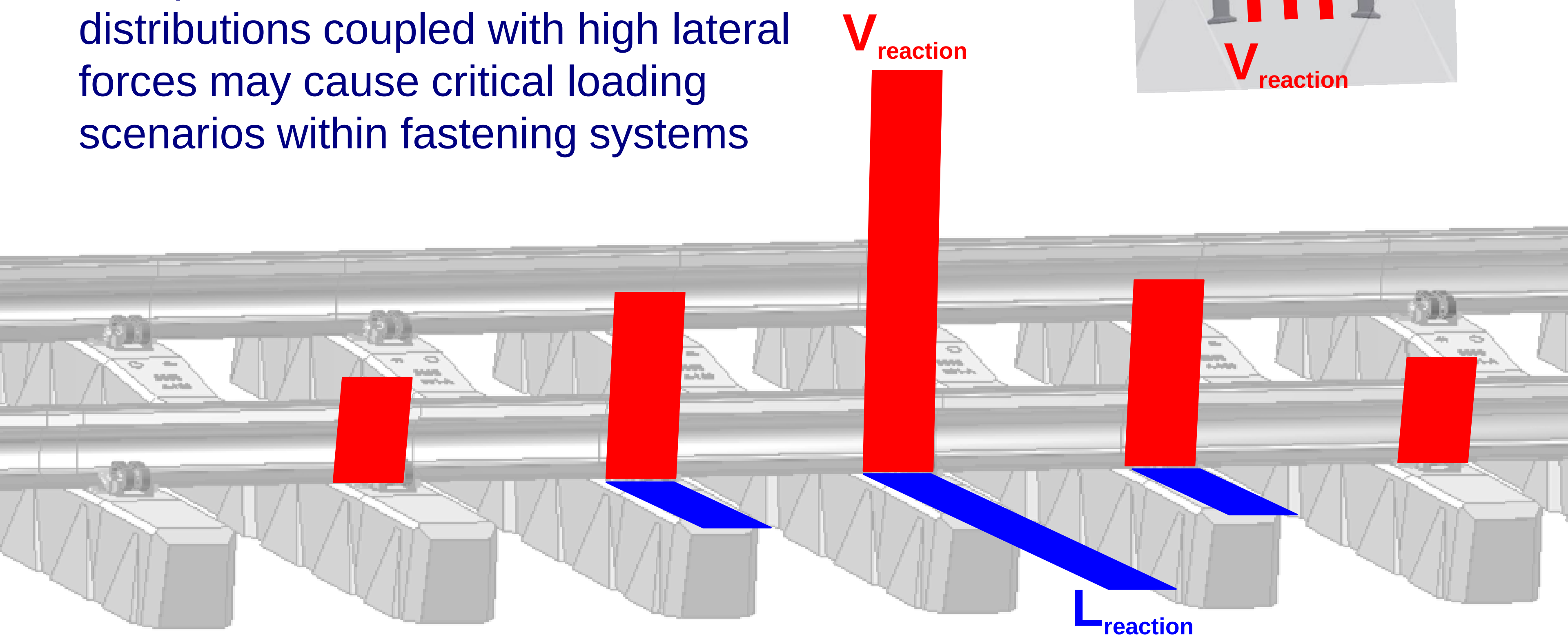
Challenges with Lateral Load Resistence

- Lateral loads appear to be primarily distributed among three crossties
  - Vertical load is distributed to five or more crossties based on previous research conducted at UIUC
- Lateral loads entering the shoulder appear to be primarily influenced by the lateral wheel load
  - However, lower L/V ratios at the same lateral input load magnitude result in slightly higher loads entering the shoulder, assumed to be due to friction
  - Stress on insulator can reach >17,000 psi
- Lateral loads are significantly higher from passing freight trains than from passenger trains
- L/V ratio not sufficient for describing force distribution at crosstie and fastening system

Rail Seat Lateral to Vertical Reaction Ratio (RSR)

- Failed insulators are often seen on heavy haul lines in sharp curvature
  - High lateral fastening system forces the likely cause
- Unequal vertical and lateral load distributions coupled with high lateral forces may cause critical loading scenarios within fastening systems

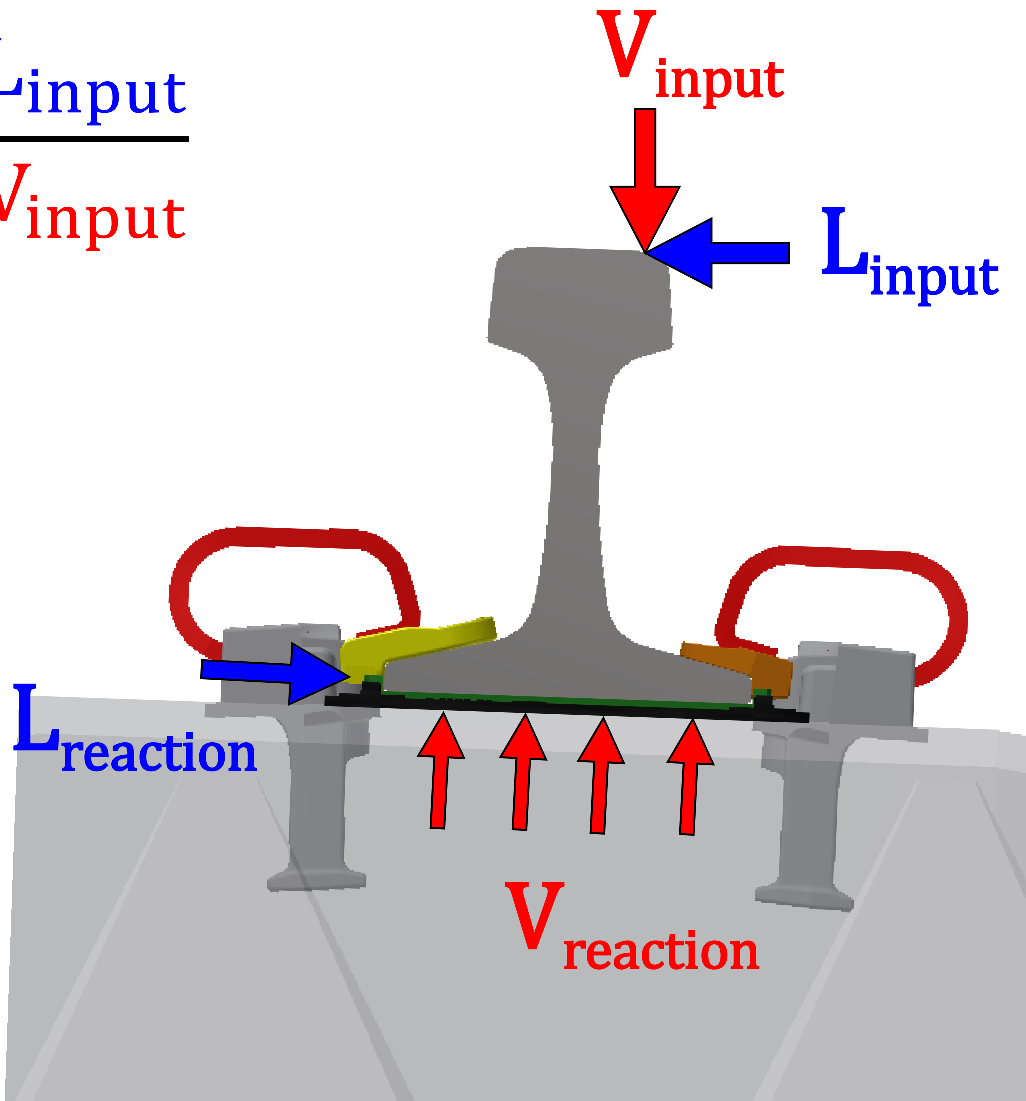




Rail Seat Lateral to Vertical Reaction Ratio (RSR)

$$\text{L/V Force Ratio} = \frac{L_{input}}{V_{input}}$$

$$RSR = \frac{L_{reaction}}{V_{reaction}}$$



Rail Seat Lateral to Vertical Reaction Ratio (RSR)

- Given:
  - Lateral bearing load is distributed to three crossties
  - Vertical bearing load is distributed to five crossties
- A 0.5 L/V Force Ratio applied directly over Tie B will result in a 0.25 RSR Ratio at the rail seat of Tie B and a 0.31 RSR at the rail seat of adjacent Ties A and C
- Adjacent fastening systems may have to withstand higher load ratios than what is applied at the WRI
- Future research will investigate threshold RSR values (i.e. what RSR values are associated with failure)

Future work

- Lateral load measurement on revenue service track
  - What are lateral load magnitudes and distribution under demanding field conditions?
  - What are the effects of varying track geometry?
- Full-scale laboratory testing
  - What are the effects of varying component tolerances?
  - How does lateral track stability affect lateral fastening system forces?
- Component-level laboratory testing
  - What are the thresholds of plastic damage?
  - How do alternative material properties affect load transfer and distribution in the fastening system?

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  - Hanson Professional Services, Inc.
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  - TTX Company
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FRA Tie and Fastener BAA Industry Partners:

Questions or Comments?

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