Basic Rail Vehicle Suspension Parameters
Rail Vehicle Suspension Agenda

• 3 Primary Suspension Modes
  – Lateral, vertical, yaw/warp

• Freight Cars
  – Springs and friction dampers
  – Yaw mode and truck warp

• Passenger/Transit Cars
  – Springs and dampers
  – Lateral suspensions

• Locomotives
Primary Role of Suspension

• 1. Absorb vertical and lateral road shocks from perturbations in the track. Springs are used to slow down the accelerations over time, and store the energy.

• 2. Dissipate the energy stored in the springs to prevent it from amplifying the motions of the road shocks and returning the energy back to the car. Dampers are used to dissipate the energy.
Energy Storage in a Spring

Energy forms:

(a) Kinetic energy: \( E = \frac{1}{2} m v_i^2 \)

(b) Total energy: \( E = \frac{1}{2} m v^2 + \frac{1}{2} k x^2 \)

(c) Potential energy: \( E = \frac{1}{2} k x_m^2 \)

(d) Kinetic energy (opposite direction): \( E = \frac{1}{2} m v_i^2 \)
Typical Motion Response of an Undamped Spring

Displacement

Velocity

Acceleration
Motion Response of a Damped Spring
Vehicle Suspension Elements - 3 Principal Modes

- Vertical Suspension
- Lateral Suspension
- Yaw/Warp Suspension
Vertical Suspension

• Freight Cars
  – Secondary suspension springs between truck frame and bolster
  – Friction snubbers between frame and bolster
  – No Primary suspension

• Passenger/Transit Cars
  – Primary suspension between wheelset and frame
  – Secondary suspension between frame and bolster, or frame and body

• Locomotives
  – Primary and secondary elements
Major Bodies
Freight Cars

- Truck Frame
- Truck Bolster
- Secondary Suspension Damper
- Secondary Suspension Springs
- No Primary Suspension
Spring: An Energy Storage Device
Damper: Dissipates Energy
Springs and Dampers Working in Parallel
Major Bodies
Passenger Vehicles

- Car Body
- Secondary suspension supports carbody
- Bolster - swivels on truck
- Truck frame - holds wheels in place
- Primary suspension - lets wheel sets move up/down in frame
Major Bodies
Passenger Vehicles

Bolster

Secondary suspension supports carbody

Truck frame - holds wheels in place

Primary suspension - lets wheel sets move up/down in frame

Car Body
The Standard 3-Piece Truck:
A long history of design improvements
Bolster and Sideframe Interface Area
Nominal Wedge Position above top of Bolster
Wear occurs on these 4 surfaces
Wedge rise above top of bolster due to wear
AAR Rule 46 (2007)

• Developed to address both friction casting front face wear, and total friction casting rise above top of bolster. Rules applicable when:
  – At any time of inspection
  – When car is on repair track
• Rule 46 also addresses gib wear, centerbowl clearance, and column plate wear
Common Friction Casting (Wedge) Designs

RIDE CONTROL

BARBER S-2
Worn Out Friction Castings (Wedges)
Ride Control Design

AAR Rule 46 - Truck System Performance
   A. Wear Limits, Gaging, Cause for Renewal
      2. Condemnable When Car is on Repair Track for Any Reason

FIGURE A-1
RIDE CONTROL AND SUPER SERVICE RIDE CONTROL TRUCK

> 1 13/16” (~1 3/4”) Condemnable Per Rule 46
Barber Design

AAR Rule 46 - Truck System Performance
A. Wear Limits, Gaging, Cause for Renewal
2. Condemnable When Car is on Repair Track for Any Reason

> ¾” Generally Condemnable Per Rule 46 (Check Rule for exceptions!)
## Barber Variable Damped Trucks - Allowable Wedge Rise AAR Rule 46

### Stabilizer Wear Gage Table

<table>
<thead>
<tr>
<th>Gage No.</th>
<th>Bearing Size</th>
<th>AAR Spring Travel</th>
<th>Iron Wedge</th>
<th>Split Wedge</th>
<th>Life Guard Wedge</th>
<th>Twin Guard Wedge</th>
<th>Dim A</th>
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<tr>
<td>SK-1546-1</td>
<td>6 x 11</td>
<td>D-3</td>
<td>609-D</td>
<td>955-SW</td>
<td>913-LG</td>
<td>-</td>
<td>3/4</td>
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<tr>
<td></td>
<td>6 x 11</td>
<td>D-4 or D-5</td>
<td>678-C</td>
<td>678-B</td>
<td>787-C</td>
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<td>925-SW</td>
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<td>955-SW</td>
<td>913-LG</td>
<td>-</td>
<td>3/4</td>
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<tr>
<td></td>
<td>6 1/2 x 12</td>
<td>D-5</td>
<td>876</td>
<td>834-CB</td>
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<td>905-SW</td>
<td>915-SW</td>
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<td>877-LG</td>
<td>921-PC</td>
<td>921-PC</td>
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<td>SK-1546-2</td>
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<td>D-4 or D-5</td>
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<td>762-C</td>
<td>-</td>
<td>-</td>
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</table>

Be Careful!!
787-C Wedge
½” Wedge Rise
Barber Gage

Ride Control Gage
Springs

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PRINCIPLES COURSE • JUNE 6, 2017
Count Springs; Verify Type; Verify Inner and Outer Springs; Check Free Height
**Spring Groupings II**

<table>
<thead>
<tr>
<th>SINGLE SIDE SPRINGS</th>
<th>5&quot; X 9&quot; JOURNALS</th>
<th>5-1/2&quot; X 10&quot; JOURNALS</th>
<th>6&quot; X 11&quot; JOURNALS</th>
<th>6-1/2&quot; X 12&quot; JOURNALS</th>
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<td>2-1/4&quot;</td>
<td>2-1/4&quot;</td>
<td>2-1/4&quot;</td>
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<tr>
<td>FREE HEIGHT</td>
<td>2-3/16&quot;</td>
<td>2-3/16&quot;</td>
<td>2-3/16&quot;</td>
<td>2-3/16&quot;</td>
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<tr>
<td>SOLID HEIGHT</td>
<td>6-7/16&quot;</td>
<td>6-7/16&quot;</td>
<td>6-7/16&quot;</td>
<td>6-7/16&quot;</td>
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<td>WEIGHT PER CAR SET</td>
<td>4 GROUPS (LBS.)</td>
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<td></td>
<td></td>
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<tr>
<td>5 OUTERS (LBS.)</td>
<td>402</td>
<td>431</td>
<td>452</td>
<td>402</td>
</tr>
<tr>
<td>2-1/2 OUTERS (LBS.)</td>
<td>570.66</td>
<td>548.25</td>
<td>551.90</td>
<td>973.66</td>
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<tr>
<td>SOLID CAPACITY (LBS.)</td>
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<td>68257</td>
<td>67822</td>
<td>97209</td>
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<td>6 OUTERS (LBS.)</td>
<td>487</td>
<td>555</td>
<td>545</td>
<td>402</td>
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<tr>
<td>2-1/2 OUTERS (LBS.)</td>
<td>570.66</td>
<td>548.25</td>
<td>551.90</td>
<td>973.66</td>
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<tr>
<td>SOLID CAPACITY (LBS.)</td>
<td>67787</td>
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<td>67822</td>
<td>97209</td>
</tr>
<tr>
<td>6-1/2 OUTERS (LBS.)</td>
<td>402</td>
<td>431</td>
<td>452</td>
<td>973.66</td>
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<tr>
<td>SOLID CAPACITY (LBS.)</td>
<td>97209</td>
<td>96572</td>
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</table>

**AAR Designated Spring Groups**
<table>
<thead>
<tr>
<th>Part No.</th>
<th>Bar Dia.</th>
<th>Outer Dia.</th>
<th>Solid Height</th>
<th>Free Height</th>
<th>Solid Capacity</th>
<th>Scrap Height</th>
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<tbody>
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<td>D2-Outer</td>
<td>1 7/32</td>
<td>5 1/2</td>
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<td>8 1/4</td>
<td>15,959</td>
<td>7 15/16</td>
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<td>D2-Inner</td>
<td>11/16</td>
<td>2 15/16</td>
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<td>8 1/4</td>
<td>5,386</td>
<td>7 15/16</td>
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<td>D3-Outer</td>
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<td>6 9/16</td>
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<td>10,721</td>
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<td>D3-Inner</td>
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<td>6 9/16</td>
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<td>4,299</td>
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<td>D4-Outer</td>
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<td>D5-Inner</td>
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<td>6 9/16</td>
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<td>D6-Inner</td>
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<td>6 9/16</td>
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<td>2</td>
<td>5 11/16</td>
<td>9</td>
<td>1,536</td>
<td>8 3/8</td>
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<td>D7-Outer</td>
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<td>5 1/2</td>
<td>6 9/16</td>
<td>10 13/16</td>
<td>8,642</td>
<td>10</td>
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<tr>
<td>D7-Inner</td>
<td>5/8</td>
<td>3 1/2</td>
<td>6 9/16</td>
<td>10 3/4</td>
<td>4,108</td>
<td>10</td>
</tr>
</tbody>
</table>
Left Side; Missing corner inner coils

Right Side
Spring showing sign of fatigue/set
Checking Free Height
Broken Spring
Solid Spring – Indicates Excessive Rock/Roll
General Passenger Truck Components

- Truck Frame
- Pedestal
- Bolster
- Side Bearings
- Spring Plank
- Swing Hanger
- Swing Hanger Bushings
- Equalizer
- Tie Rod

Primary Suspension
Secondary Suspension
LOAD PATH

Secondary Suspension

Truck Bolster

Frame

Primary Suspension

Equalizer

Spring Plank

Basic GSI 70 Suspension
Equalizer Springs
Primary Suspension

Equalizer Bar

Truck Frame
Air Spring Secondary Suspension Between Bolster and Car Body
Amfleet Passenger Car Trucks

Primary suspension at each journal

Shock Ring
Light Rail Vehicle Suspension

- Air Spring
- Secondary Suspension Between Bolster and Frame
- Note: vertical damper

Primary suspension at each journal
Amtrak Superliner Car

Wagon Union Truck
Amtrak Superliner Car

Primary Suspension
Amtrak Superliner Car

Secondary Suspension
Locomotive Suspensions
Primary Suspension
Genesis Trucks
Dampers

- Mostly hydraulic or friction style used on passenger cars
- Used to absorb lateral and vertical shocks from track
- Dissipates Energy from spring suspension
- Restores ride quality
Hydraulic Dampers - Construction

FIG. 4. CROSS SECTION VIEW OF HYDRAULIC SNUBBER (TYPICAL). E-33517.

Courtesy Koni Company

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WOLF Railway Consulting

WRI 2017
Typical Transit Car Vertical Suspension Showing Hydraulic Damper in Parallel with Air Spring
Friction Dampers

Courtesy Vibrtech Company
Dampers - Inspection Items

- **Worn Bushings**: Will make shock absorbers noisy and reduce their effectiveness.
- **Body Damage**: Large dents in the shock absorber will cause the unit to deteriorate.
- **Loose Dust Shield**: Will cause noise and may further damage the unit.
- **Leaking Fluid**: Will make shock absorber lose effectiveness.
Lateral Suspension
Lateral Suspension

• 3-Piece trucks have relatively poor lateral suspension characteristics, relying primarily on shear stiffness of load springs and friction damping due to wedge motion

• Passenger/locomotive trucks have improved lateral suspension relying on both swing motion of the bolsters, shear of the secondary springs, and bump stops. In addition, lateral shock dampers are used.
Bolster & Lateral Bump Stops

1” Nominal Bolster Stop to Body clearance; +1/4”, -0” tolerance

Lateral Bump Stops
Lateral Secondary Suspension Elements of Typical Transit Car Showing Damper and Air Spring.
Yaw/Warp Suspension

- Warp Stiffness Sideframe to Bolster
- Warp/Yaw Stiffness Wheelset to Sideframe
Yaw/Warp Suspension

Warp Stiffness Sideframe to Bolster
Yaw/Warp Suspension

Warp/Yaw Stiffness
Wheelset to Sideframe
Yaw/Warp Suspension

• Yaw/Warp Stiffness influences two primary responses
  – Hunting (high speed stability)
  – Truck Warp (Curving)
• Freight Cars depend on the friction wedge system for warp stiffness
• Passenger cars are normally rigid frame possessing high warp stiffness, but typically possess lower yaw stiffness
Truck Hunting
Lateral Instability

Wedges Help to Keep Truck Square

90 Degrees
Hunting Oscillation of a Tapered (Conical) Wheelset
Truck Hunting
Truck Stable Remains Square

Friction wedges provide squaring force

Truck Hunting Bolster Sideframe Out of Square

Friction wedges worn providing no squaring force
Hunting Speed Response

Hunting Severity

Critical Speed for Hunting Prone Cars
BH, ET, EF, EG

Lateral G’s

Critical Speed for Most Cars

Speed MPH

10 20 30 40 50 60 70 80
Truck Warp Restraint

Ideally, a truck should remain “Square” during curving to allow radial alignment of wheelsets with curve.
Nominally Curving Truck
Warped Truck
Barber Frame Brace Truck

Frame Bracing increases the warp stiffness of the truck improving both high speed stability and curving.
The End

Truck Suspension Basics