Freight Train Make-up and Handling: Conditions that Cause Derailments

Dr. Elton Toma, Ph.D., P.Eng.

August 26, 2015

Freight Train Make-up and Handling

- Summarize work from several projects completed by National Research Council (NRC) Canada, Automotive and Surface Transportation (AST).
  - NRC-AST

Freight Train Make-up and Handling

- Focus on “in-train” forces
- Longitudinal forces between the car
- Carried by the couplers and draft gear

- What is the cause of longitudinal forces?
- Where do these forces go?
- What are the effects on train operations, and the potential for causing derailments?

Mixed Freight

- Mixed Goods Train
- Variety of cars
- Loaded and empty

https://www.youtube.com/watch?v=zZWaGT9yOyk

Unit Trains

- All cars are the same.
- Either all loaded, or all empty.
- Typically a captive fleet.
  - Coal, mineral ores, potash, etc.
- Often operated and supervised 24/7: from mine to port, processing facility, or power station.

A coal train winds from a mine in the Powder River Basin near Gillette, Wyo. 2012 photo/Allen Best

Extreme Unit Trains: BHP Iron Ore, Australia

- In July 2001 BHP ran a single 640 car train, about 4.6 miles long, 99,000 tons.
- Typical BHP train is 1.5 to 2.3 mile long
  - Captive fleet, all cars are identical.
  - Unit trains: all empty or all loaded.
  - Distributed power.
  - Flat terrain (mild undulating, not mountainous).
  - Couplers are inspection every 300 trips!

Extreme Unit Trains: BHP Iron Ore, Australia

- BHP and Monash University have worked on measuring in-train forces for the BHP fleet.

- Train handling has a large effect on in-train forces:
  - peak forces of 331,000 and 154,000 pounds for similar trains operated under slightly different operating conditions

Mixed Goods Trains

- Prior to the 1990s, the average freight train in Canada was about 5,000 feet long and weighed 7,000 tons.
- By mid 2000's, 12,000 to 14,000 feet was not uncommon, weighing up to 18,000 tons.
- Similar changes occurred in the U.S.

- The use of distributed power (DP) allowed this change to take place.

Mixed Goods Trains: Distributed Power

- Remote locomotive(s) controlled by the lead locomotive.
- Throttle, dynamic brake and air brake commands are controlled.
- Many automatic systems and fail safes in place.

- http://www.railwayage.com/index.php/operations/the-long-and-the-short-of-distributed-power.html

Mixed goods vs. Unit trains: derailments

- In 2010 the TSB identified 13 main track derailments in Canada that were attributed to ***high in-train forces***
- None were unit trains.
- All 13 were mixed goods trains:
  - 10 caused by high buff forces
  - 1 string-lining (the only DP train to derail)
  - 1 pull apart
  - 1 emergency brake application

In-Train Forces: Longitudinal Forces

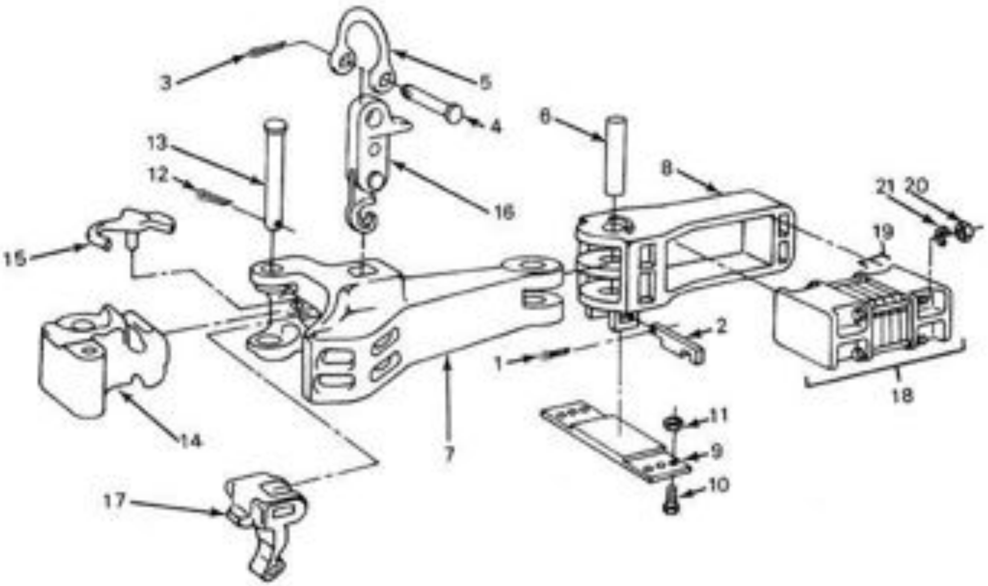
- In-train longitudinal forces arise due to "slack action" between cars.
- Slack is engineered into the system: it is not a flaw or a sign of worn couplers.
- Slack is needed:
  - to allow a stopped train to start, and
  - to allow cars to be safely uncoupled.

Longitudinal Forces: Slack Action

- *Slack* allows cars to move relative to each other:
  - A 200 car train fully stretched can be more than 50 feet longer than the same train fully compressed
- "*Run in*" can occur any time a change in throttle or brake setting occurs
- It is expected as part of normal operations on undulating terrain, and is to be controlled by the operator.

Longitudinal Forces

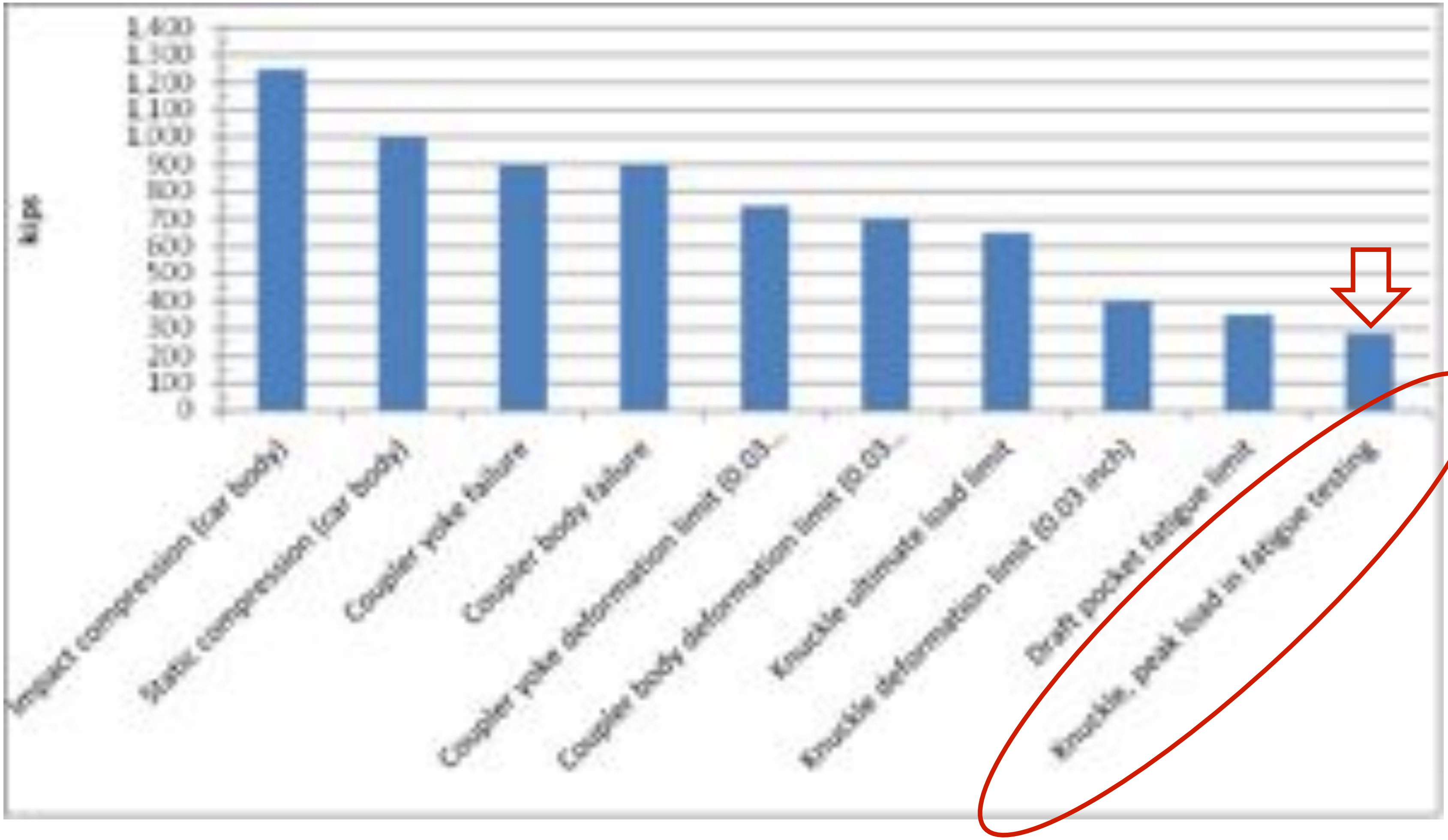
- How big are these loads?
  - Cars are designed to withstand over 1,000,000 pounds of load.



http://railroadmanuals.tpub.com/TM-55-2210-223-34/css/TM-55-2210-223-34_272.htm

  - The system is engineered with the coupler as ‘fuse’ designed to break before other car components.

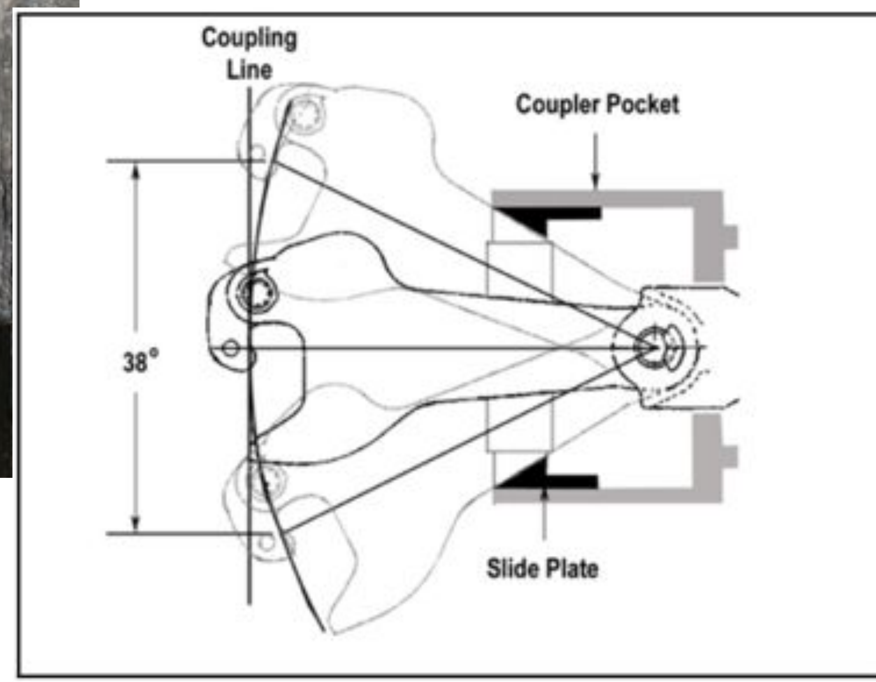
Longitudinal Forces



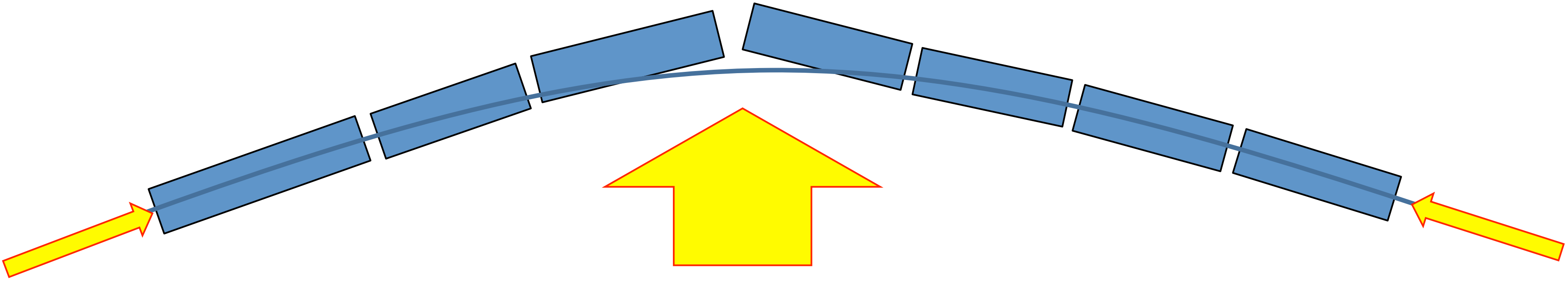
Longitudinal Forces

- What happens to these loads?
  - Transferred into the car and track longitudinally, vertically, and laterally.
- Lateral loads = derailment risk!

Longitudinal Forces: Couplers

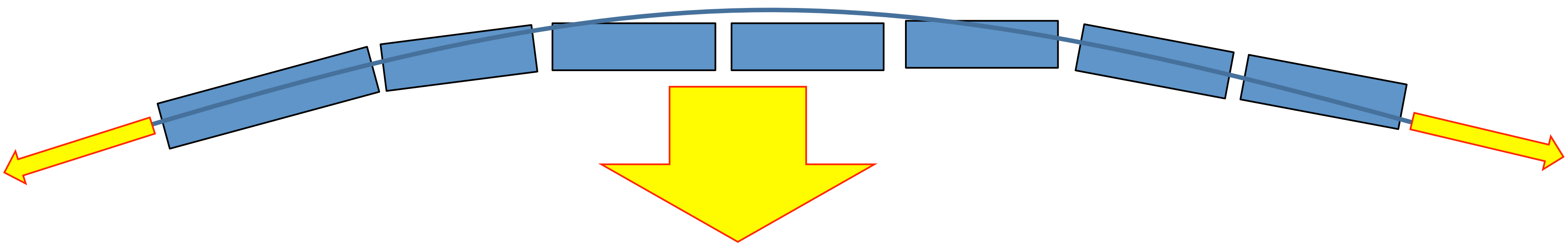


Jack-Knifing Derailment



- Caused by excessive buff forces:
  - Steady state from braking forces.
  - Dynamic from in-train forces.

String-lining Derailment



- Caused by excessive draft forces:
  - Steady state from locomotive traction.
  - Dynamic from in-train forces.

Freight Train Make-up and Handling

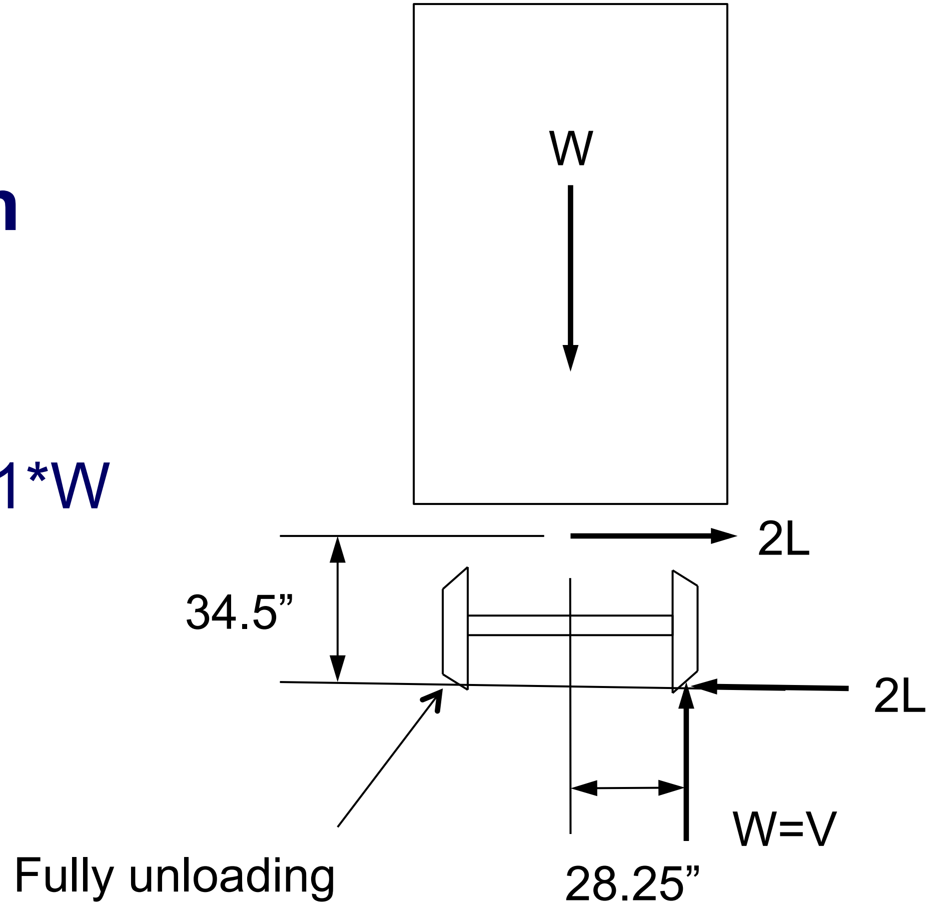
- Steady-state
  - Continuous climbing under power
  - Continuous braking
- Dynamic loads
  - Longitudinal train action

Force Balance under Static Tipping Condition

2L*34.5 = 28.25*W

2L = 28.25/34.5 = 0.41*W

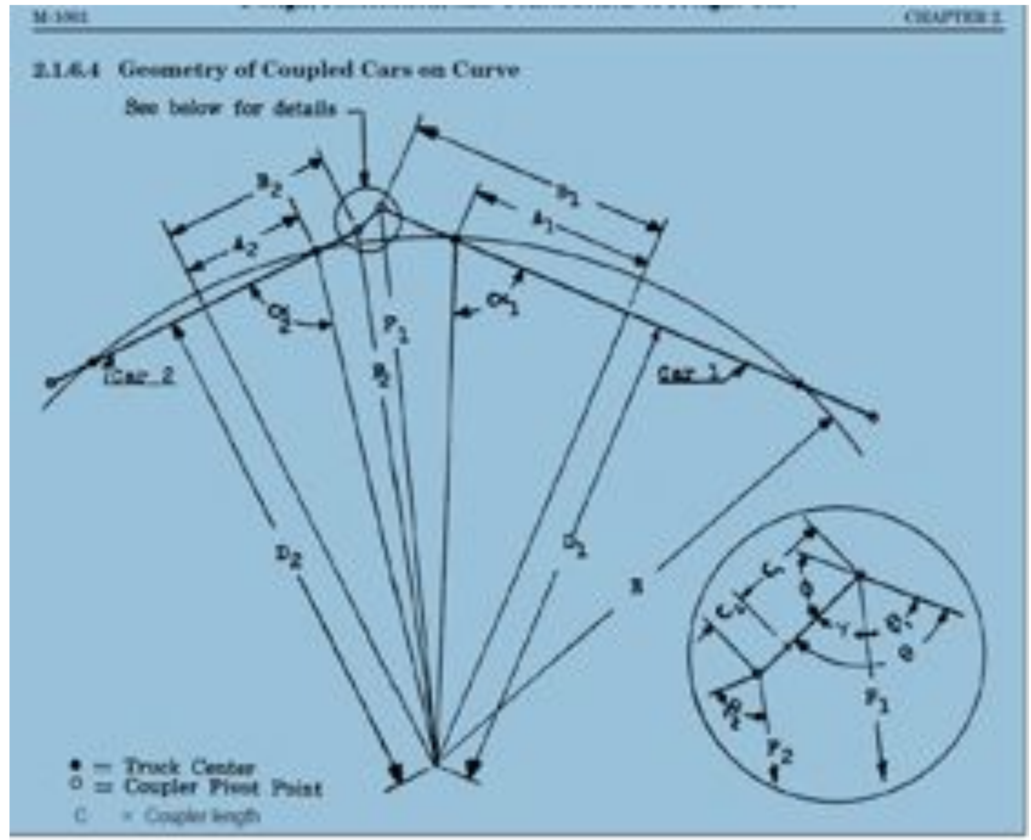
or L/V = 0.82



Controlling In-train Forces: AAR Train Make-up Manual

- Curvature
- Car Dimensions:
  - length over pulling face
  - truck spacing
  - coupler length of both cars

- AAR Trailing Tonnage Tables

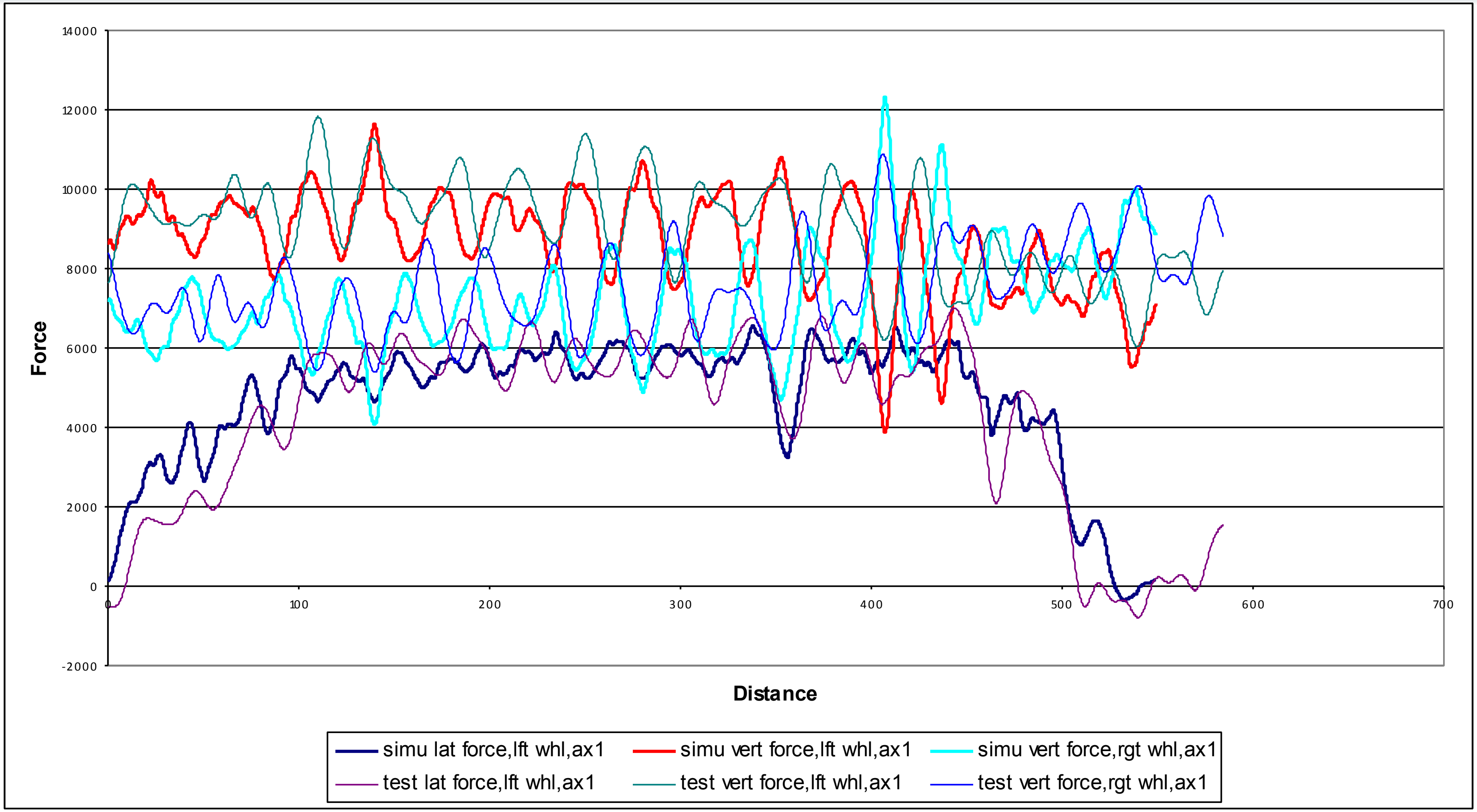


Controlling In-train Forces: AAR Train Make-up Manual

- Unrestricted service when:
  - Total train weight is less than 4000 tons, <u>and</u>,
  - Maximum gradient is less than 2.0%, <u>and</u>
  - Maximum curvature is less than 8 degrees.
- Guidelines
  - Steady state operations.
  - Starting accelerating, decelerating or stopping trains.

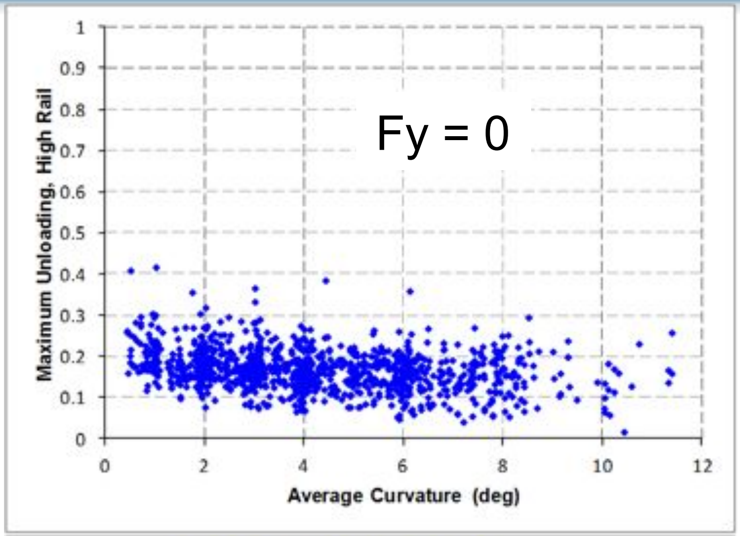
- No guidelines based on *dynamic* conditions.

Controlling In-train Forces: Dynamic Conditions

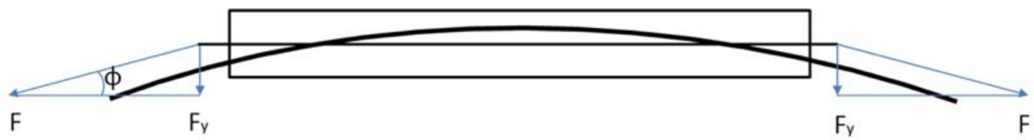


Empty Tank Car on Measured 12 Degree Curve

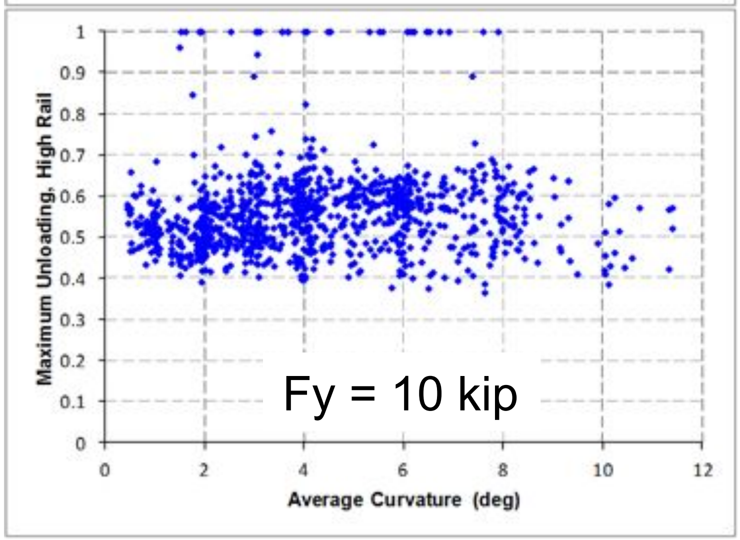
Controlling In-train Forces: Dynamic Conditions

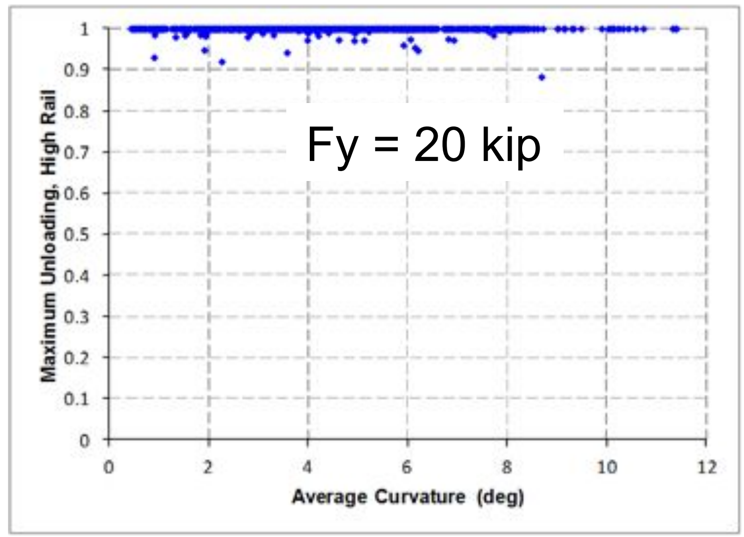


Lateral Force Limits by Simulations on 1000 Measured Curves



62 kip lumber car simulated under string lining condition





Controlling In-train Forces: Trailing Tonnage Tables

- From simulation results a new set of Trailing Tonnage Tables can be produced.
- Account for car and coupler dimensions, and track curvature.

- Results in conservative estimates for number and weight of cars following the locomotives.

Controlling In-train Forces: Trailing Tonnage Tables

Trailing Tonnage /Ton of Long Car Weight																
Coupler Angle (deg)	Grade = 0.5%				Grade = 0.75%				...				Grade = 2.5%			
	R = 5 deg	R = 6 deg	...	R = 12 deg	R = 5 deg	R = 6 deg	...	R = 12 deg	R = 5 deg	R = 6 deg	...	R = 12 deg	R = 5 deg	R = 6 deg	...	R = 12 deg
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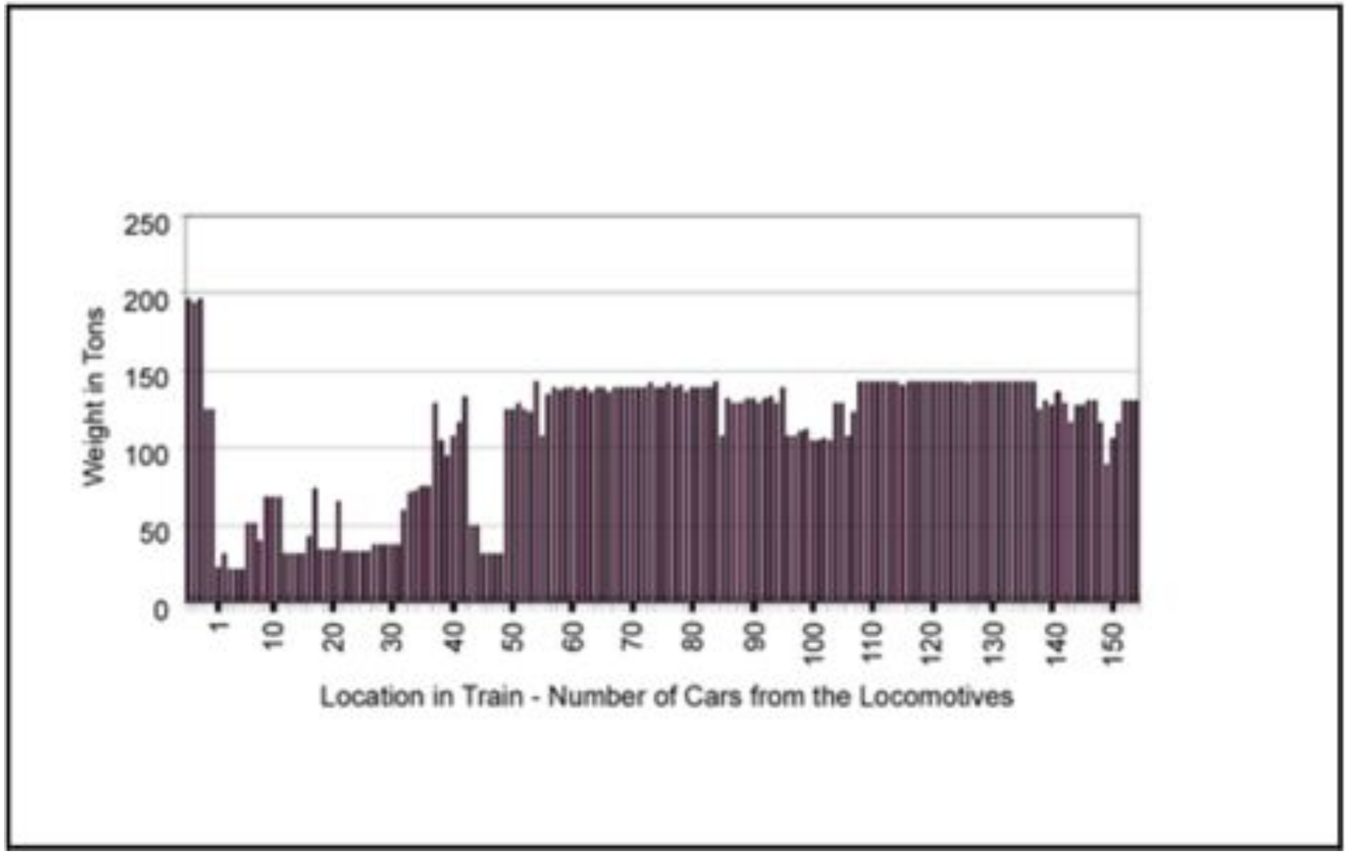
≥15																

Based on these results, NRC has developed a new method for calculating trailing tonnage tables.

Controlling In-train Forces: Trailing Tonnage Tables

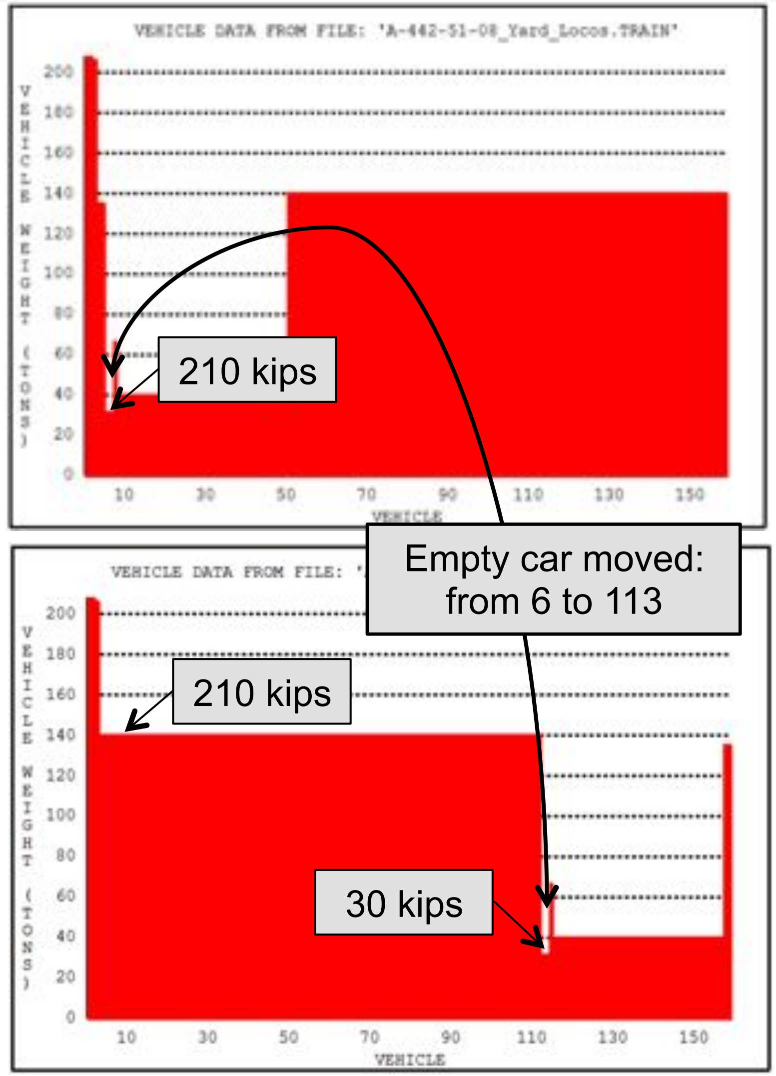


Trailing tonnage behind empty cars are most affected by the new table.

Controlling In-train Forces: TEDS Simulations

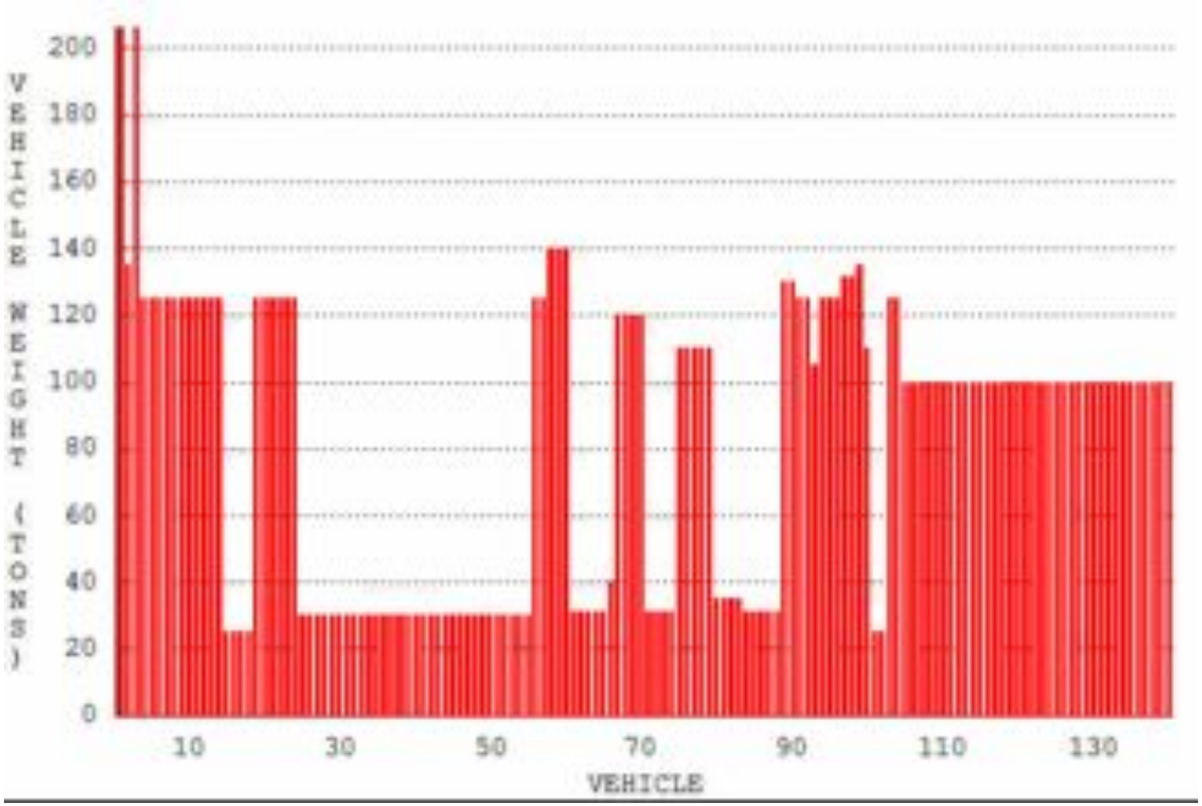
- 210 kips buff load onto car 6 (empty car)
- L/V estimated to be > 2.0

- same 210 kip onto car 6
- L/V reduced to 0.36 at car 6 (loaded)
- empty car moved to 113: buff load drops to 30 kips



Controlling In-train Forces: TEDS Simulations

- TEDS Demonstration video



- Sample mixed goods train: 137 cars, 3 locomotives

TEDS: Train Energy Dynamics Simulator

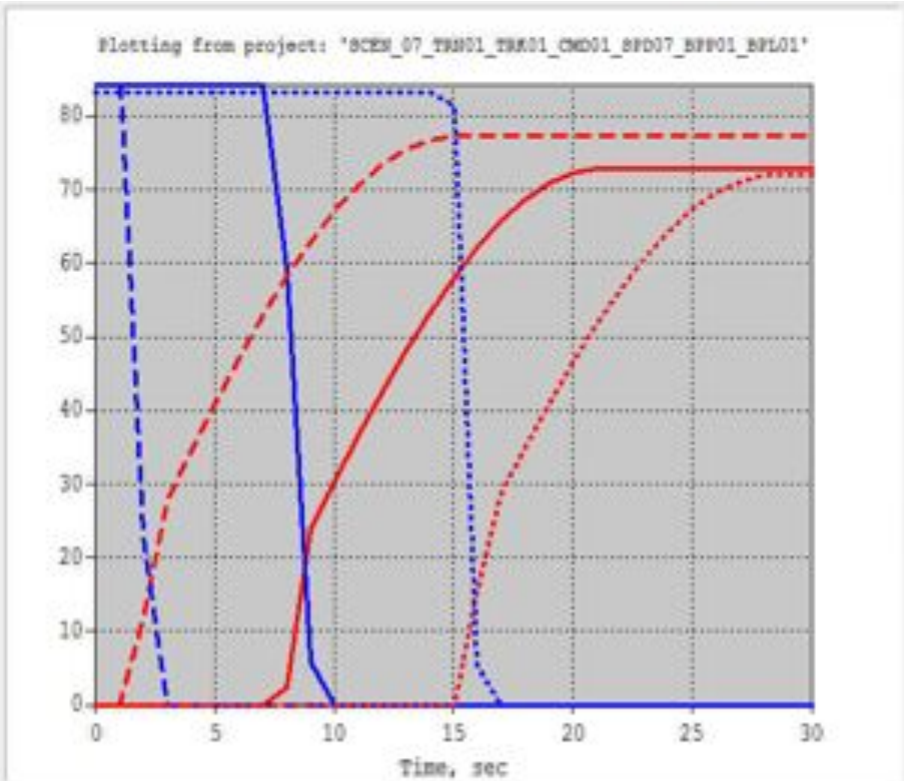
- TEDS Demonstration video

Controlling In-train Forces: Emergency Conditions

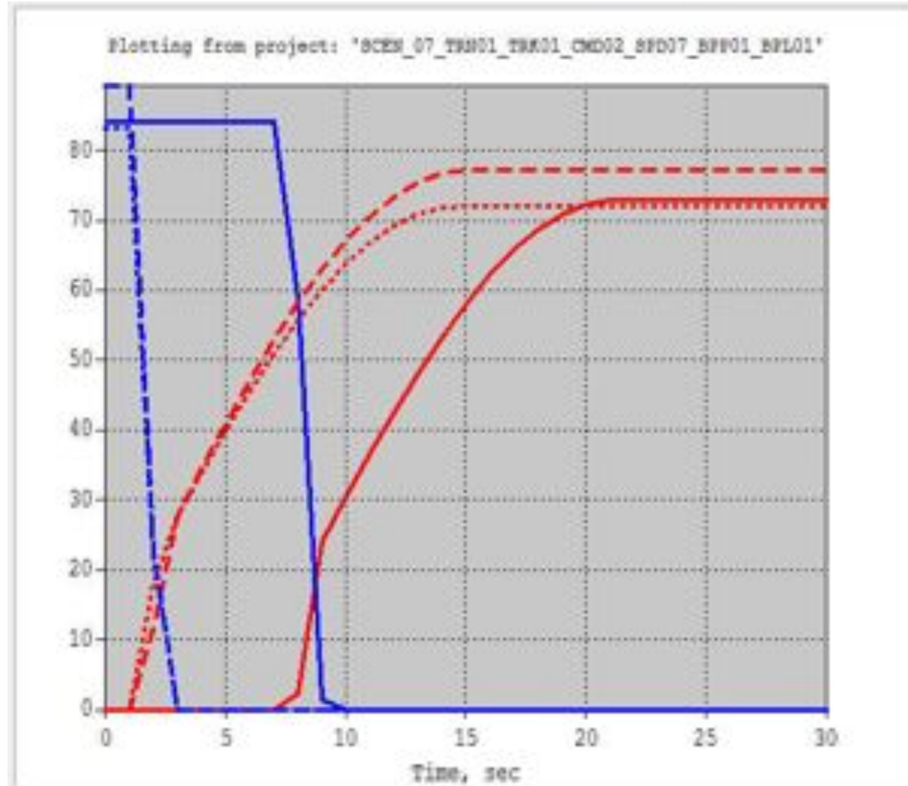
- Stopping distance, in-train forces, and derailment risks.
- What are the effects of:
  - air brake operation,
  - TIBS (EOT device),
  - train length,
  - and train speed.

Controlling In-train Forces: Air Brake Operations During Emergency Conditions

First (dashed), middle (solid), and last (dots) car brake pipe (blue) and brake cylinder (red) pressure. (14,000 ft train).



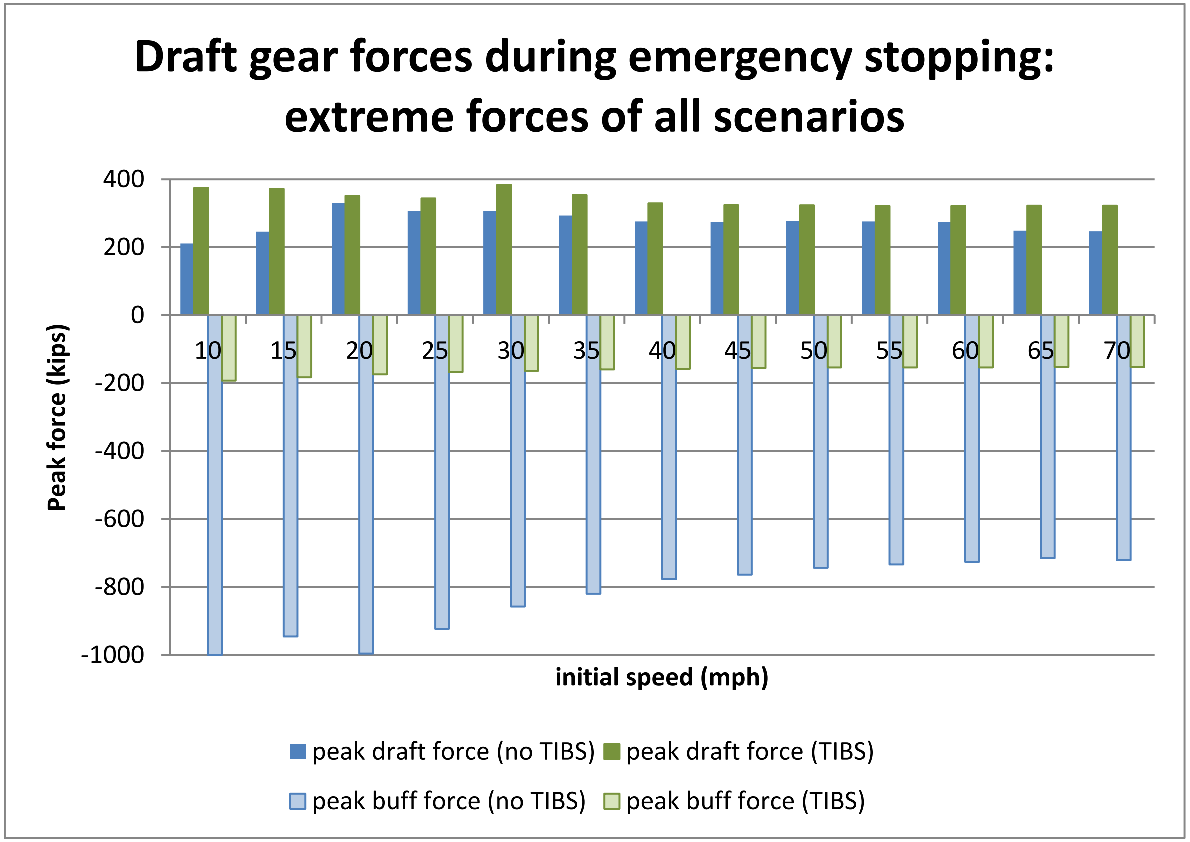
Without EOT brake device



With EOT brake device

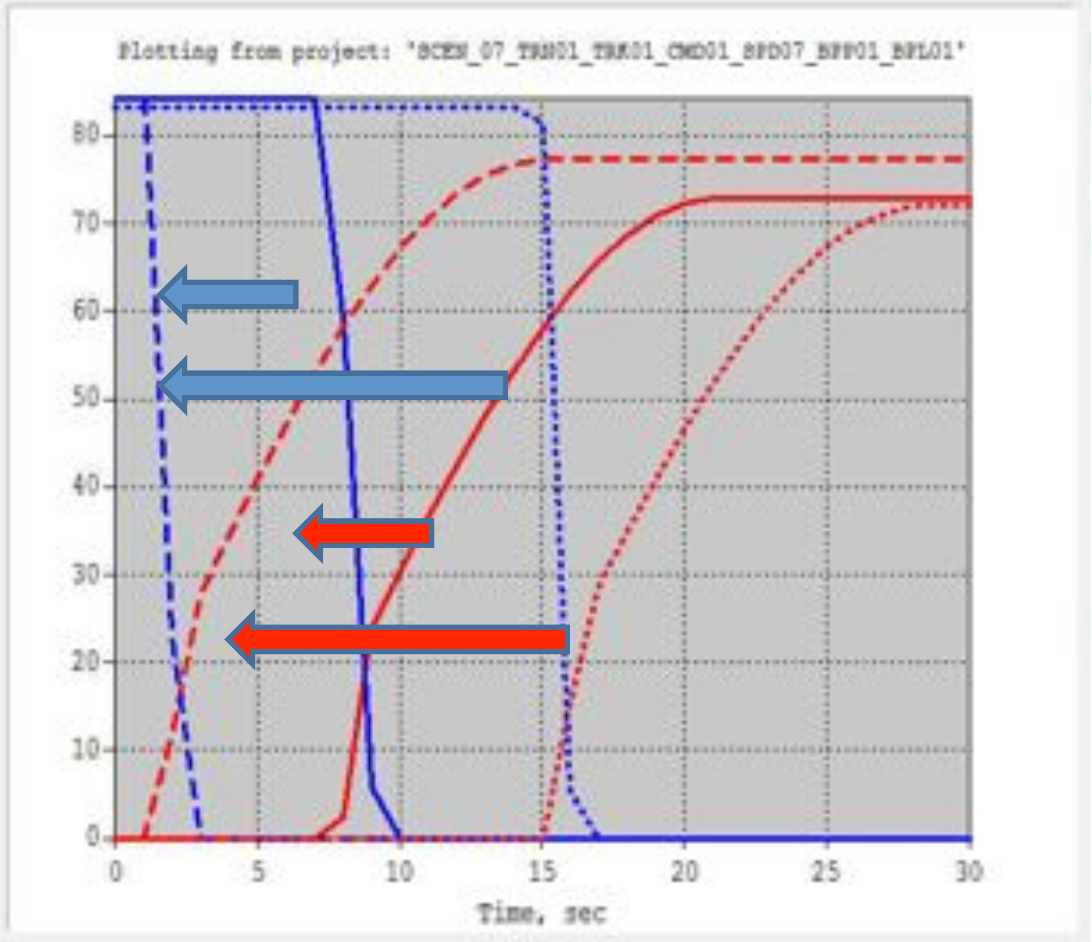
Controlling In-train Forces: Emergency Conditions

- TEDS simulations, several dozen preliminary scenarios.
- EOT brake device (TIBS) reduces peak buff forces during emergency braking.



Controlling In-train Forces: ECP Brakes

- All cars begin braking at the same time.
- Reduction in time to reach full brake force is ~1 second per 1000 feet of train.
- In-train forces are reduced significantly.
- Number of derailed cars estimated to be reduced significantly.



Thank you