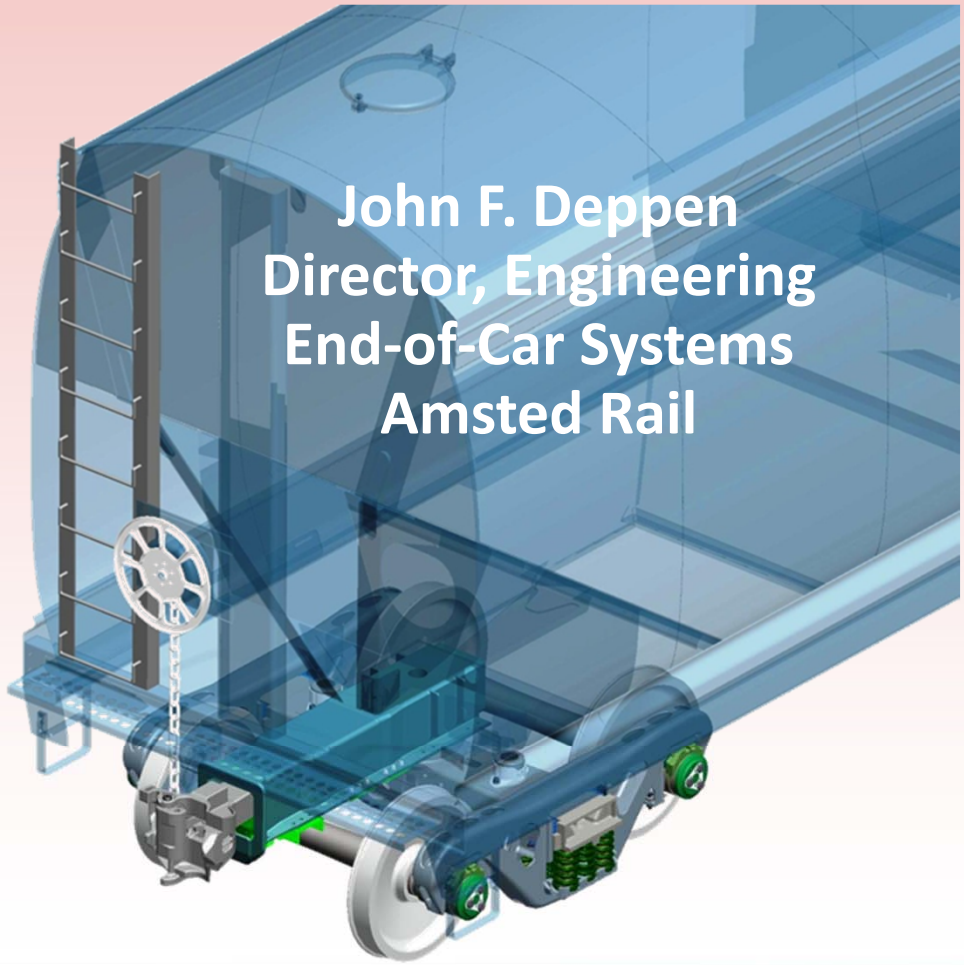
The Dynamics of Freight Car Cushioning



John F. Deppen
Director, Engineering
End-of-Car Systems
Amsted Rail

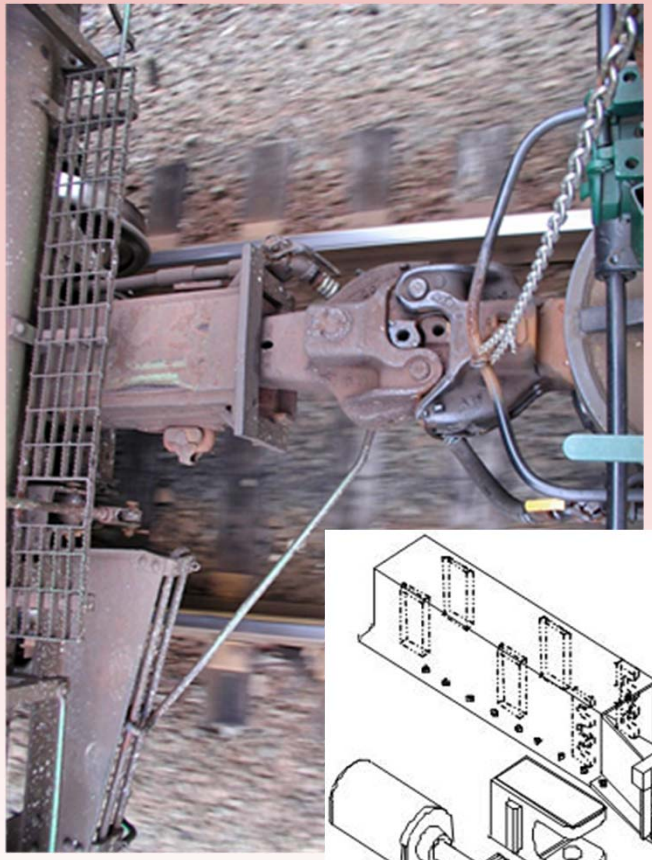
Abstract

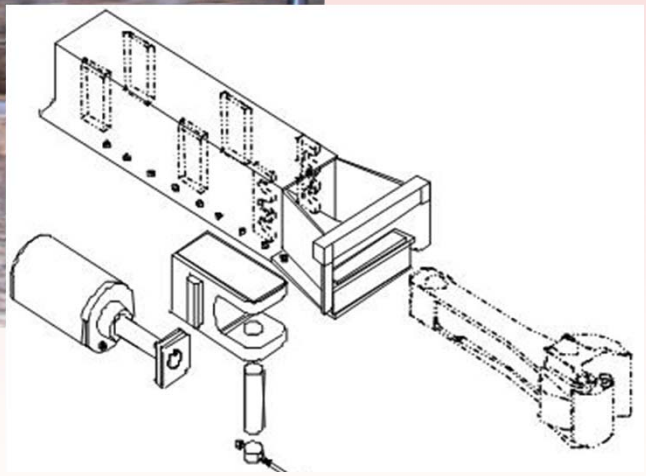
It is typical for railcars to be assembled into a train by coupling individual cars together in a marshalling yard. These yards often use impact ramps or flat switching to accelerate the railcar to a velocity sufficient to roll through a series of switches and tracks to the designated train. Rail operations attempt to keep these velocities to a minimum, but unfortunately at times impact velocities can be higher than desirable. Depending on the type of coupling system (i.e. draft gear or end-of-car cushion unit), damage to the railcar, lading or both can occur at these velocities.

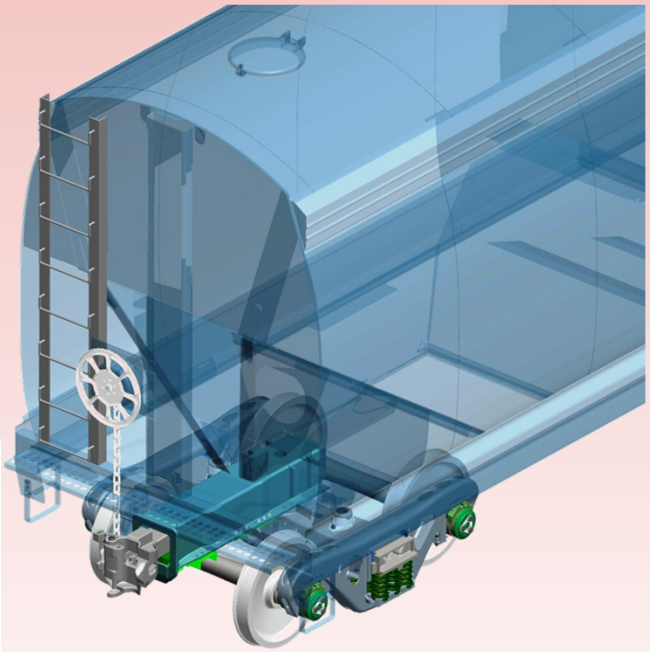
Another source of damage can occur in-train, where relative velocities between railcars can become large. Train length, gross rail load, terrain and the locomotive inputs are sources for these in-train shocks along with automatic couplers and their inherent free-slack. Coupling components must be designed to account for these various inputs to reduce in-train shocks to acceptable levels. Computer simulations validated through over-the-road testing is one of the tools that used to predict the performance of various end-of-car products.

As trains become longer and heavier, it's critical that coupling component manufactures understand railcar dynamics and focus their efforts on products that can reduce in-train shocks. Products such as active draft cushioning along with improvements to A.A.R. specifications will be instrumental to support global heavy haul operations.

End-of-Car (EOC) Product Offering

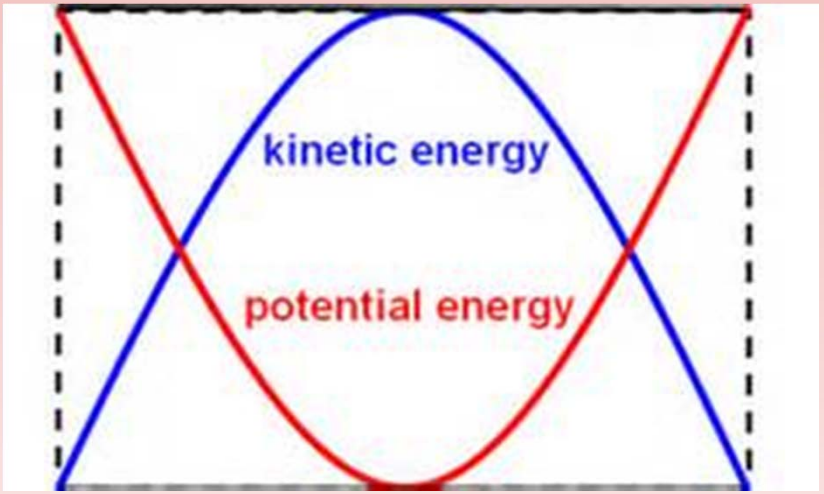


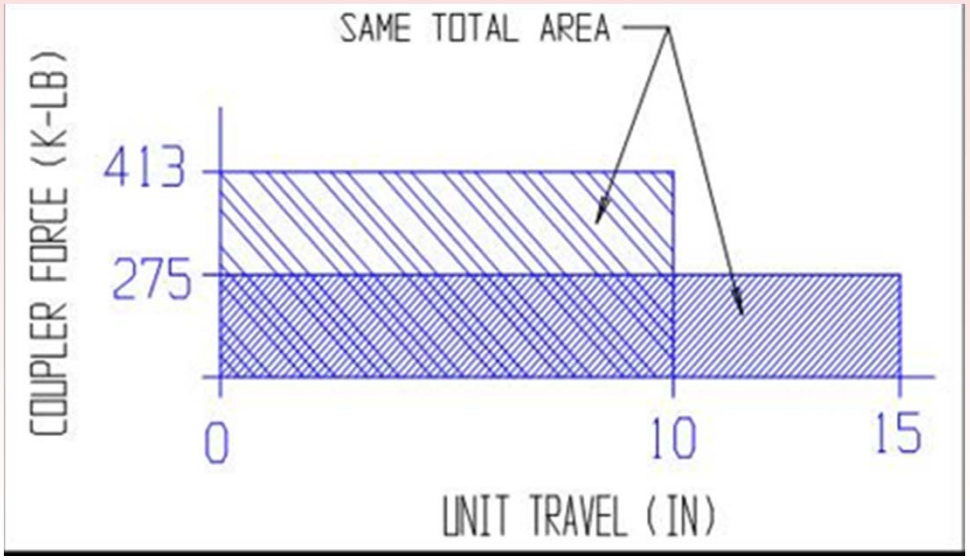




Car Body → Coupler → Attachment via. “EOC Product”

It's all about Energy Management…





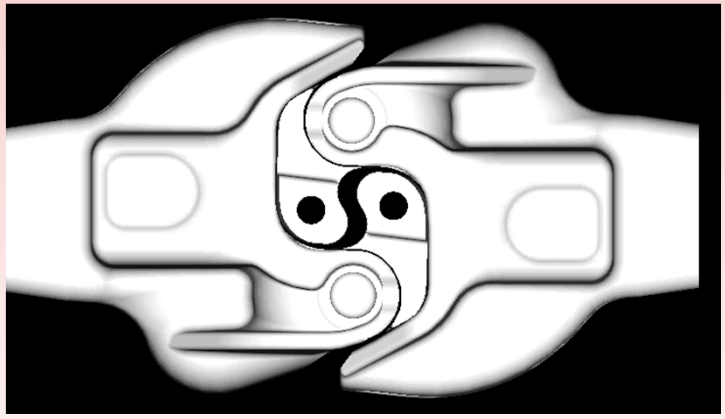
Where does the Energy Come From

…and where does it go?

Kinetic energy of moving car = Work done by End-of-Car Device

½MV² = Coupler Force x Travel (Longer the Travel; Lower the Force)

lading protection from Yard Impacts



lading protection from In-Train Events

“Slack is the Enemy”

Damage *Not* Limited to Yard Impacts

"Slack is the Enemy"

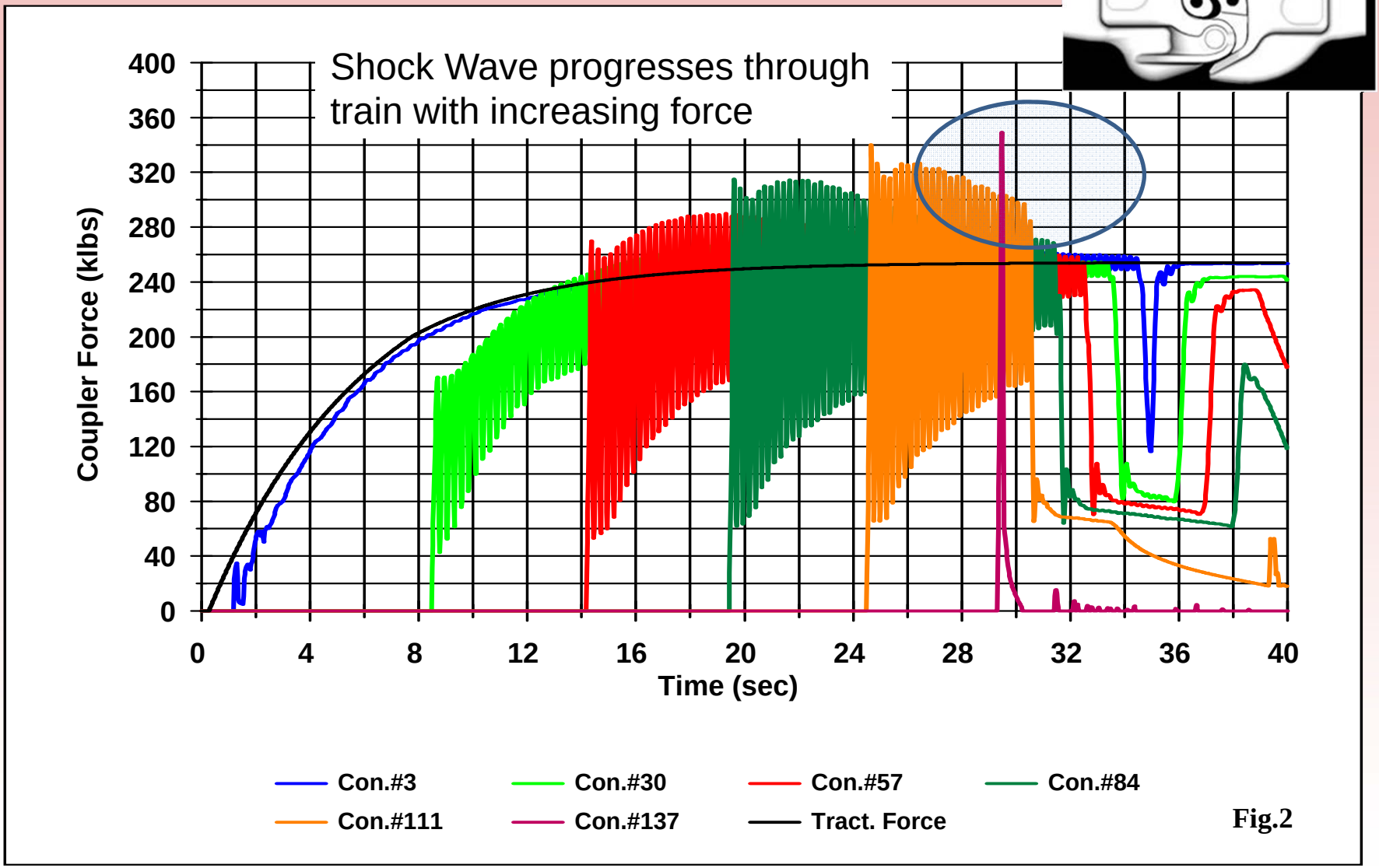
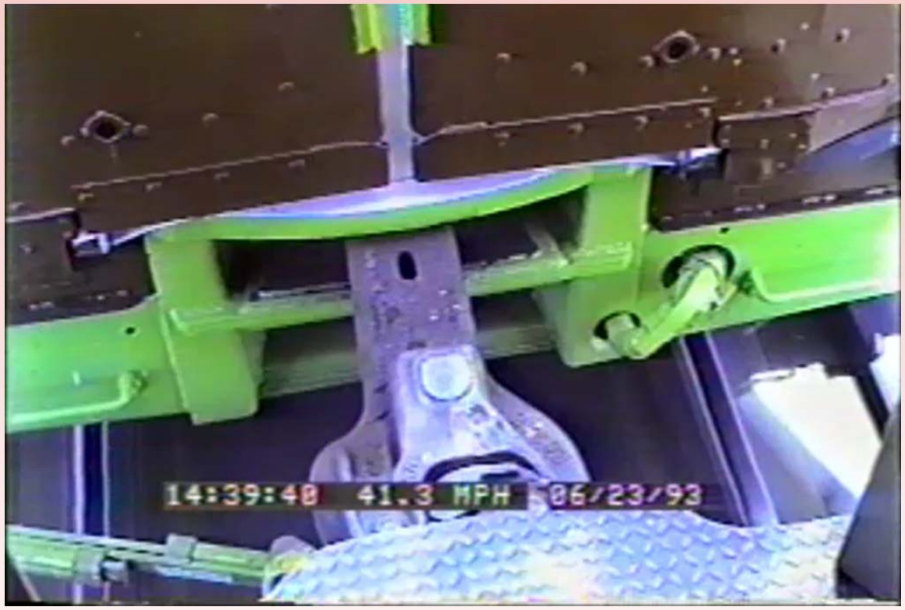


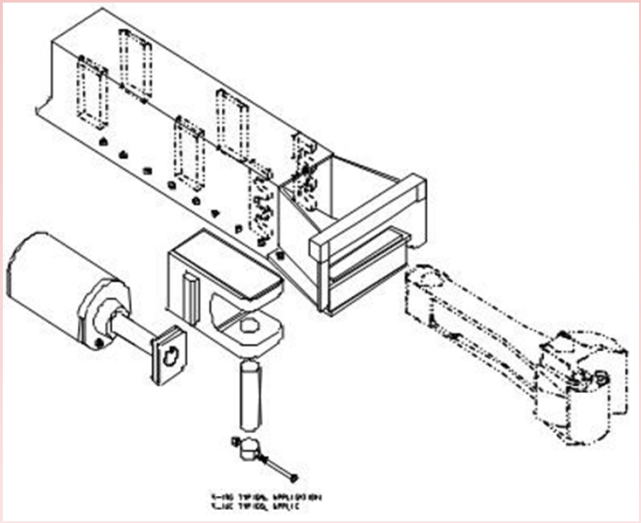
Fig.2

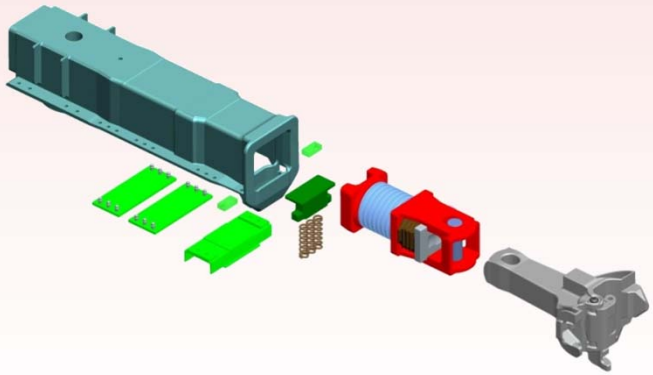
Other Sources of Energy Input?



Energy Management Objectives…

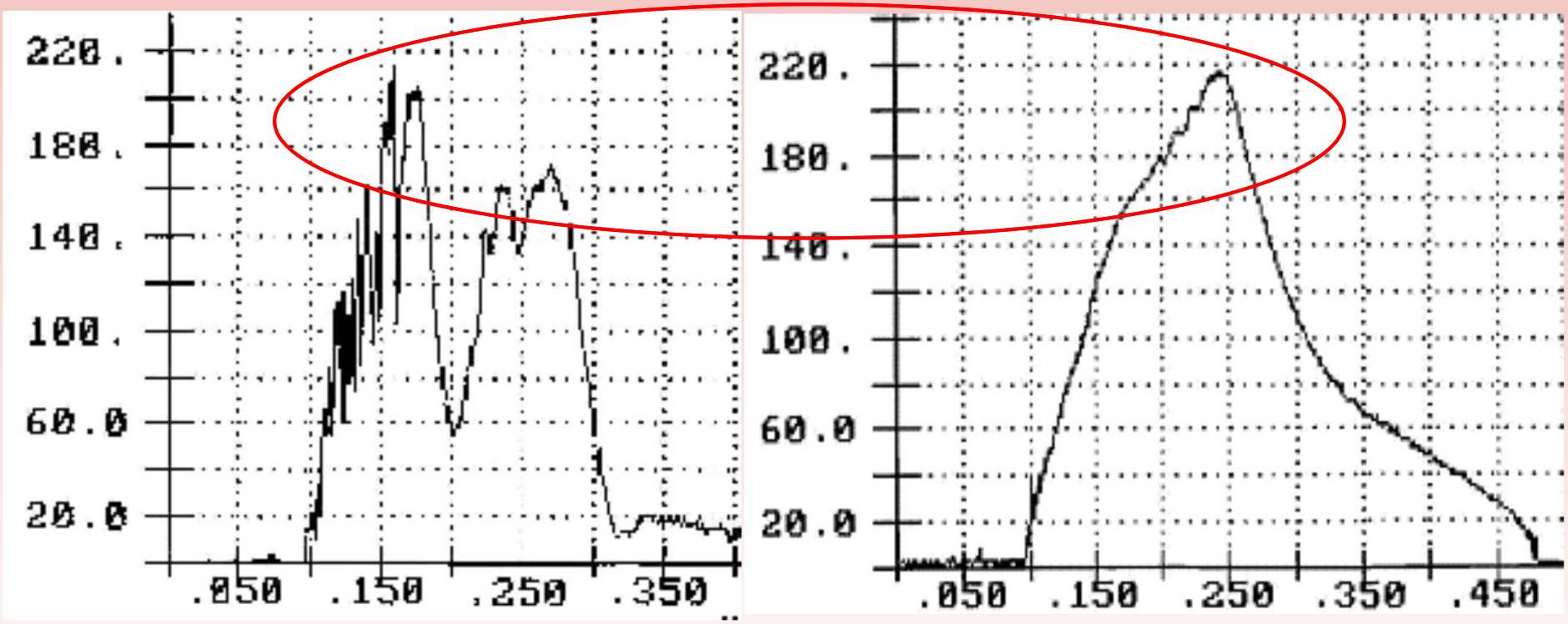
- Coupling Impacts
  - Protect freight car structure
  - Protect sensitive lading
- Train Operation
  - Protect sensitive lading
  - Improve train handling
  - *Prevent high forces v. Managing high forces*





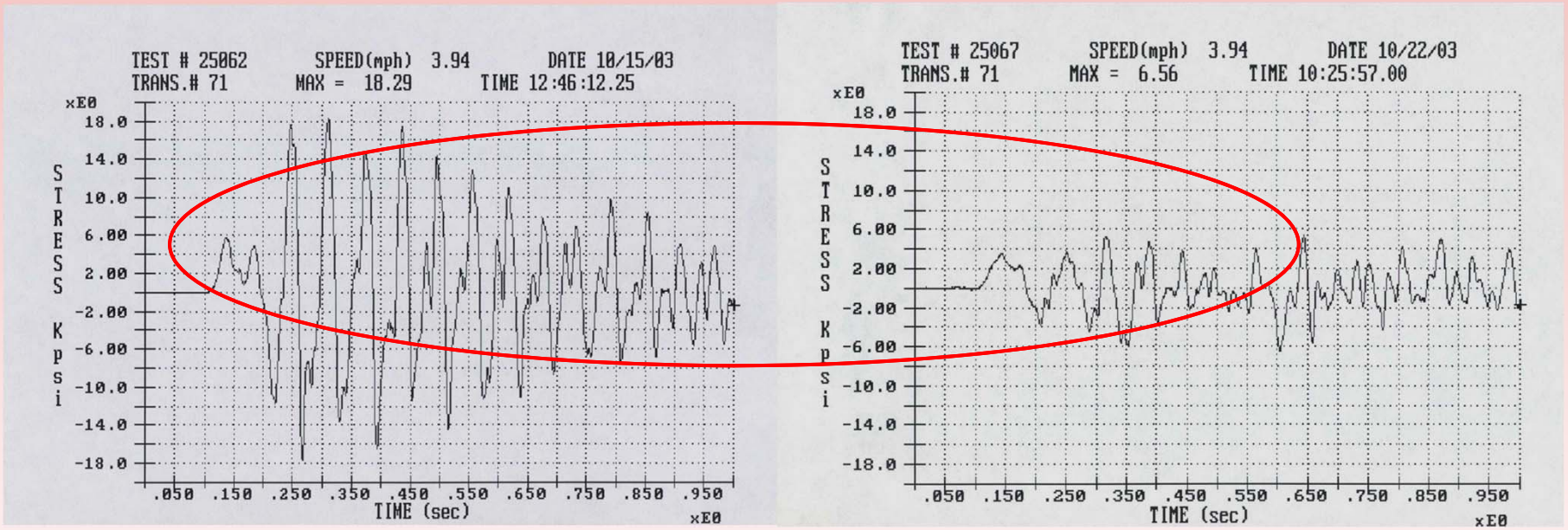
If *not* Properly Managed…

How the force is applied is important…



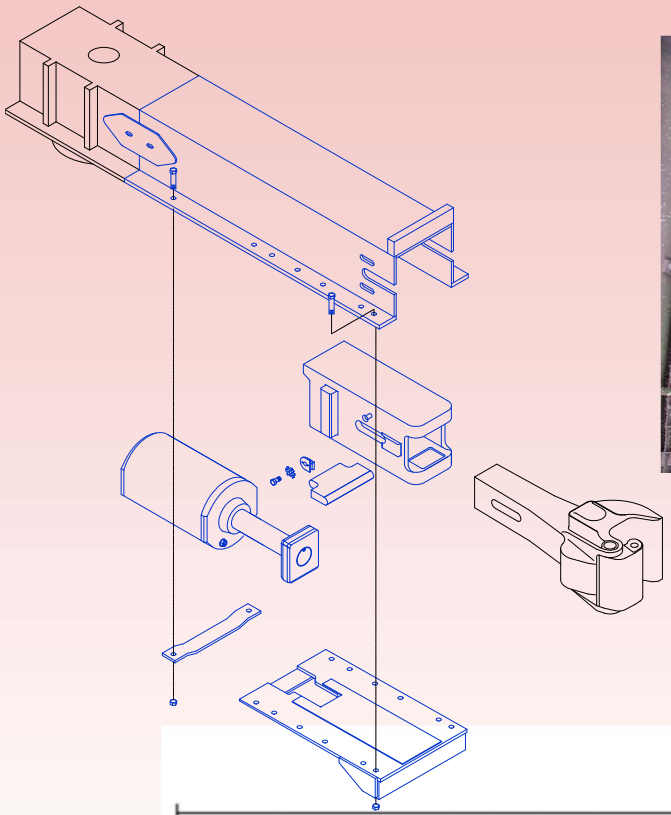
Two Different Draft Gear; Same Peak Force

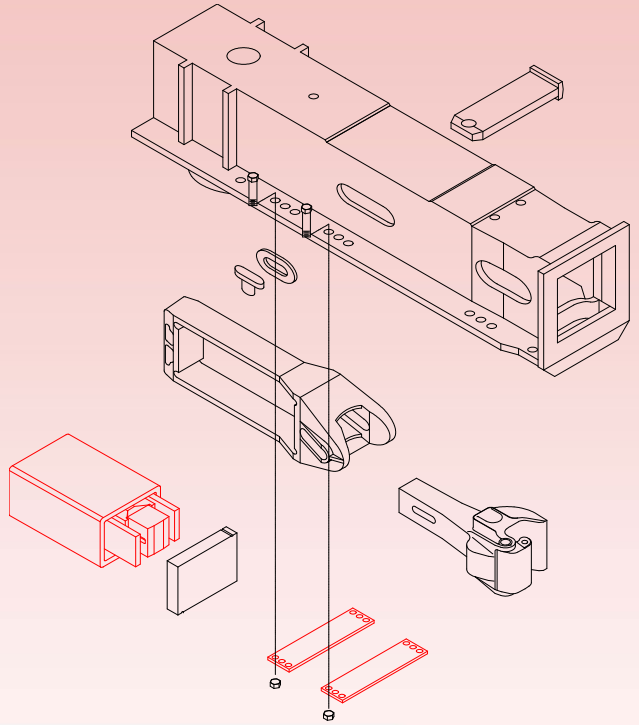
How the force is applied is important…

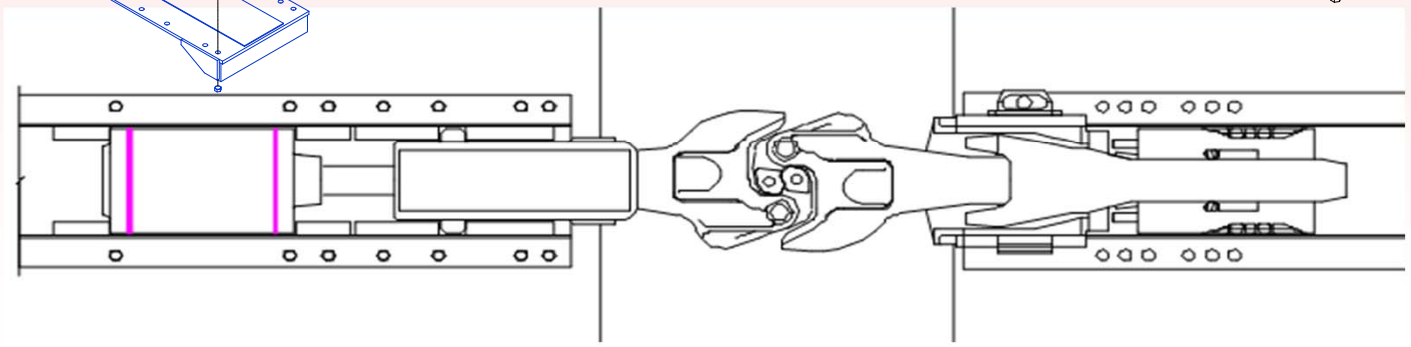


Two Different Draft Gear; Same Peak Force…*Significantly* different Car Body Stresses

Cushion Unit vs. Draft Gear Application

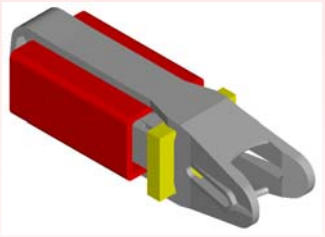


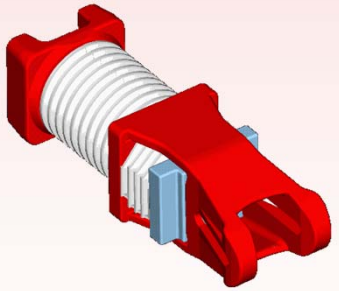




Cushion Unit v. Draft Gear

Vs.





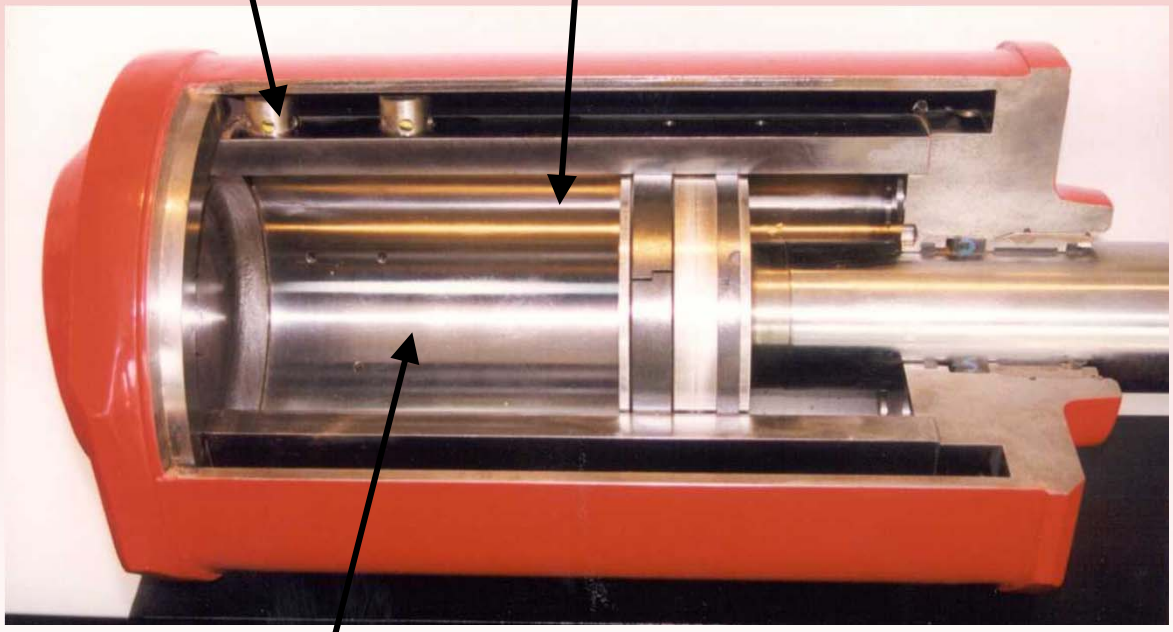
~20% N.A. Fleet Equipped with End-of-Car Hydraulic Cushioning

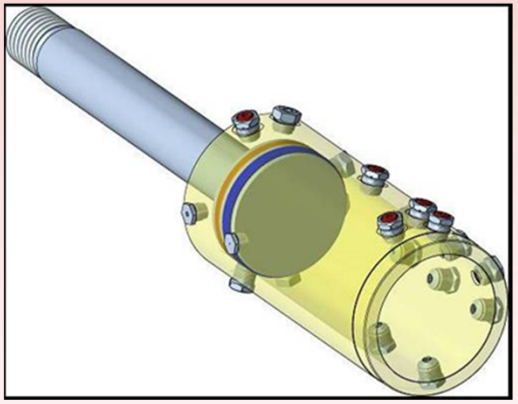
Lading Protection (automotive, paper, building materials)

Cushion Unit Basics

2. Piston forces hydraulic fluid through specially designed valves

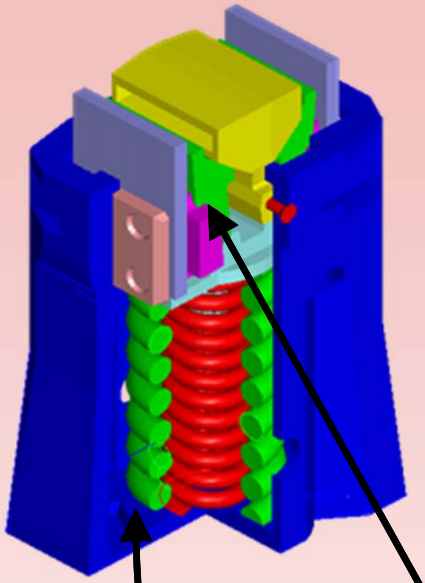
3. Nitrogen gas pushes piston back to neutral after impact



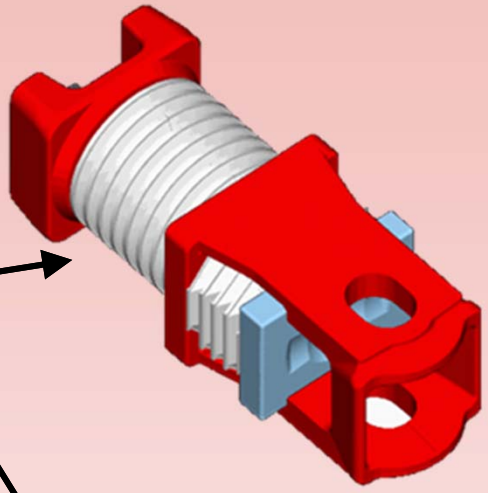


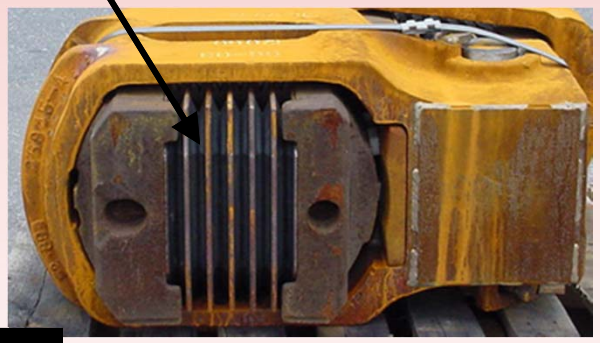
1. Inner cylinder filled with hydraulic fluid

Draft Gear Basics

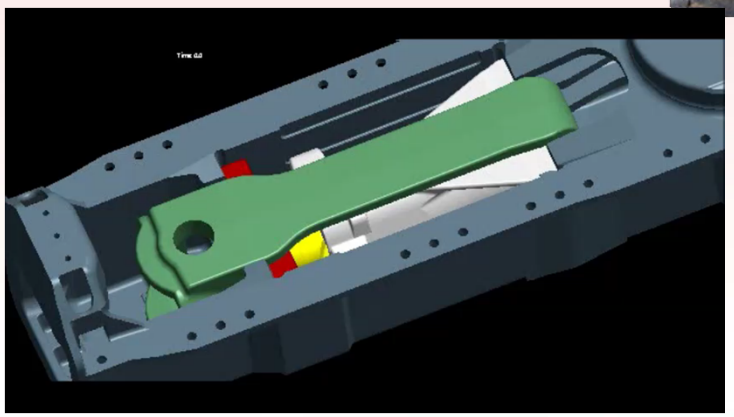


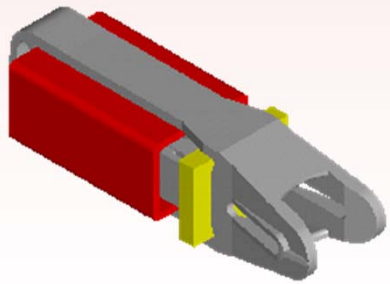
Elastomer Elements compress and absorb energy via. Hystersis…and act as ‘return spring’





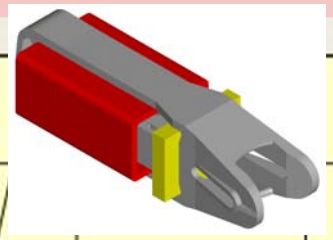
Friction Elements compress and absorb energy.
Mechanical or Elastomer Springs ‘return’ unit back to neutral position.





15

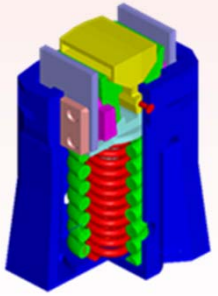
Draft Gear v. Cushion Unit



6 mph Impact…Cushion Unit v. Draft Gear

Hydraulic Cushion Unit

Standard Draft Gear



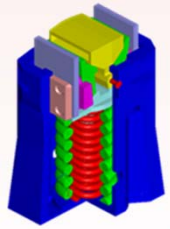
6 mph Impact…Cushion Unit v. Draft Gear

Hydraulic Cushion Unit

Movement @ impact: .75”

Standard Draft Gear

Movement @ impact: 3.6”



162 lb. Steel Block *Lading Damage* Demonstration…

Computer Simulation Code Development

- Apply physics and computational methods
- Evaluate changes in design parameters
- Compare performance predictions
- Reduce product development cycle time
- Facilitate proper equipment selection

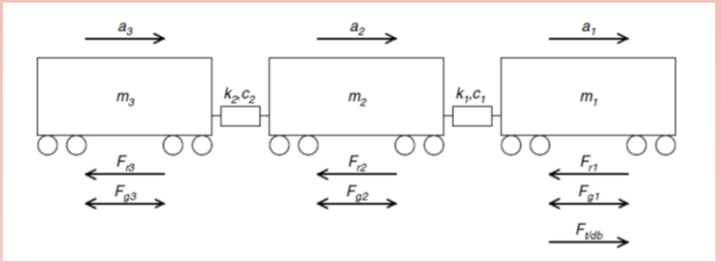
$$m_1 a_1 + c_1(v_1 - v_2) + k_1(x_1 - x_2) = F_{t/db} - F_{r1} - F_{g1}$$

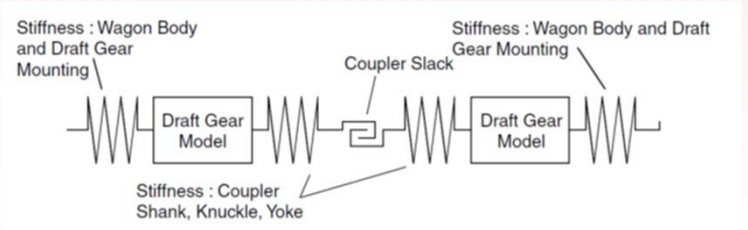
$$m_2 a_2 + c_1(v_2 - v_1) + c_2(v_2 - v_3) + k_1(x_2 - x_1) + k_2(x_2 - x_3) = -F_{r2} - F_{g2}$$

$$m_3 a_3 + c_2(v_3 - v_2) + k_2(x_3 - x_2) = -F_{r3} - F_{g3}$$

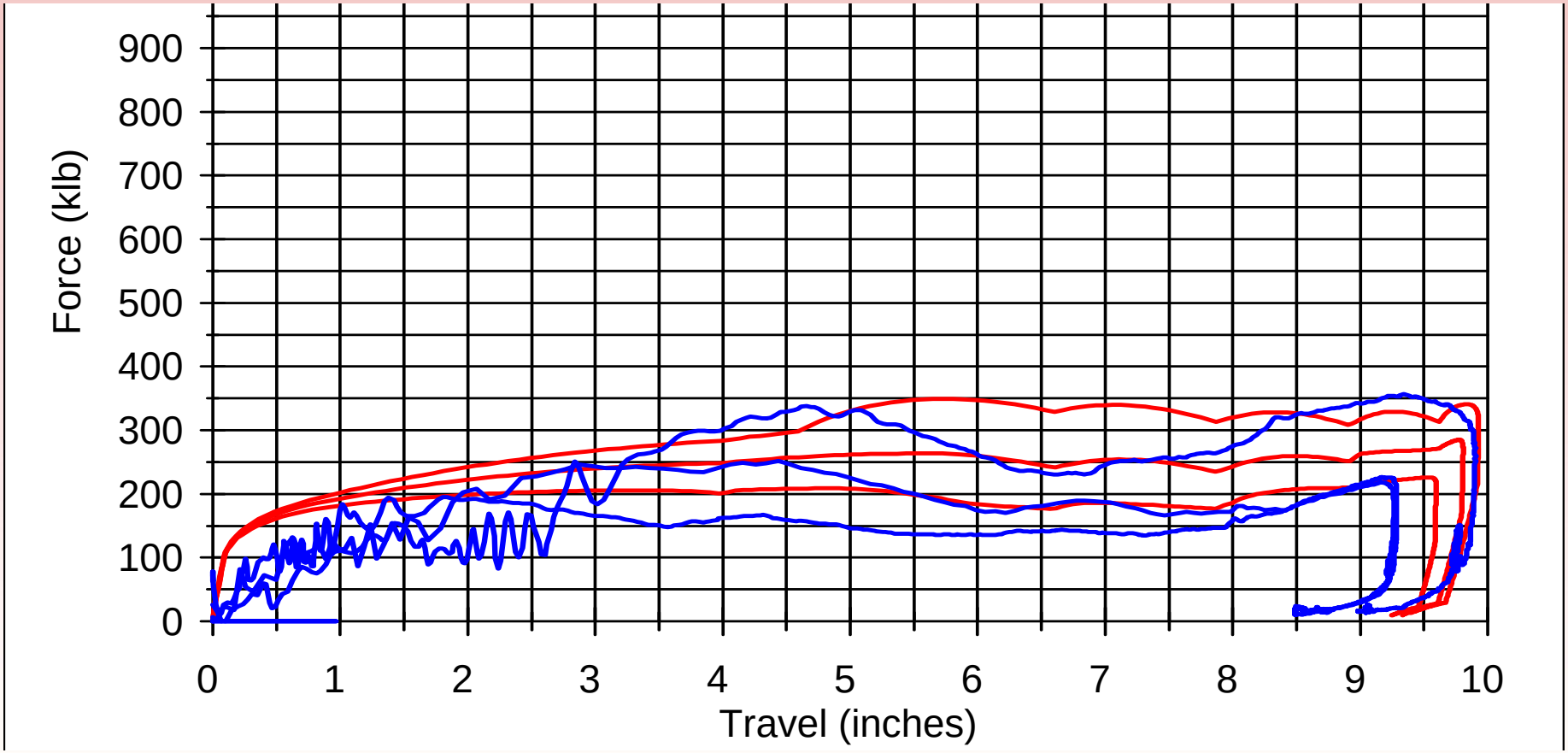
Modeling Capabilities

- Impact and Train-Action
  - ~ 200 individual characteristics
    - Lading density
    - Car body stiffness
    - Draft gear characteristics
    - Free slack
    - Rolling resistance
    - Braking characteristics
    - Locomotive characteristics
    - Other

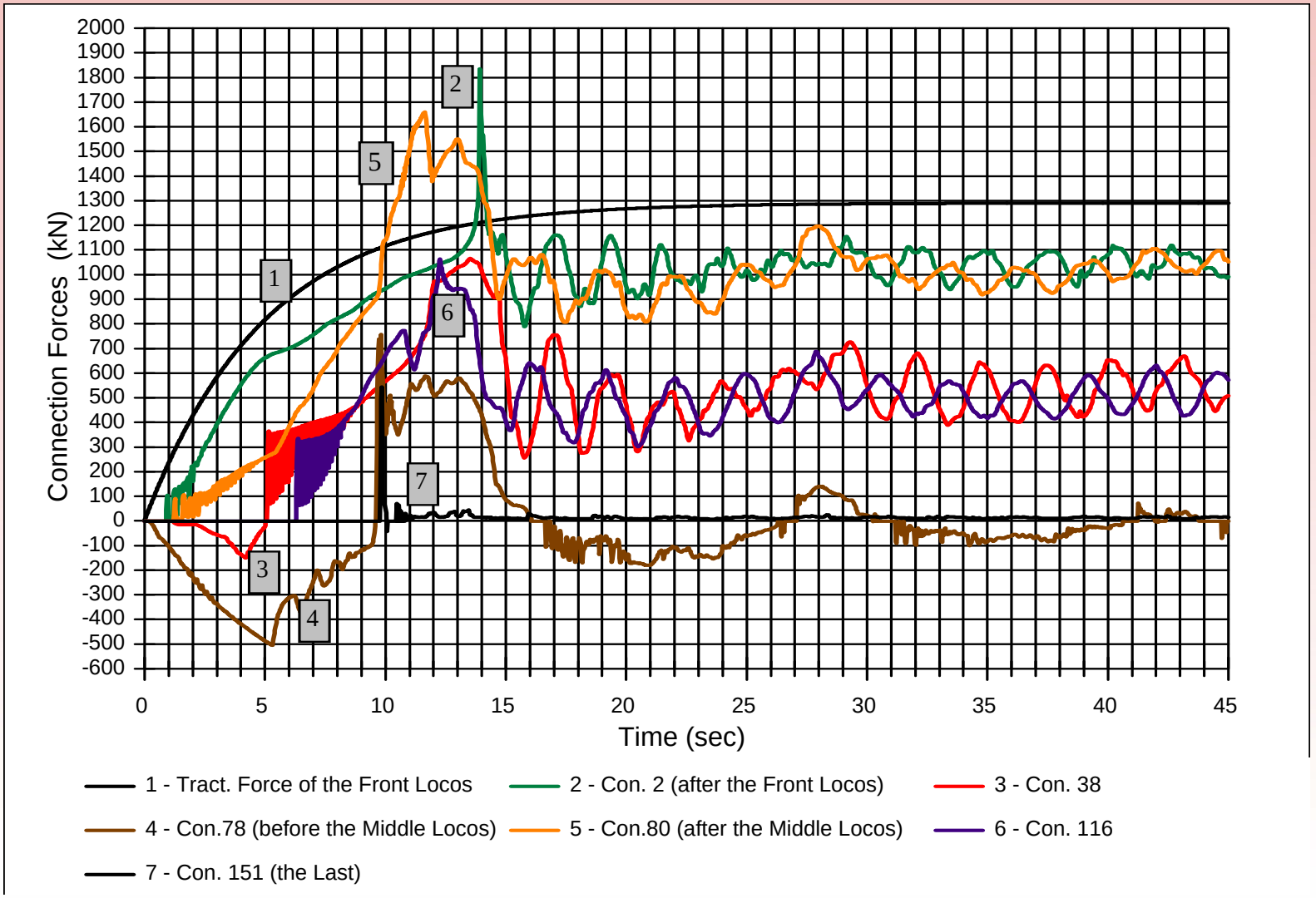




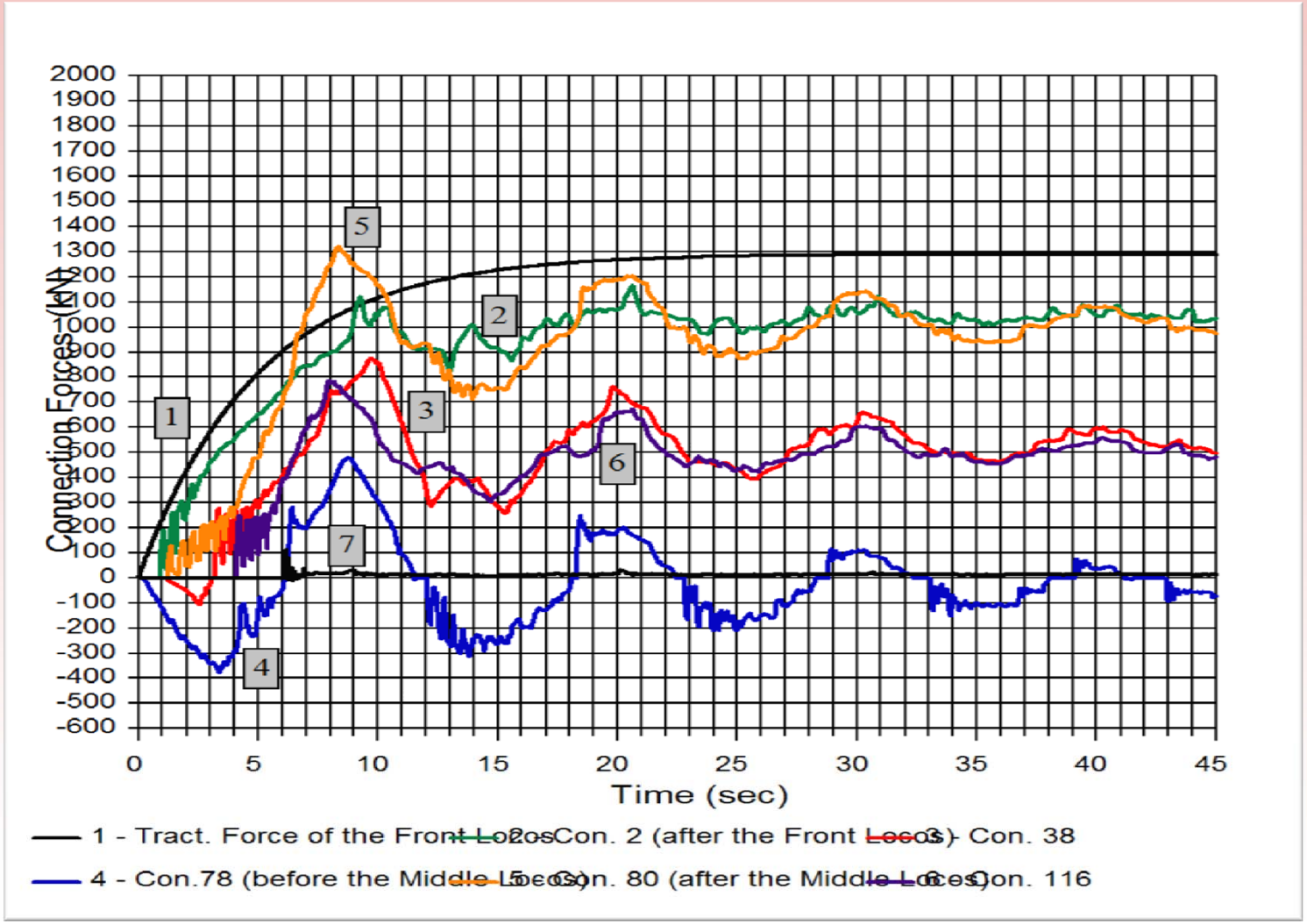
Impact Simulation



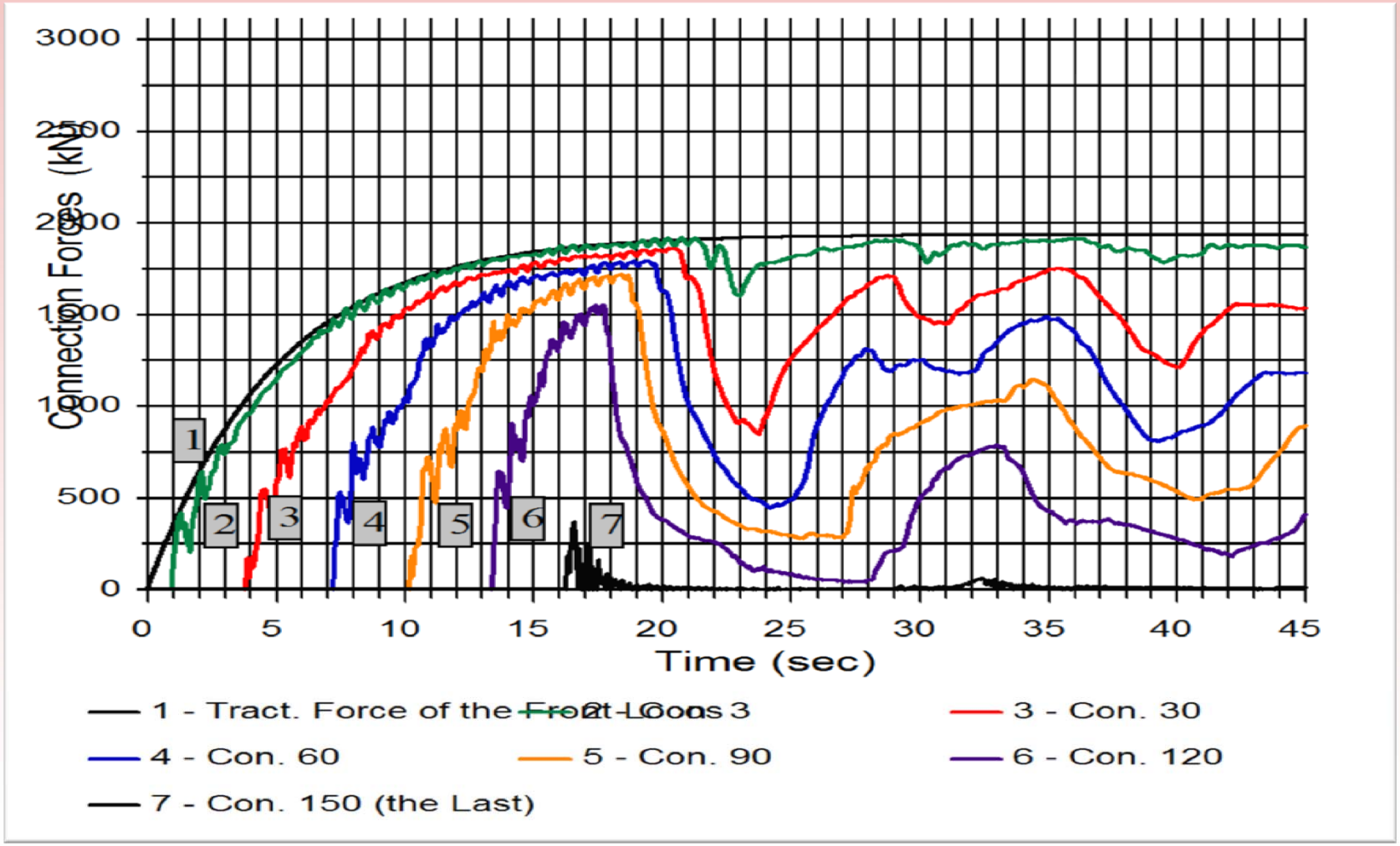
Train Start-Up Simulation



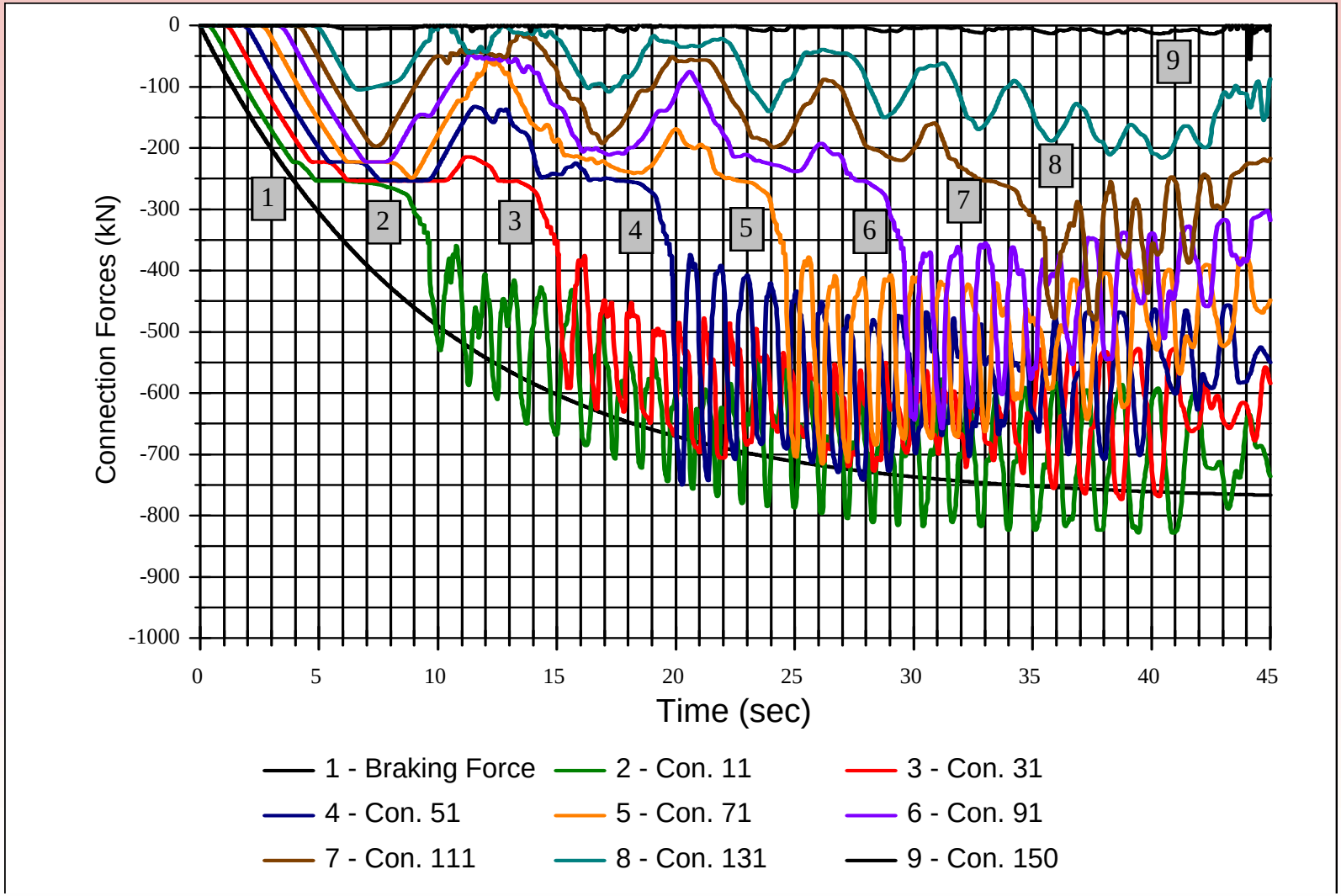
Train Start-Up Simulation



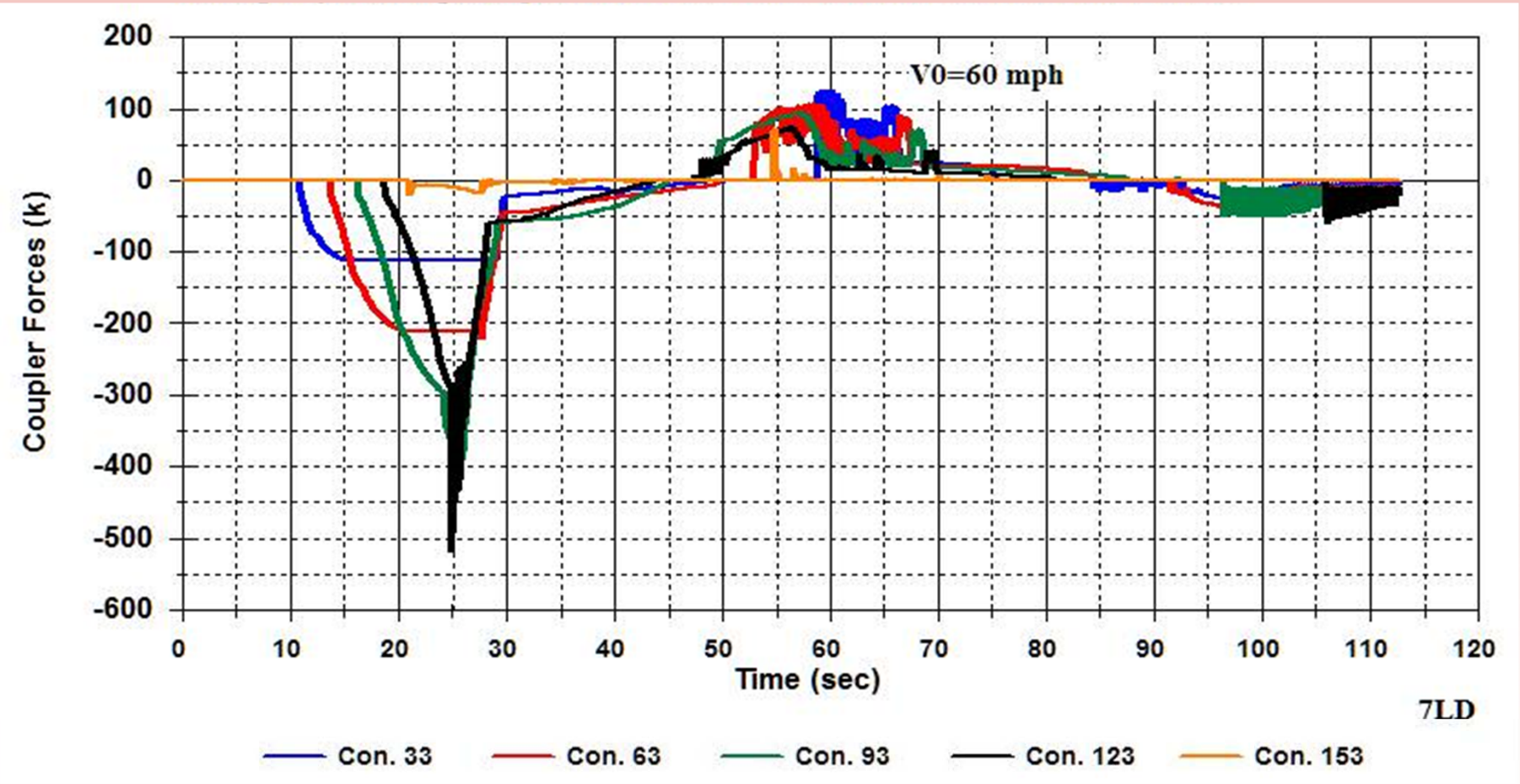
Train Start-Up Simulation



Dynamic Brake Simulation



Emergency Brake Simulation



Real-Time Asset Monitoring

Problematic Location for Car Handling

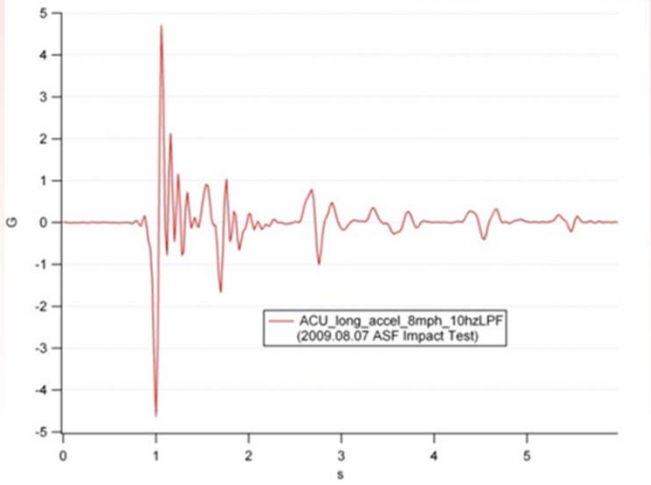
AmstedRail

- 16 events occurred in which there was 4g or greater on all three monitoring systems:

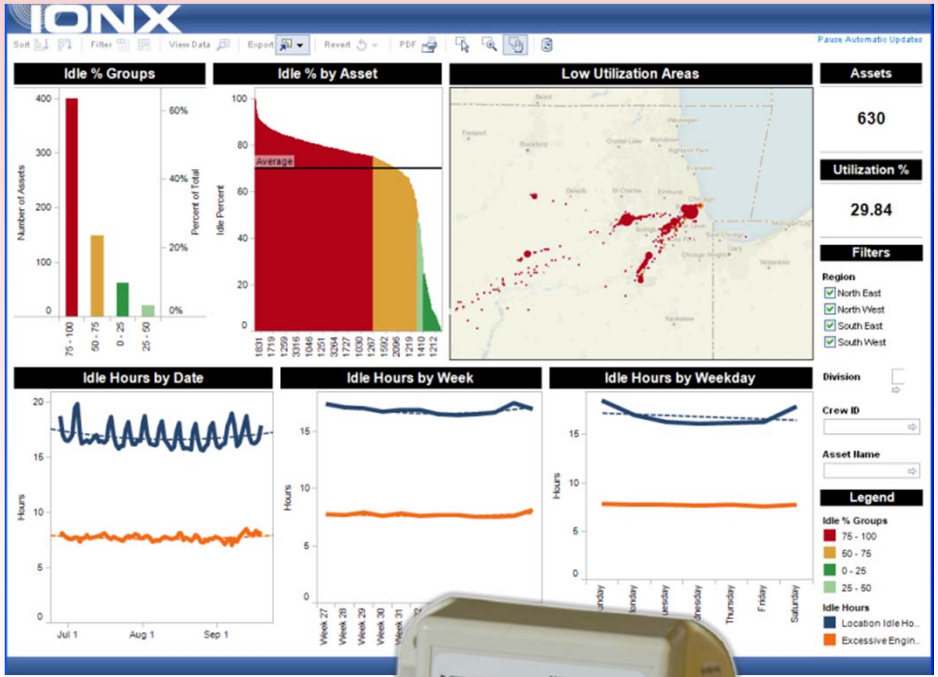
Event no.	Event Type	A-end (g)	Middle (g)	B-end (g)
1	Y	5.8	5.6	4.6
2	Y	4.1	4.9	6.0
3	Y	5.0	5.0	6.5
4	Y	4.8	4.5	6.6
5	Y	4.1	4.1	6.2
6	OTT	4.5	5.5	6.4
7	OTT	6.2	6.1	6.5
8	OTT	4.4	5.3	6.6
9	OTT	7.3	7.3	7.5
10	OTT	7.1	7.6	8.2
11	Y	4.1	5.4	4.9
12	Y	5.0	5.5	4.2
13	Y	5.6	4.8	4.0
14	Y	4.4	5.4	4.4
15	Y	5.4	6.1	4.5
16	Y	7.2	7.3	9.5

All within 7 minutes at the same yard

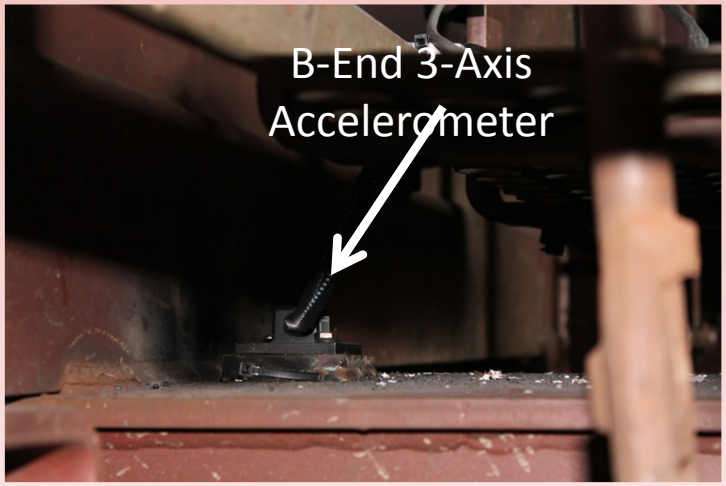
3 weeks later at the same yard

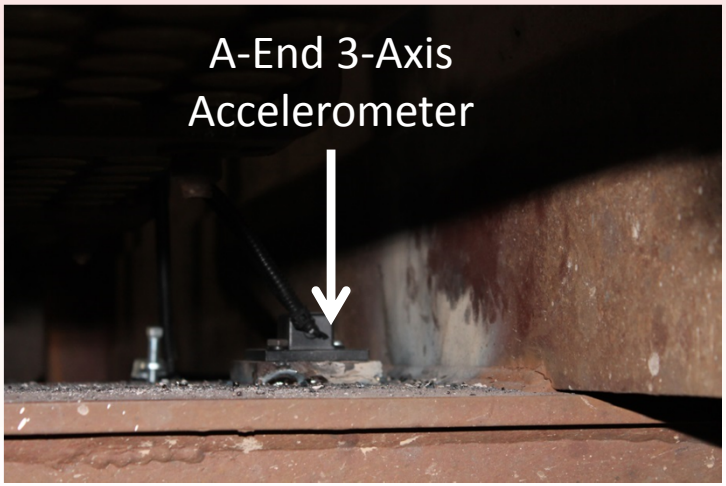


IONX



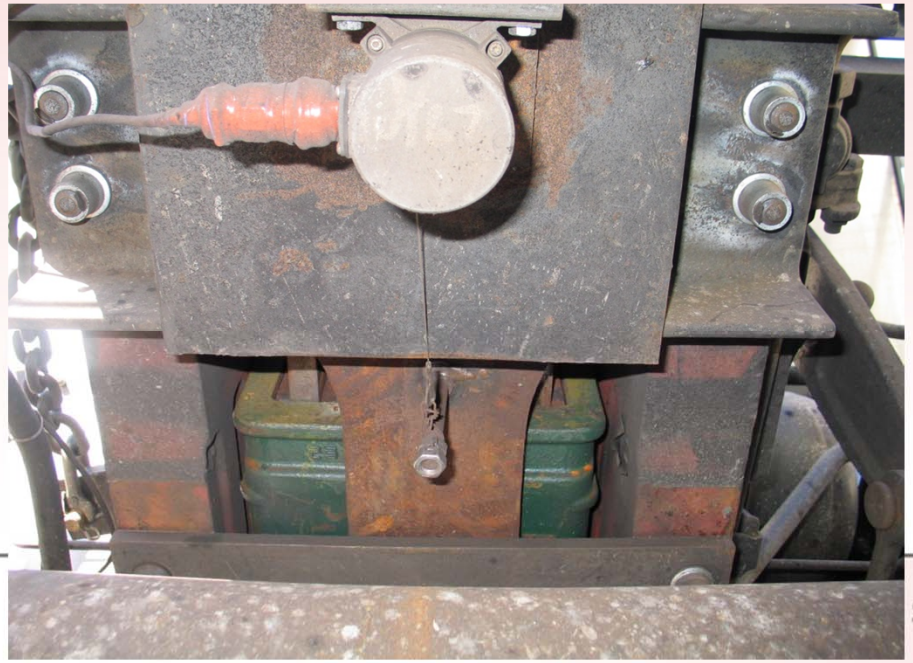
Over-the-Road Testing



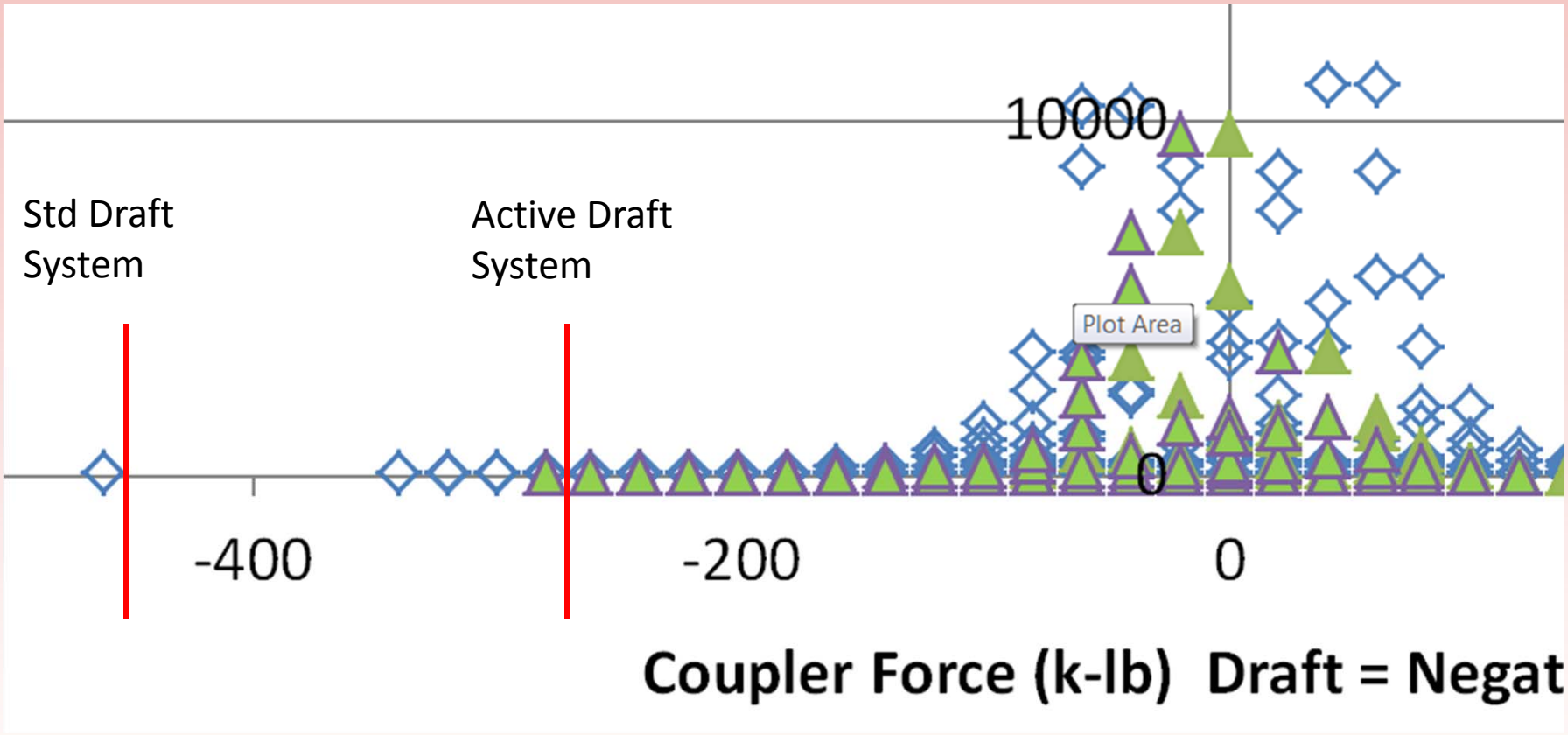


What is a *Day in the Life…*

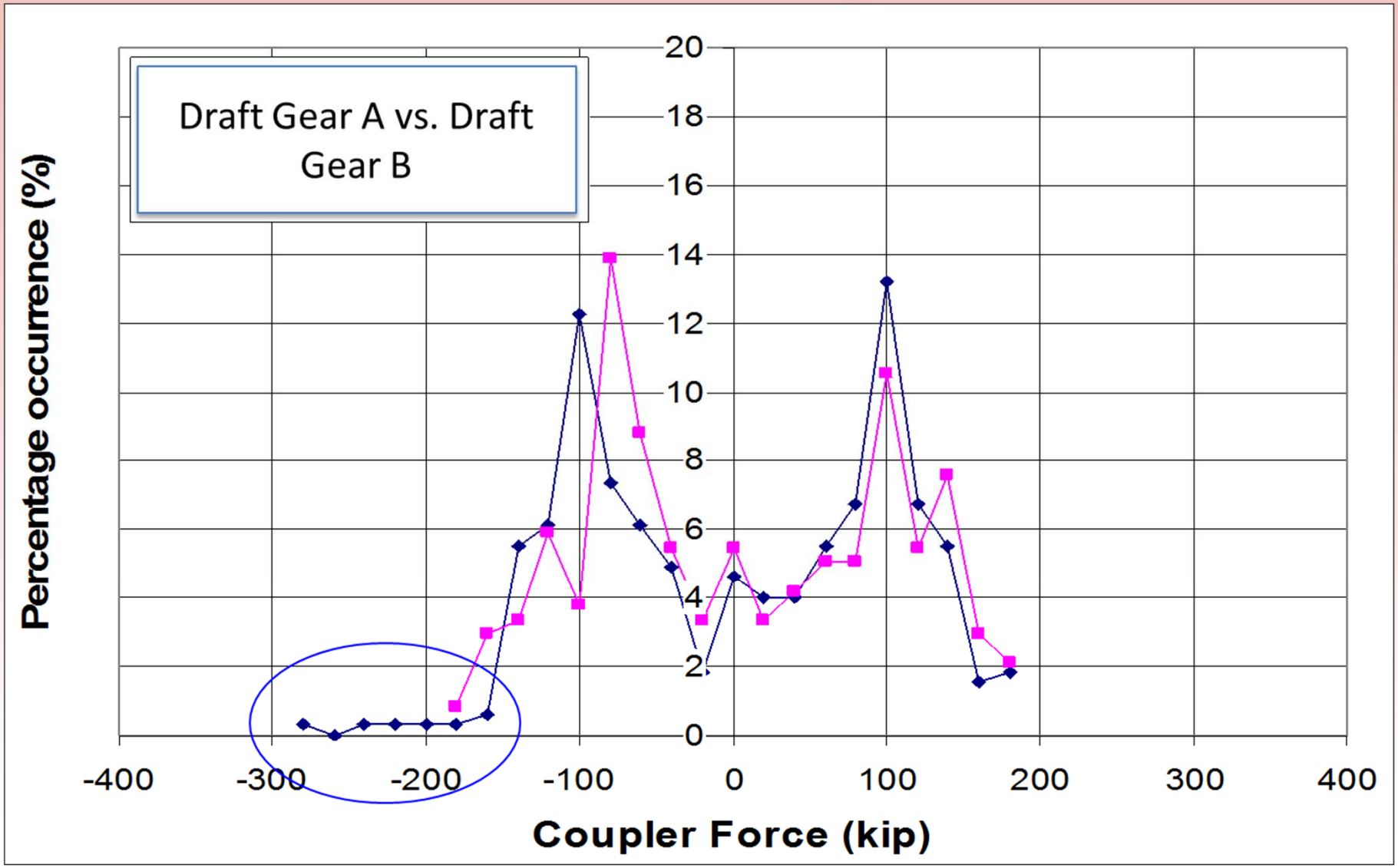

FEPX 61443
DO NOT HUM



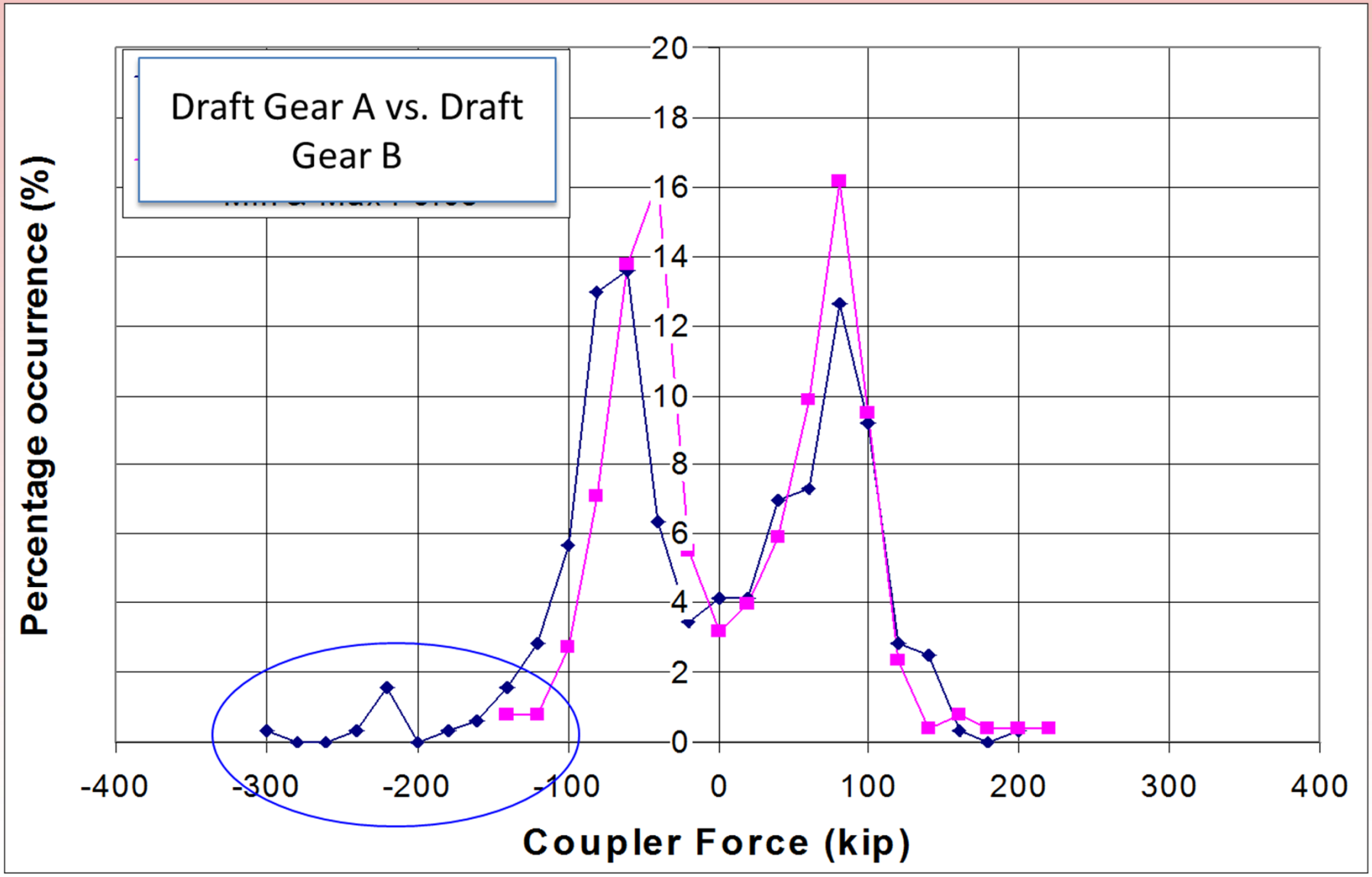
Over-the-Road Testing



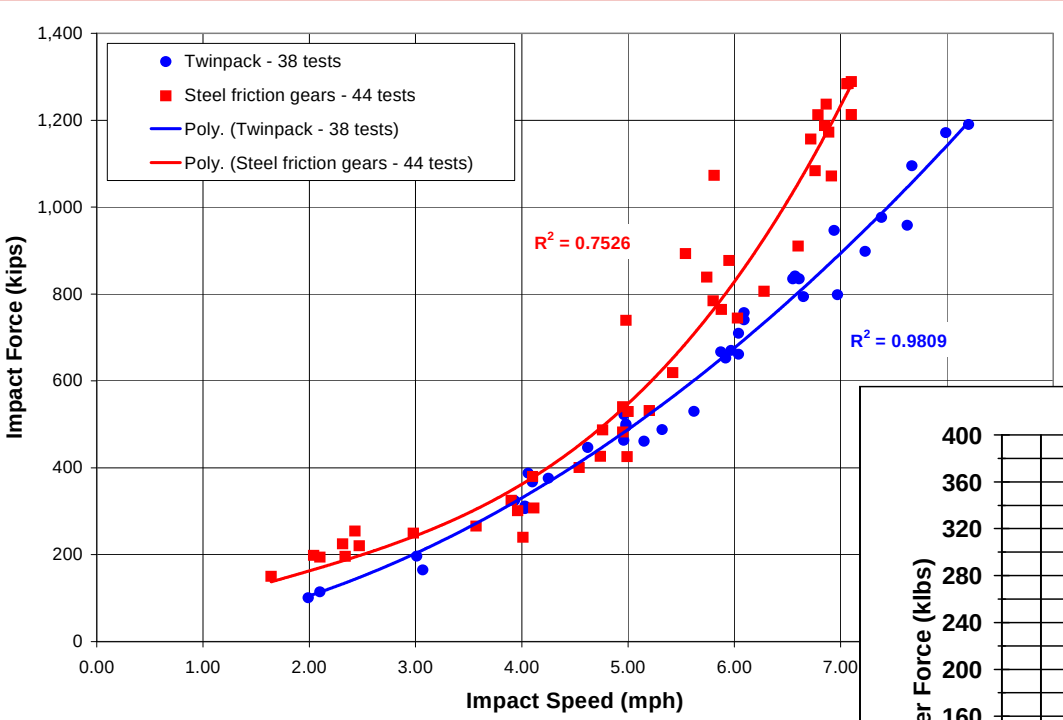
Car60 – Histogram



Car90 - Histogram



Goal- Equipment Solutions to Reduce Damage



Lower Coupler Forces

Data used to improve A.A.R. specifications via. manufacturers committees (DGMEC, CUMEC)

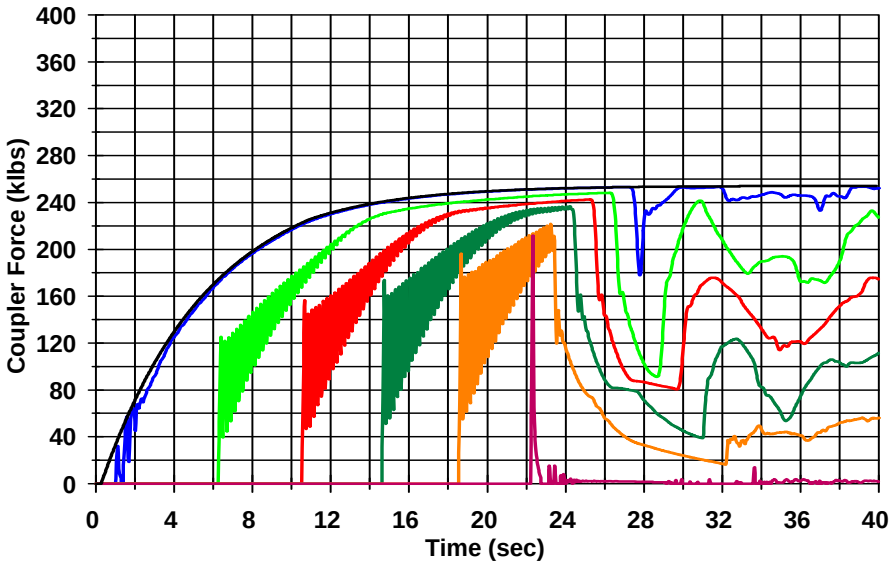


Fig. 4

Summary

- Computer simulation techniques are effective
  - Permit rapid evaluation of design iterations
  - Enhance selection of appropriate equipment

- Applied physics always permit direct comparisons
  - All parameters must be accounted for
  - Mathematical accuracy is imperative

- Actual values may slightly differ, but reflect the trends to make informed equipment design decisions

Summary

'One size fits all' may not always be appropriate.

- Unit train v. manifest train v. 'mini-unit train'
- Specific car performance expectations / requirements
- Autoracks, Container flats, ISO Tank Containers, Boxcars

Critical to working with RR's, Asset Owners, Shippers…

Understand 'energy inputs', lading, car body sensitivity and then recommend appropriate equipment.

Prevent High Forces vs. Managing High Forces

Thank You