

Basic Rail Vehicle Suspension Parameters

Presented by:

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www.wolfrailway.com



Rail Vehicle Suspension

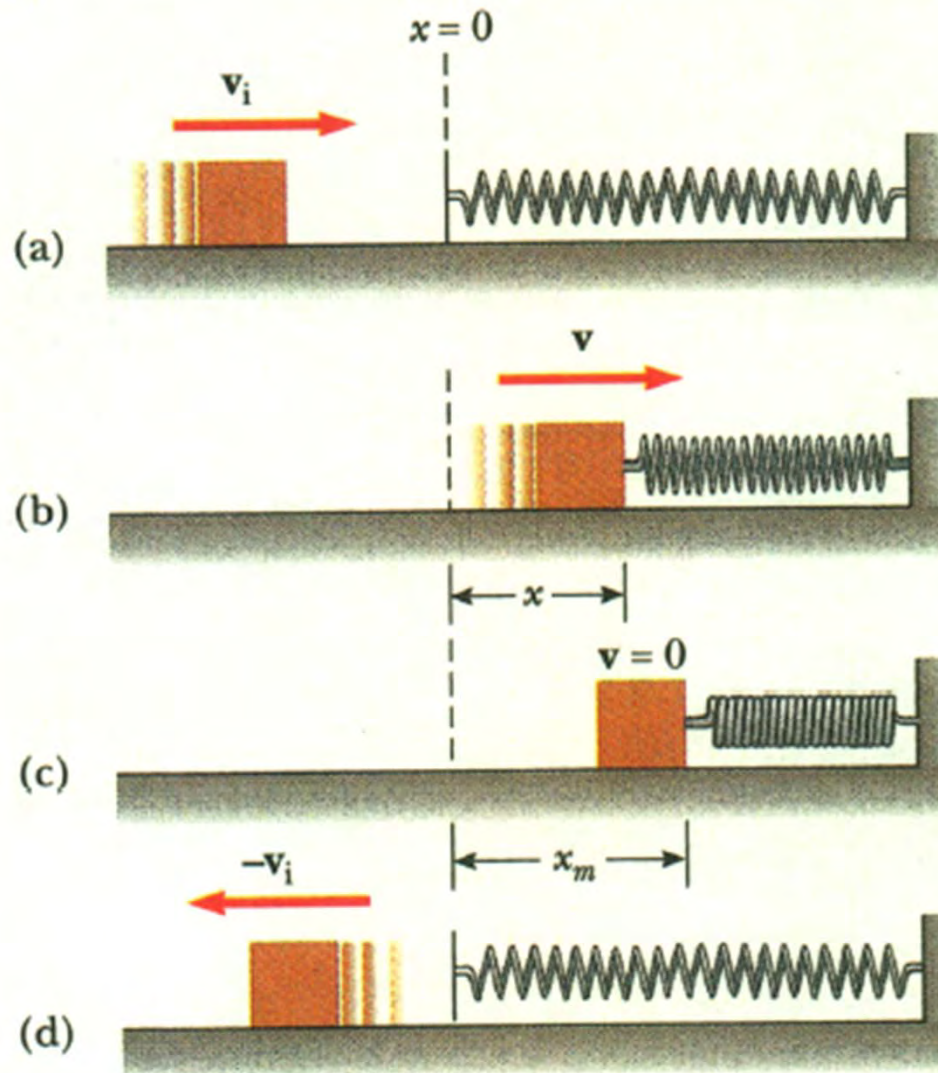
Agenda

- 3 primary suspension modes
- 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



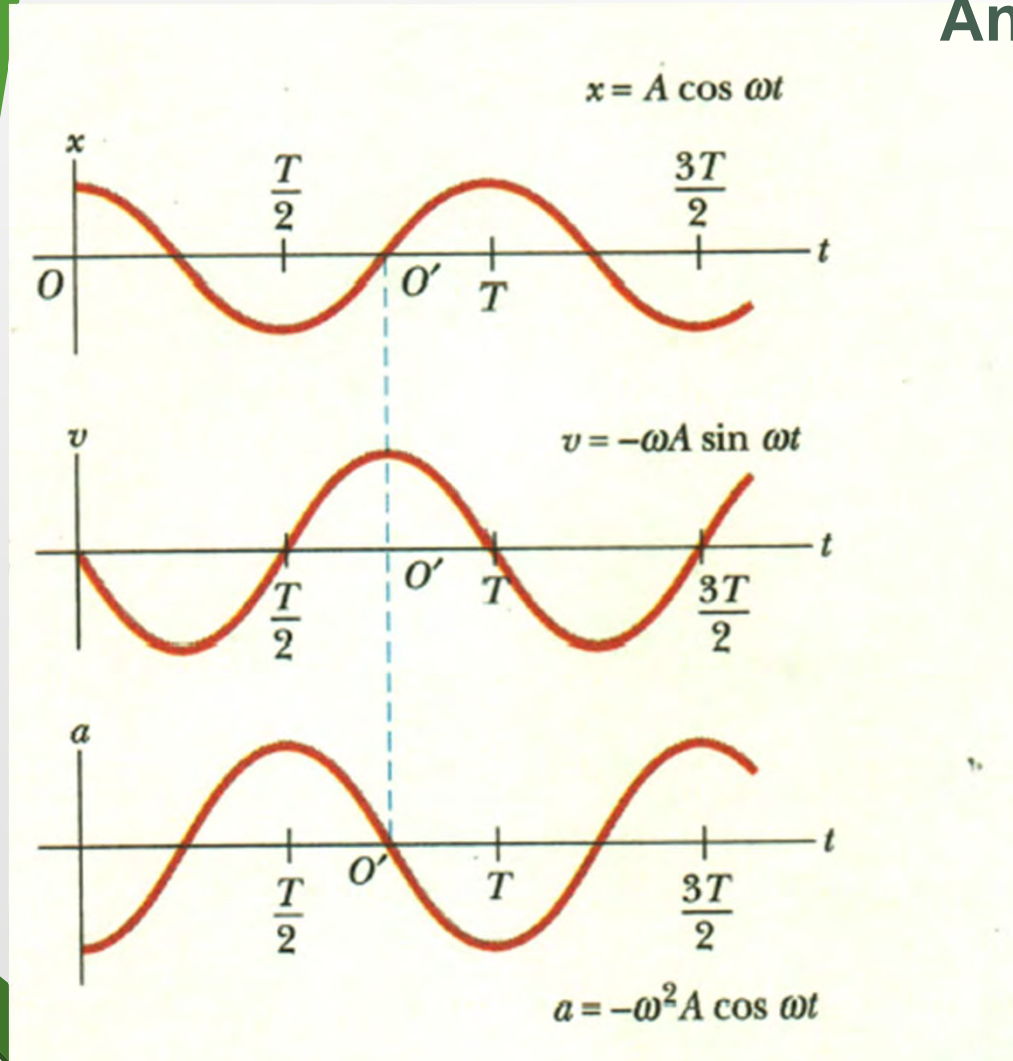
$$E = \frac{1}{2} m v_i^2$$

$$E = \frac{1}{2} m v^2 + \frac{1}{2} k x^2$$

$$E = \frac{1}{2} k x_m^2$$

$$E = \frac{1}{2} m v_i^2$$

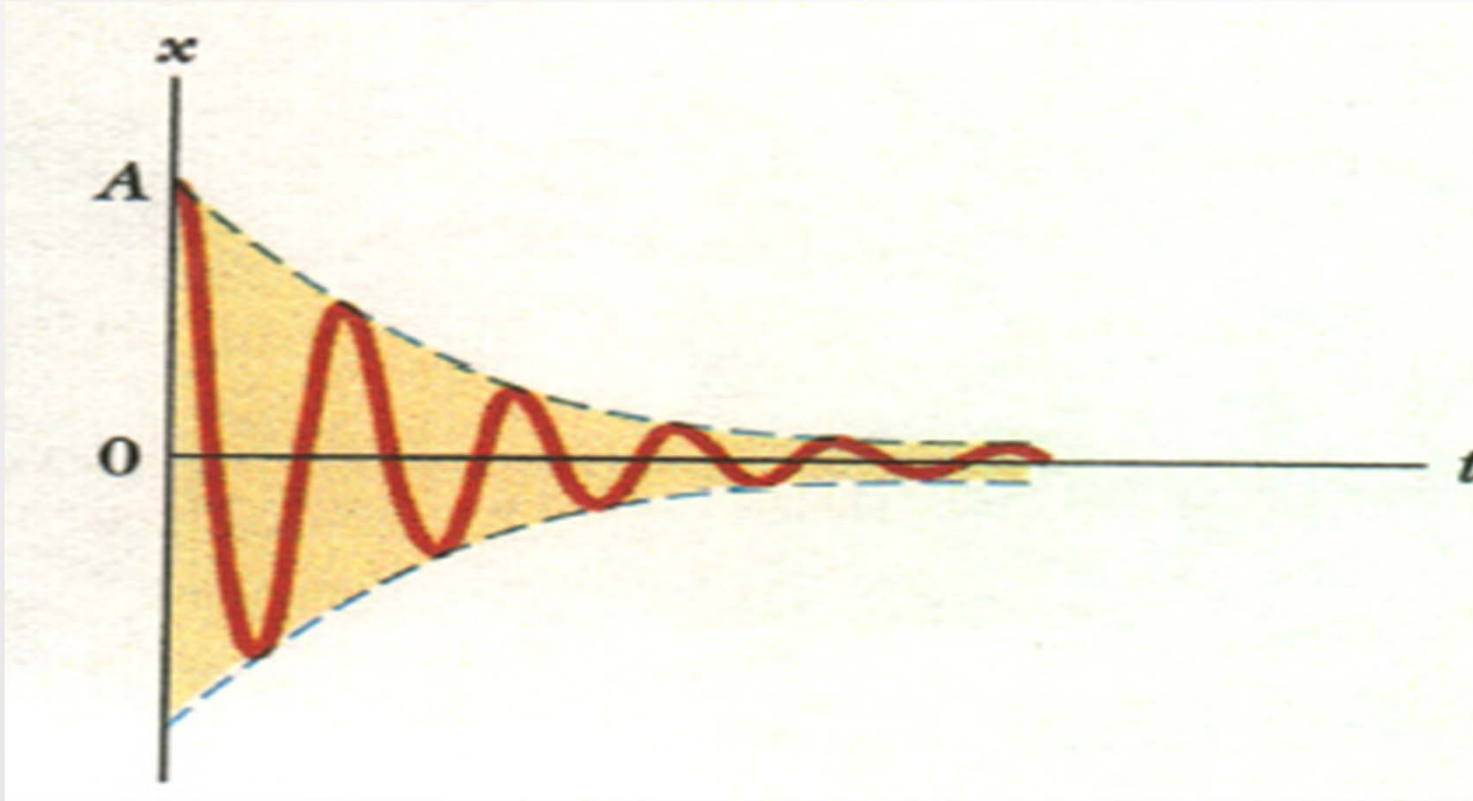
Typical Motion response of An undamped spring



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

Car Body

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

Carbody

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

Carbody

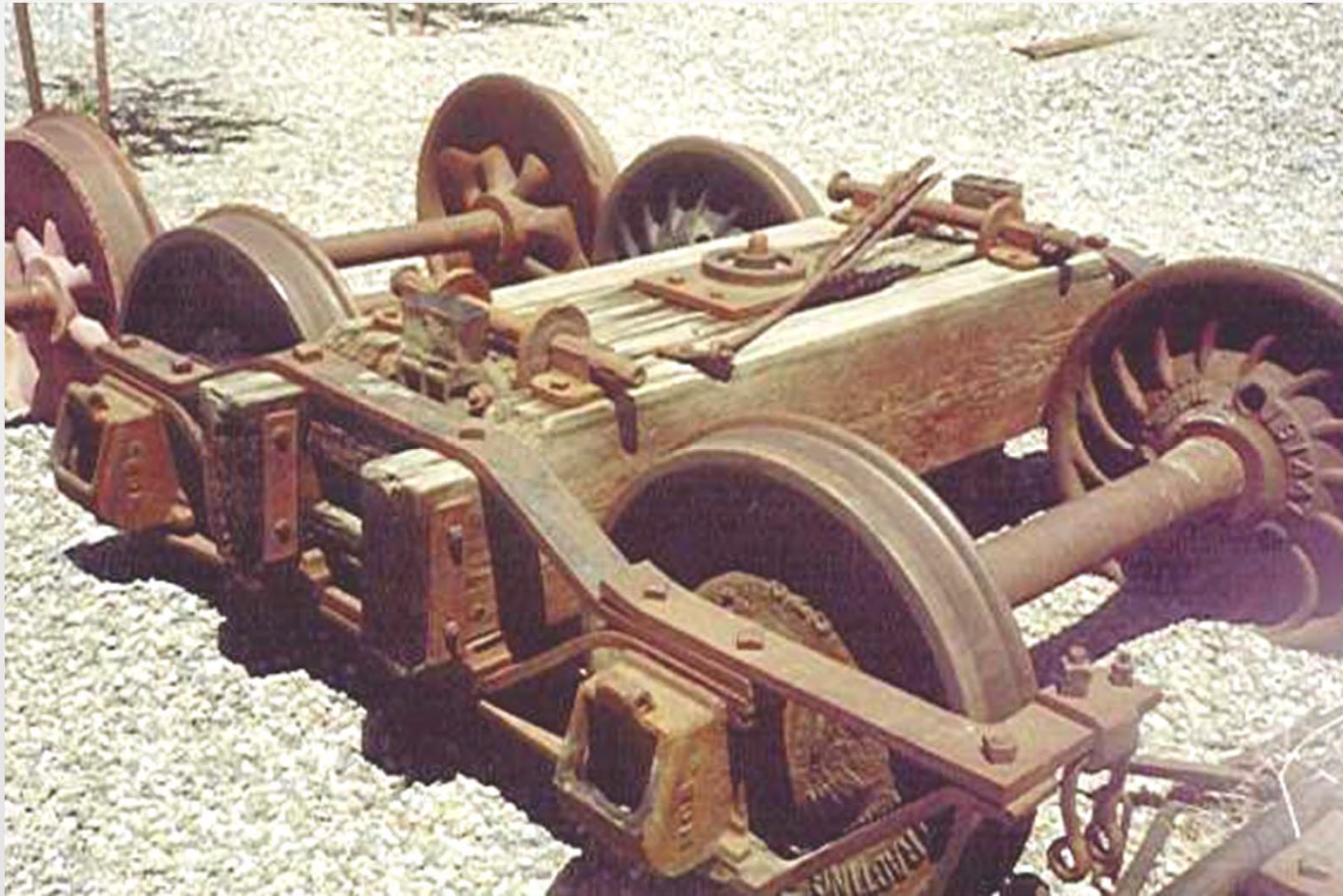
Bolster

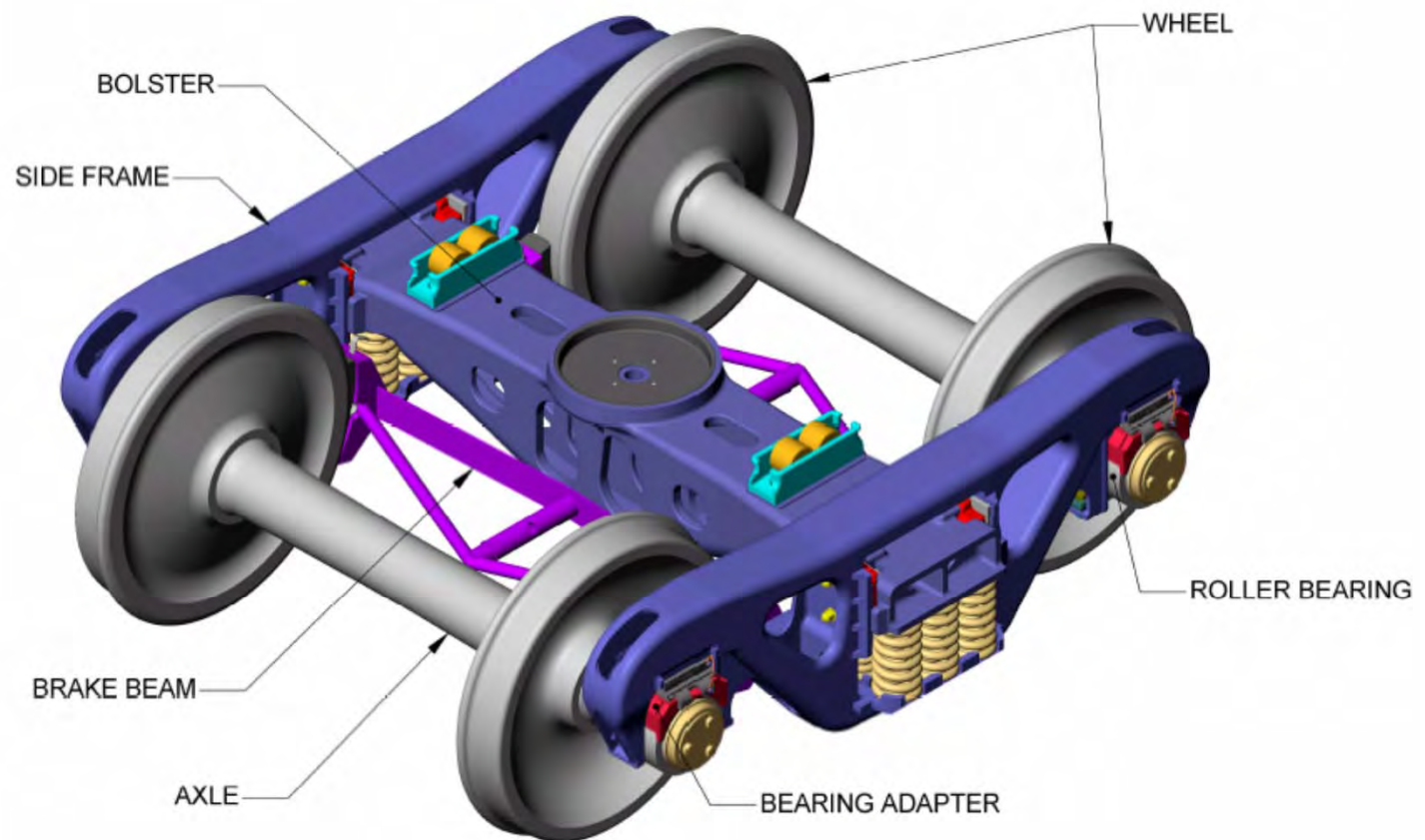
Secondary suspension supports carbody

Truck frame - holds wheels in place

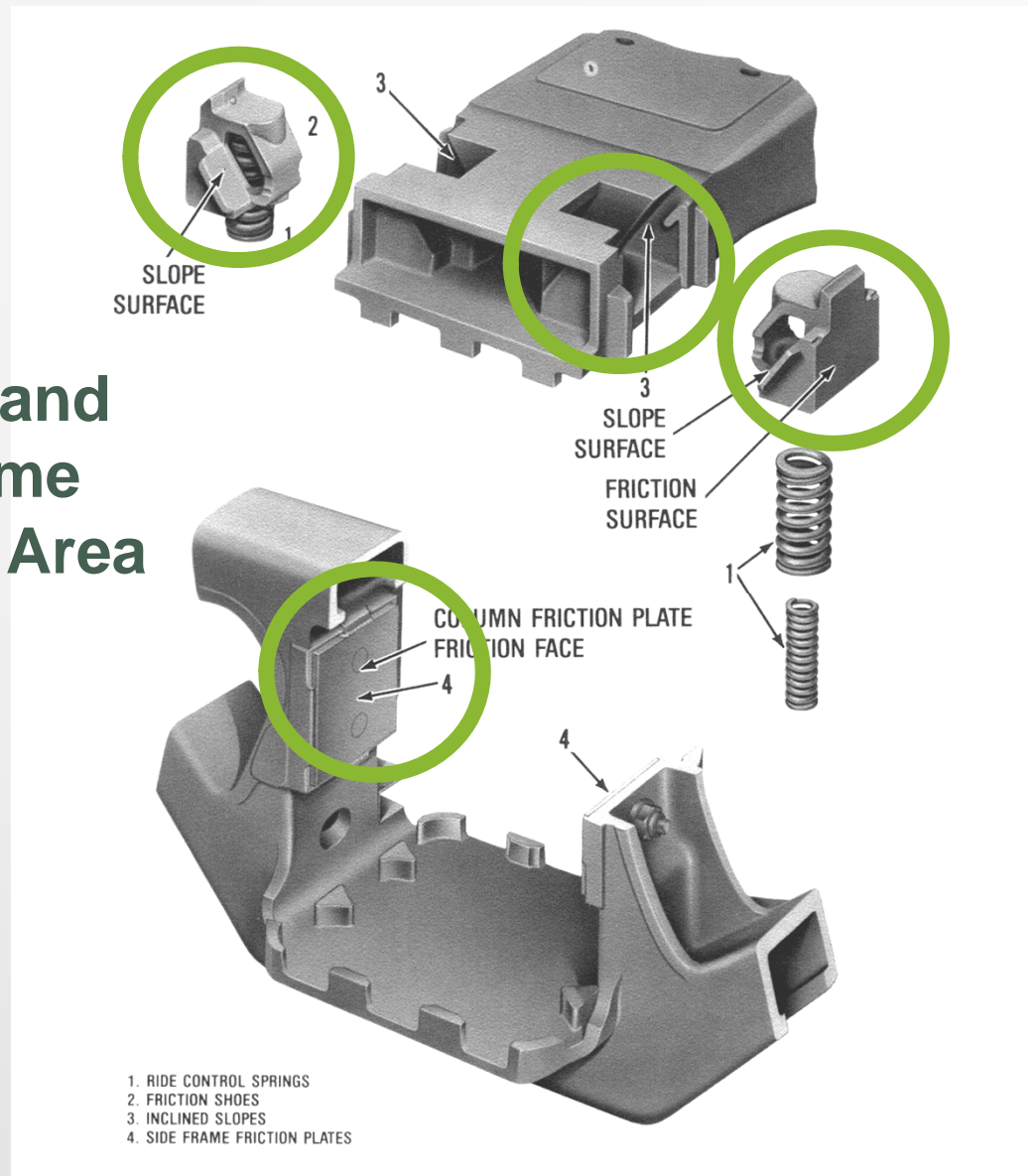
Primary suspension - lets wheel sets move up/down in frame

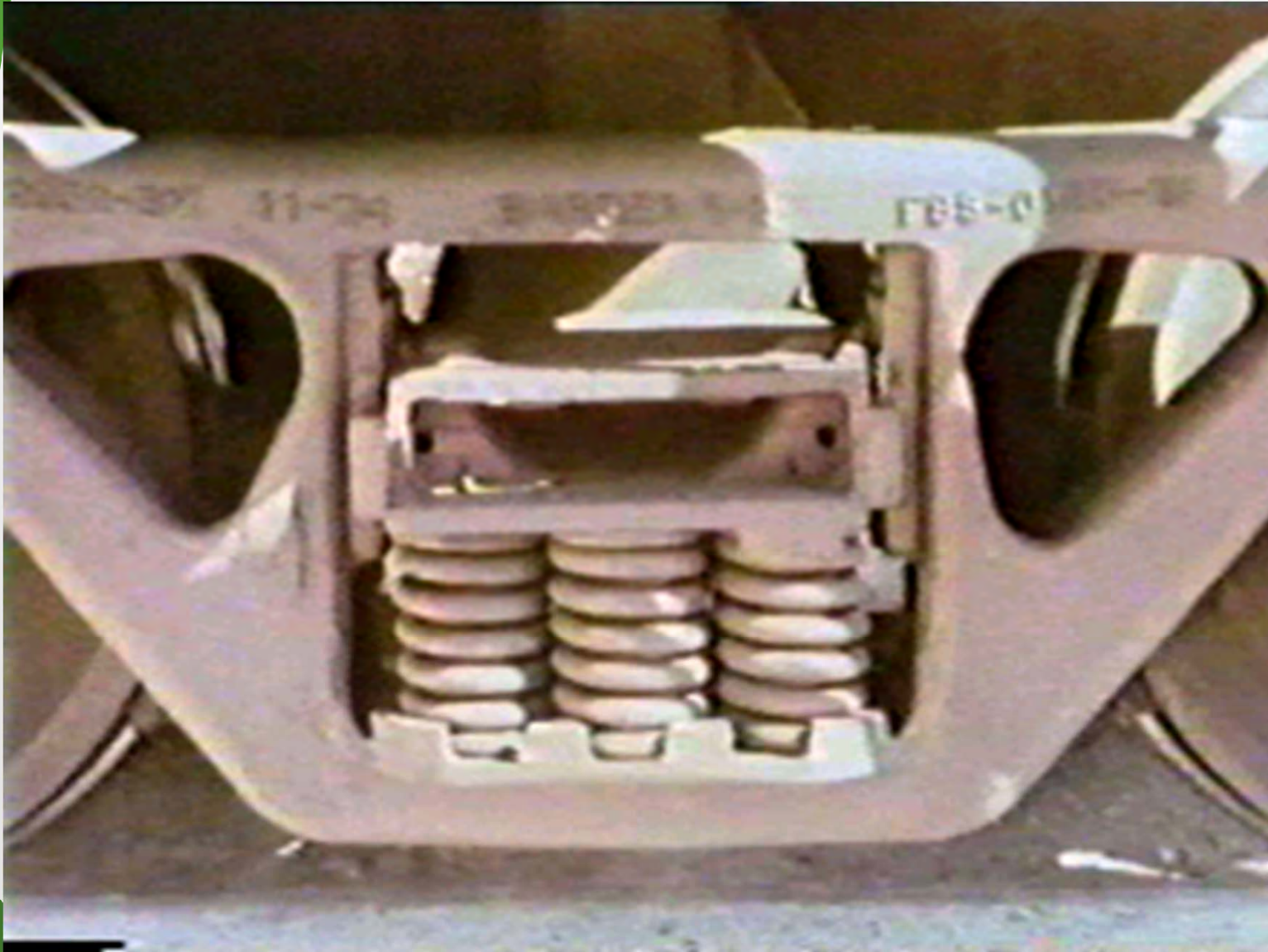
The Standard 3-Piece Truck: A long history of design improvements

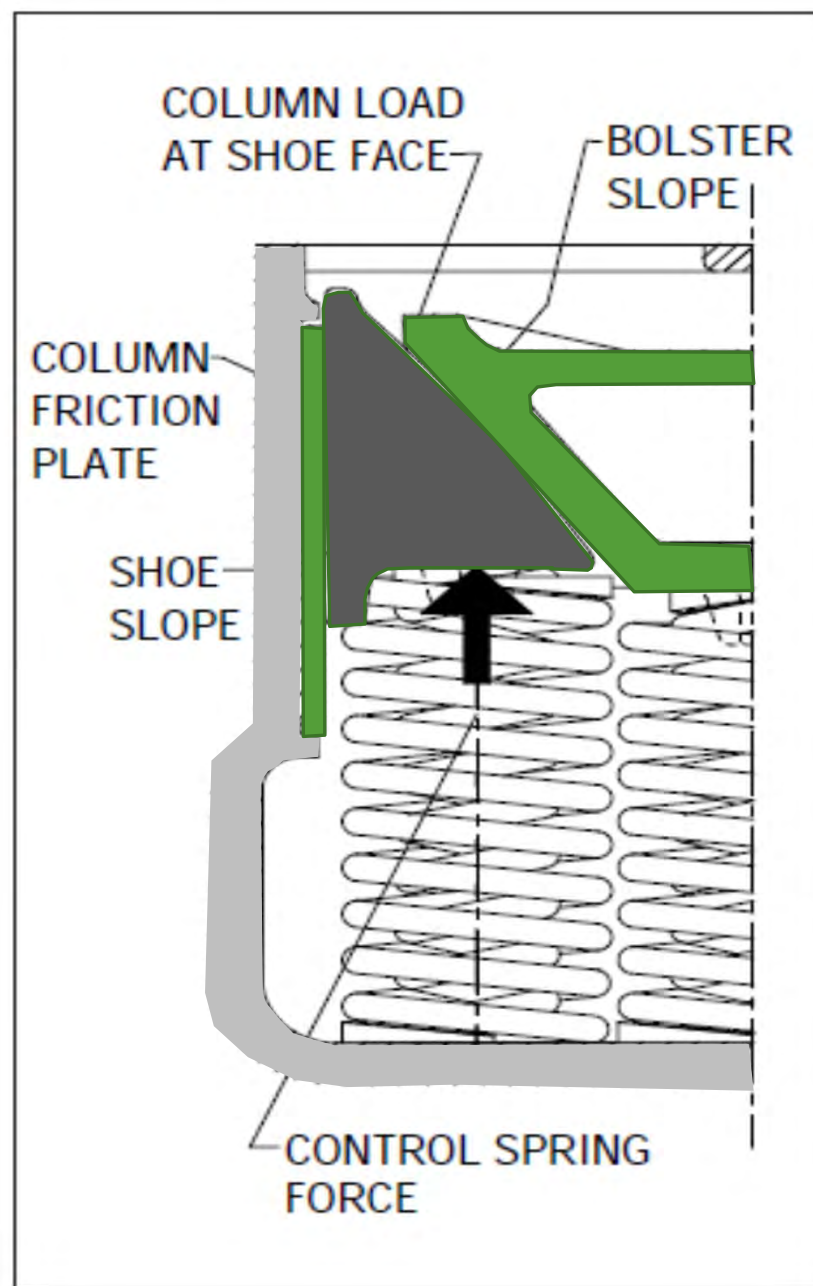




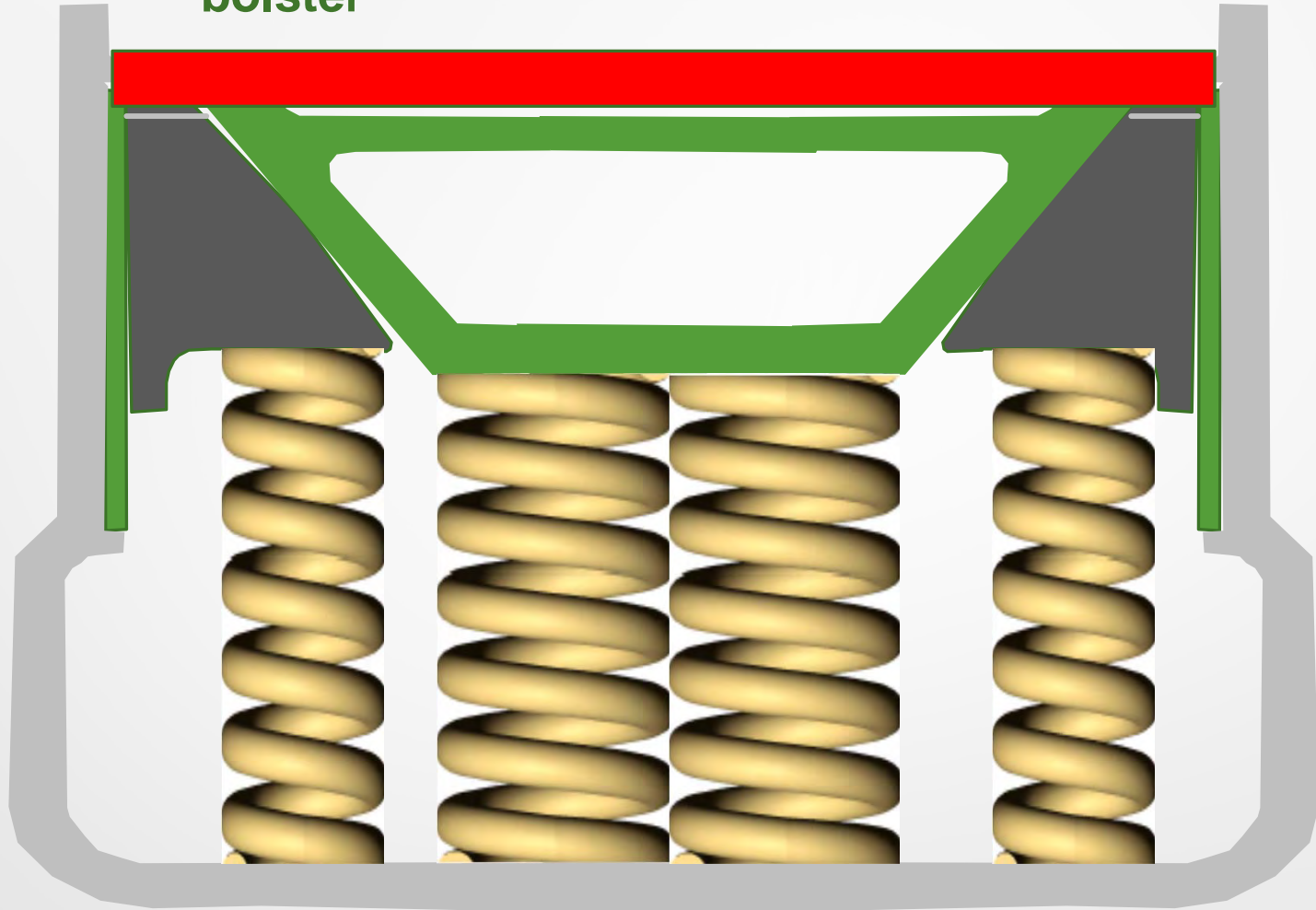
Bolster and Sideframe Interface Area

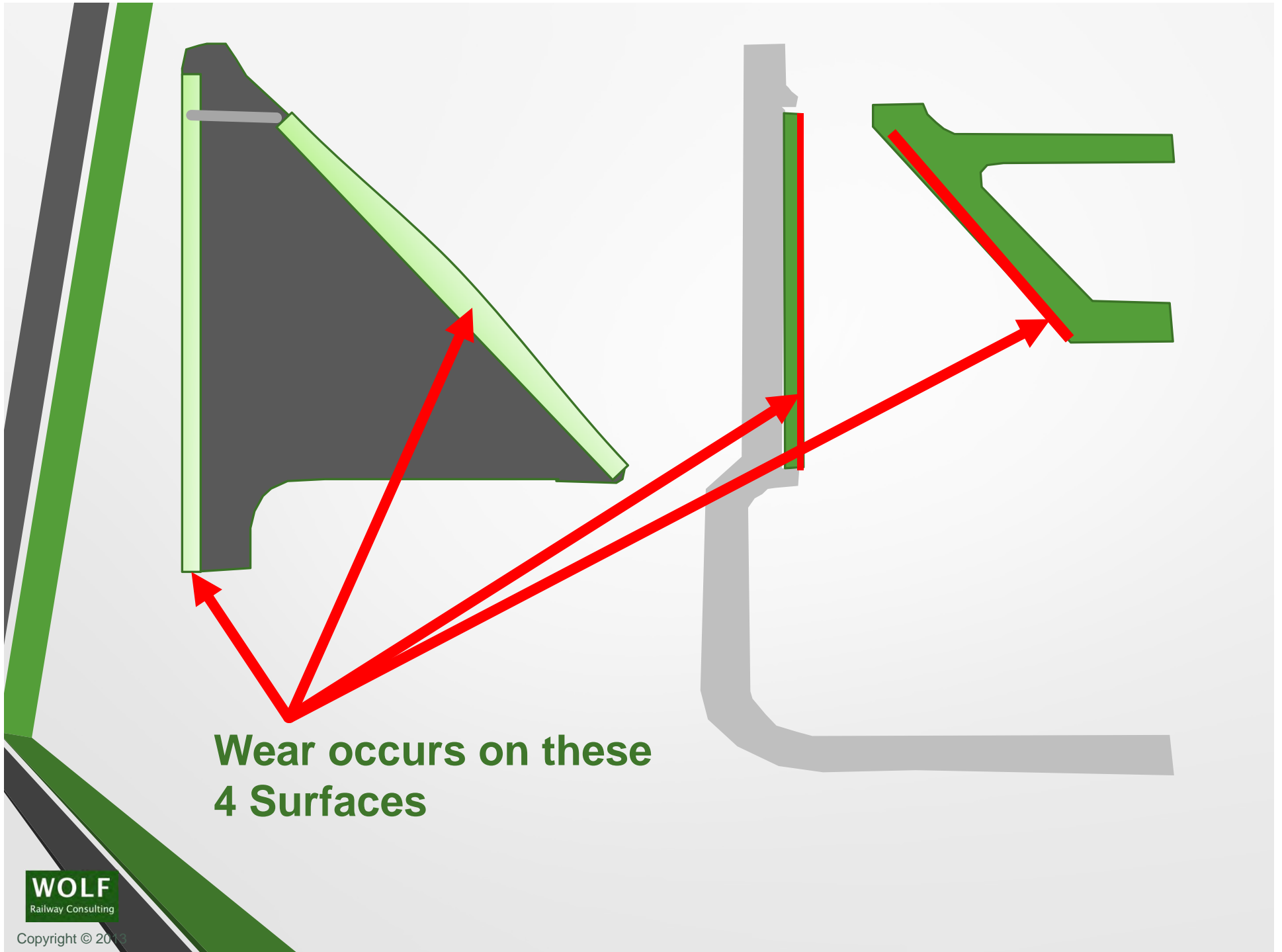




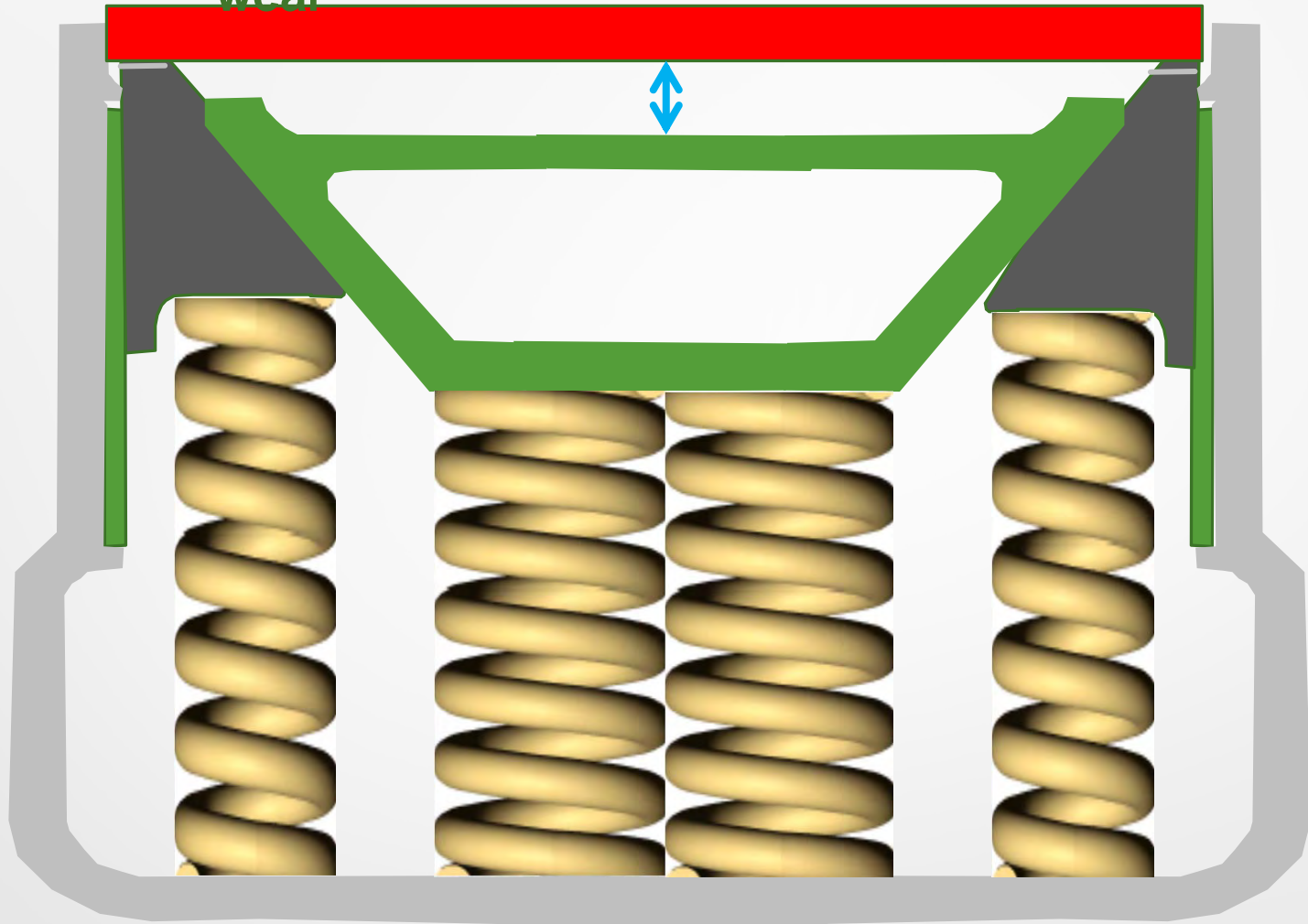


Nominal Wedge position above top of bolster





Wedge Rise above top of bolster due to wear



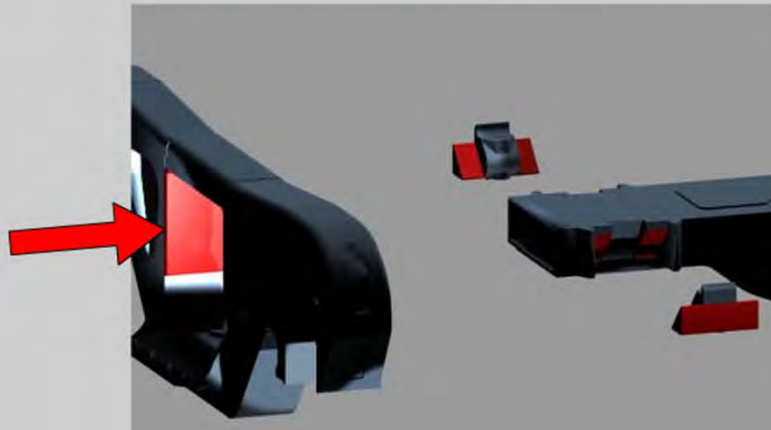
Damping System Wear - 3 Components

1) The **Bolster Pocket Slope Surface**



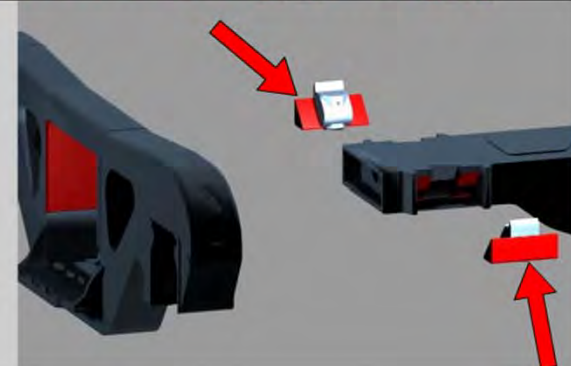
Damping System Wear - 3 Components

2) The **Column Wear Plate Surface**



Damping System Wear - 3 Components

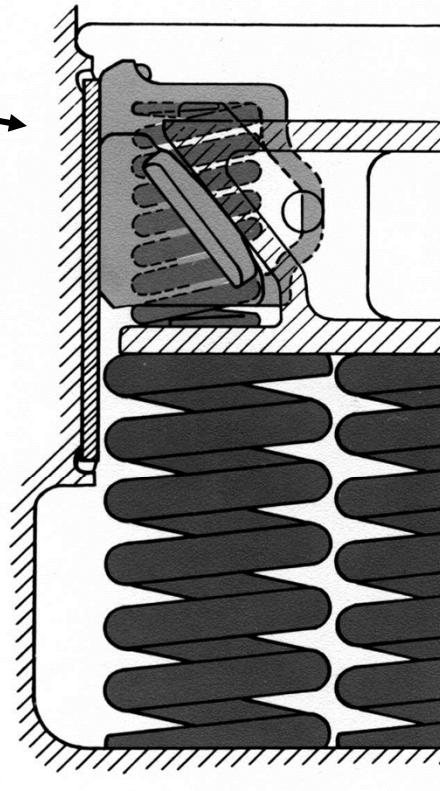
3) The Front and Back Surface of the **Friction Casting (Wedge)**



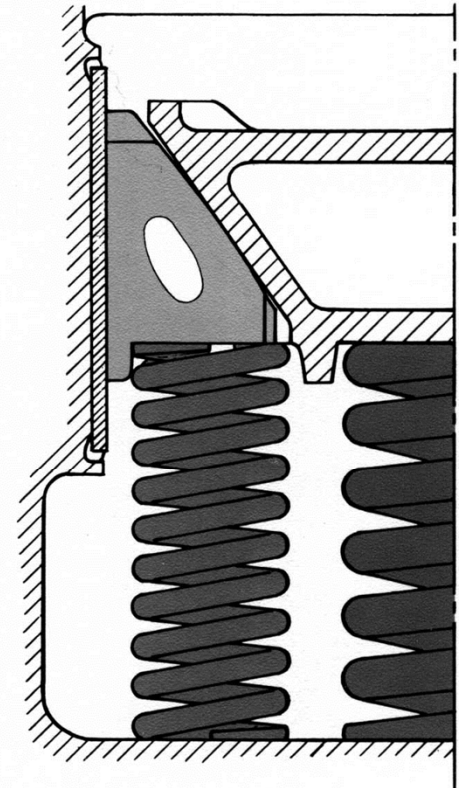
AAR Rule 46 (2007)

- 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

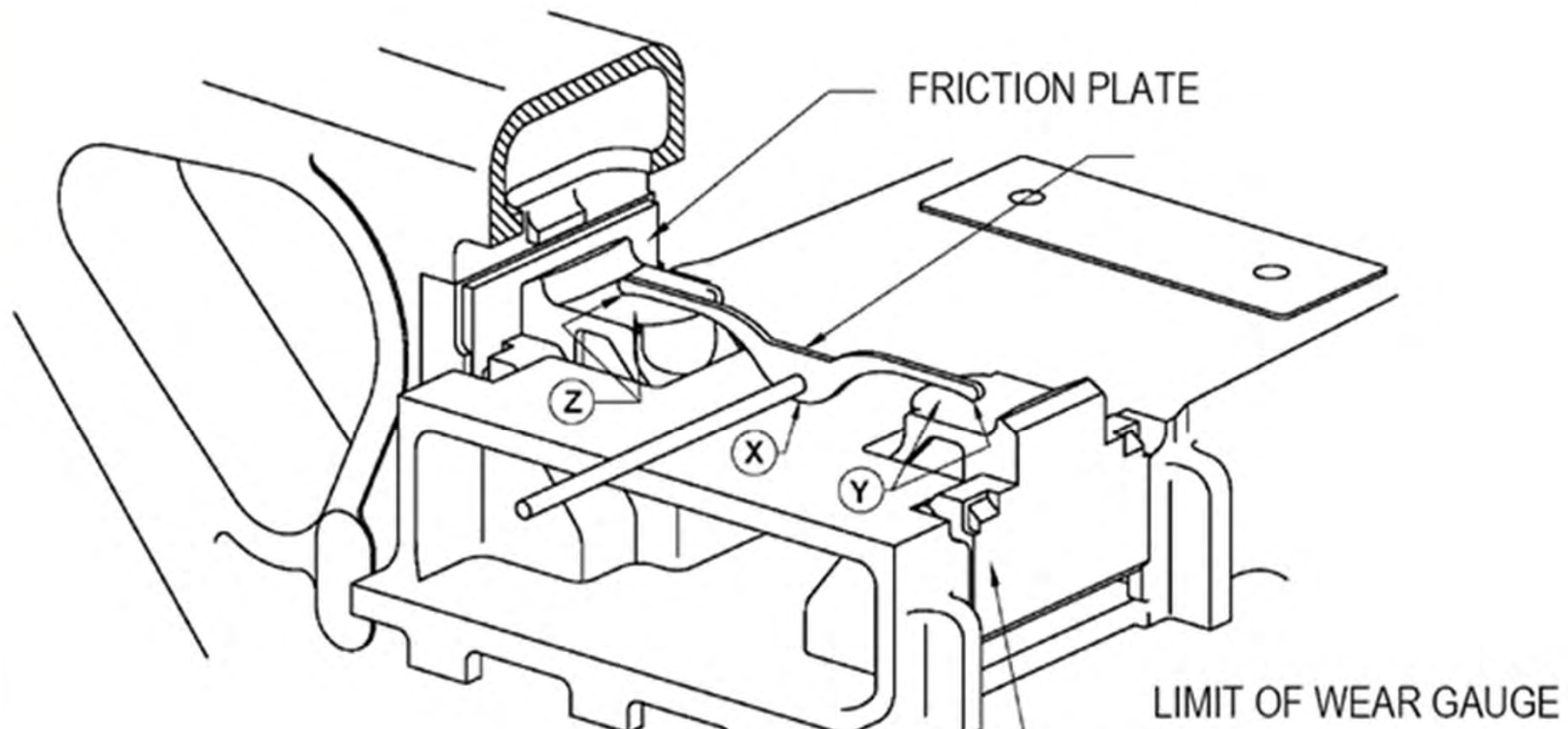


Worn Out Friction Castings (Wedges)

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

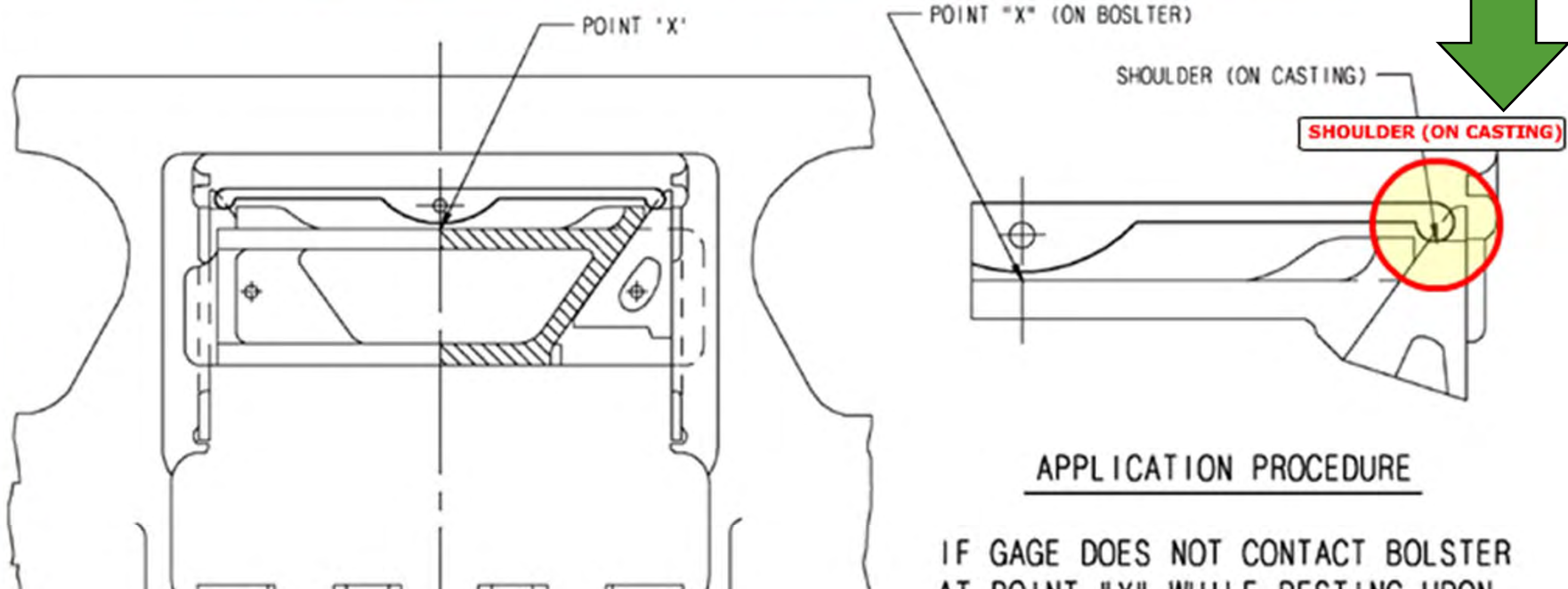


> 1 13/16" (~1 3/4")

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



**> 3/4" Generally Condemnable
Per Rule 46 (Check Rule for
exceptions!)**

SCALE 1:5

**FIGURE B-1
BARBER STABILIZED TRUCK
S-2-A, S-2-B, S-2-C, S-2-D, S-2-HD, S-2-HD-9C, S-2-E**

Barber Variable Damped Trucks - Allowable Wedge Rise AAR Rule 46

Stabilizer Wear Gage Table							
Gage No.	Bearing ^③ Size	AAR ^① Spring Travel	Iron Wedge	Split Wedge	Life ^⑤ Guard Wedge	Twin Guard Wedge	Dim A
SK-1546-1	6 x 11	D-3	609-D	955-SW	913-LG	-	3/4
	6 x 11	D-4 or D-5	678-C 678-B ^② 787-C 787-B ^②	925-SW	888-LG	911-PC	
	6 1/2 x 12	D-3	609-D	955-SW	913-LG	-	
	6 1/2 x 12	D-5	876 834-CB 917-C	905-SW 915-SW 945-SW	877-LG 950-LG	921-PC 916-PC	
	6 1/2 x 12	D-7	876	905-SW	877-LG	921-PC	
SK-1546-2	6 1/2 x 12	D-4 or D-5	678-C 678-B ^② 787-C 787-B ^②	925-SW	888-LG	911-PC	1/2
SK-1546-3	6 x 11 ^④	D-4	675-C	-	-	922-PC	1 1/4
SK-1546-4	7 x 12	D-5 or D-6	834-CB	915-SW	950-LG	916-PC	1/2
SK-1546-5	7 x 12	D-3 or D-4	762-C	-	-	-	1/4
SK-1546-6	7 x 12	D-5	762-C	-	-	-	3/4

Be Careful!!



787-C Wedge 1/2" Wedge Rise

Barber Gage



Ride Control Gage



Springs

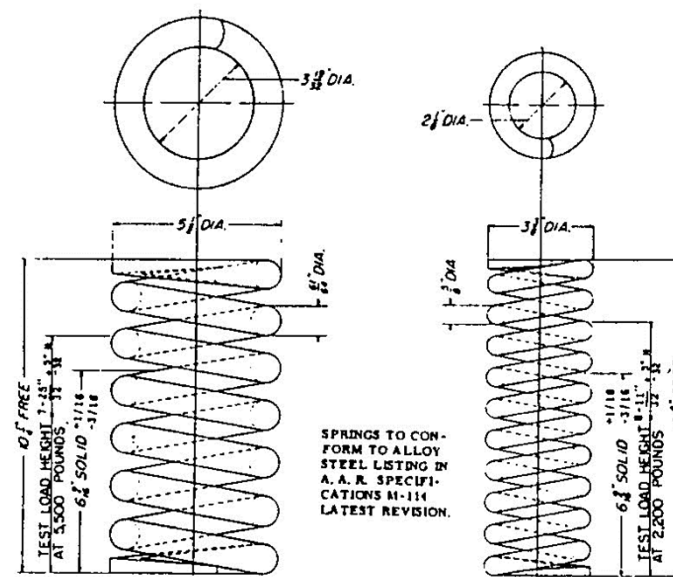


Association of American Railroads
Mechanical Division
Manual of Standards and Recommended Practices
(Former D-73)
S-335

FREIGHT CAR D5 TRUCK SPRINGS TOTAL TRAVEL 3-11/16 INCHES

Standard
S-335-78

Adopted as Alternate Standard 1947, Revised 1963, 1976
Advanced to Standard 1964, Corrected 1965, 1970, 1977
Spring Marking-D5 (Adopted, 1958)

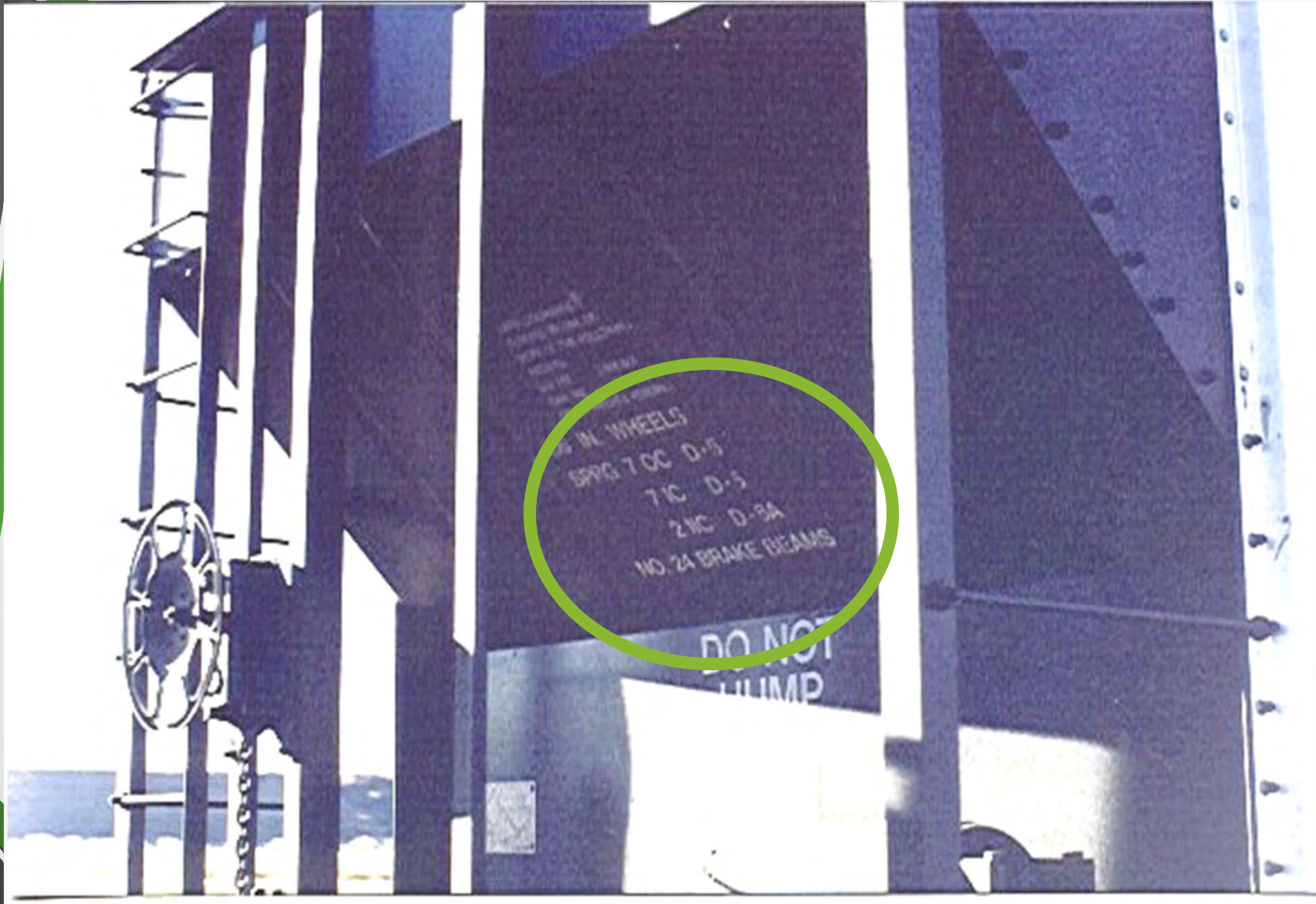


DEFLECTION-FREE TO SOLID = 3 1/4\"
SOLID CAPACITY = 8266 LBS.
LEFT HAND WINDING
ENDS TAPERED AND SQUARED
LOAD PER 1/4\" DEFLECTION =
140.1 LBS.

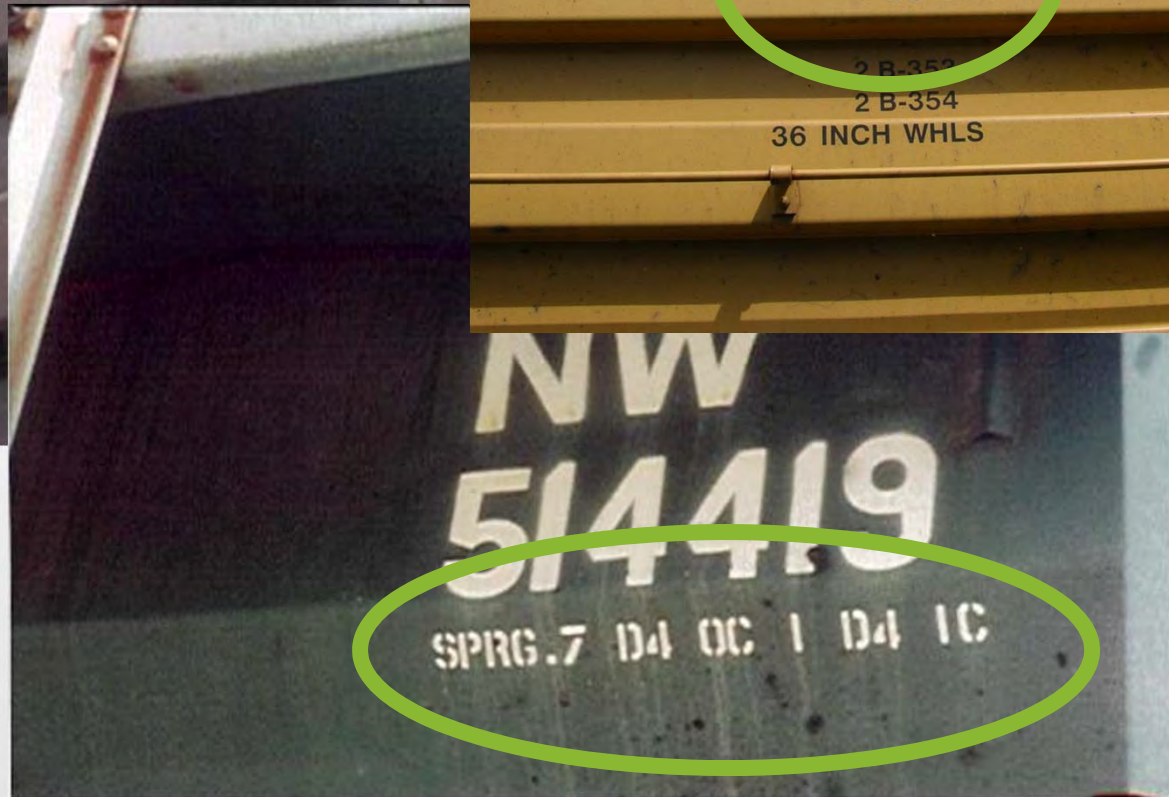
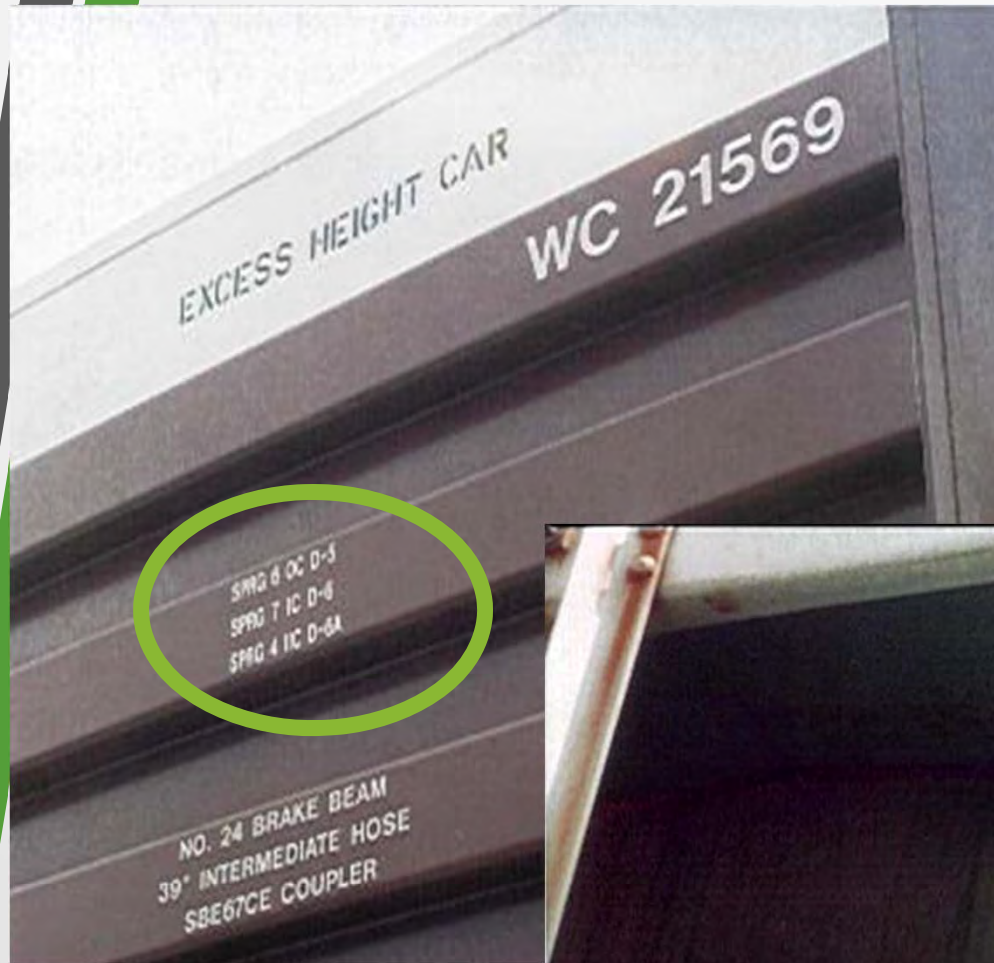
DEFLECTION-FREE TO SOLID = 3 1/4\"
SOLID CAPACITY = 4204 LBS.
RIGHT HAND WINDING
ENDS TAPERED AND SQUARED
LOAD PER 1/4\" DEFLECTION =
70.1 LBS.

*THE HEIGHT TOLERANCE MAY BE CONVERTED TO A PLUS OR MINUS LOAD TOLERANCE BASED ON THE NOMINAL SPRING RATE.

NOTE—IT IS RECOMMENDED THAT CARS EQUIPPED WITH TRUCKS HAVING THESE LONG TRAVEL SPRINGS BE STENCILED AS FOLLOWS ON EACH END OF CAR WITH FIGURES AND LETTERS 2 INCHES HIGH: SPRG. D5.



Spring Groupings

















**Count Springs; Verify Type;
Verify Inner and Outer Springs;
Check Free Height**

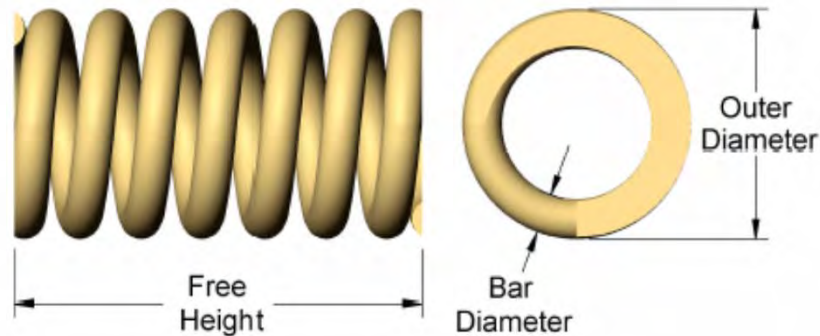
AAR Designated Spring Groups

Spring Groupings II

SINGLE SIDE SPRINGS					
SPRING TRAVEL	2-1/2"	3-1/16"	3-11/16"		
FREE HEIGHT	9-1/16"	9-5/8"	10-1/4" (OUTER COIL)		
SOLID HEIGHT	6-9/16"	6-9/16"	6-9/16"		
5" X 9" JOURNALS					
	4-OUTERS 2-INNERS 2-SIDE	D-3 D-3 B-121	5-OUTERS 1-INNER 2-SIDE	D-4 D-4 B-331	5-OUTERS 2-INNERS 2-SIDE
WEIGHT PER CAR SET 4-GROUPS (LBS.)	402	431	452		
SOLID CAPACITY (LBS)	57066	54525	55190		
5-1/2" X 10" JOURNALS					
	5-OUTERS 2-INNERS 2-SIDE	D-3 D-3 B-121	5-OUTERS 2-INNERS 2-SIDE	D-4 D-4 B-331	5-OUTERS 2-INNERS 2-SIDE
WEIGHT PER CAR SET 4-GROUPS (LBS.)	487	555	545		
SOLID CAPACITY (LBS)	67787	68257	67802		
6" X 11" JOURNALS					
	5-OUTERS 3-INNERS 2-SIDE	D-3 D-3 B-421	7-OUTERS 3-INNERS 2-SIDE	D-4 D-4 B-432	7-OUTERS 4-INNERS 2-SIDE
WEIGHT PER CAR SET 4-GROUPS (LBS.)	580	653	670		
SOLID CAPACITY (LBS)	84522	83477	83960		
6-1/2" X 12" JOURNALS					
	7-OUTERS 3-INNERS 2-SIDE	D-3 D-3 B-421	7-OUTERS 3-INNERS 2-SIDE	D-4 D-4 B-432	7-OUTERS 3-INNERS 2-SIDE
WEIGHT PER CAR SET 4-GROUPS (LBS.)	402	431	452		
SOLID CAPACITY (LBS)	97366	97209	96572		

AAR Freight Car

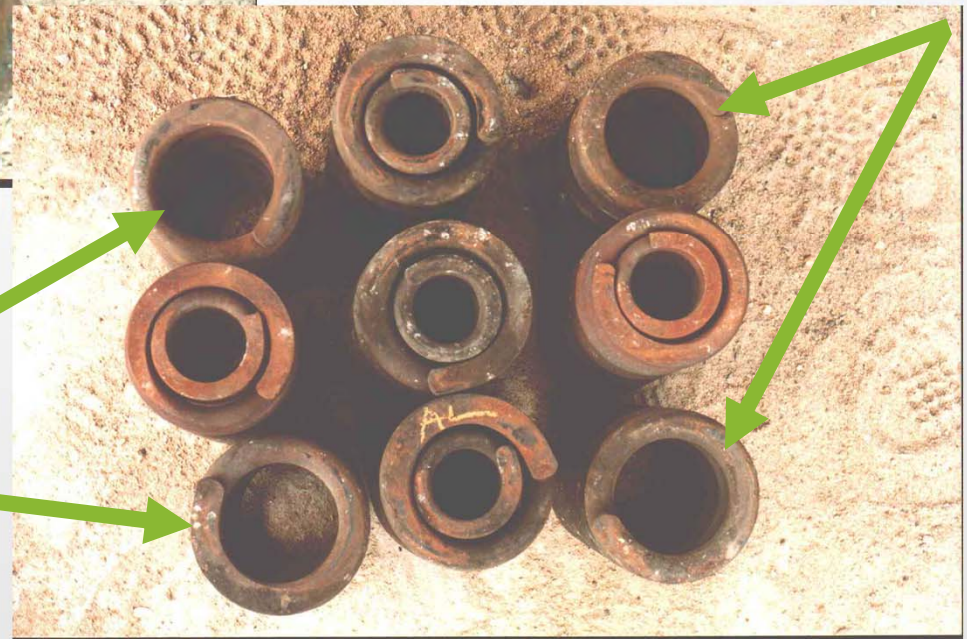
Part No.	Bar Dia.	Outer Dia.	Solid Height	Free Height	Solid Capacity	Scrap Height
D2-Outer	1 7/32	5 1/2	6 5/8	8 1/4	15,959	7 15/16
D2-Inner	11/16	2 15/16	6 5/8	8 1/4	5,386	7 15/16
D3-Outer	1 1/16	5 1/2	6 9/16	9 1/16	10,721	8 5/8
D3-Inner	21/32	3 1/4	6 9/16	9 1/16	4,299	8 5/8
D4-Outer	1	5 1/2	6 9/16	9 5/8	9,128	9 1/16
D4-Inner	5/8	3 3/8	6 9/16	9 5/8	3,433	9 1/16
D5-Outer	61/64	5 1/2	6 9/16	10 1/4	8,266	9 5/8
D5-Inner	5/8	3 3/8	6 9/16	10 5/16	4,204	9 5/8
D6-Inner	21/32	3 7/16	6 9/16	9 15/16	4,707	9 5/16
D6A-Inner	3/8	2	5 11/16	9	1,536	8 3/8
D7-Outer	15/16	5 1/2	6 9/16	10 13/16	8,642	10
D7-Inner	5/8	3 1/2	6 9/16	10 3/4	4,108	10





Right Side

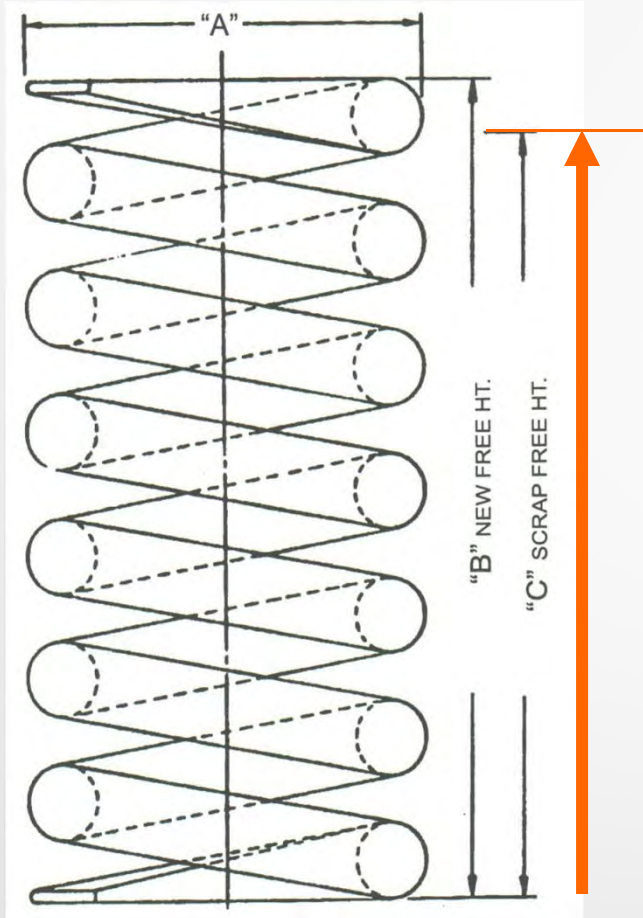
**Left Side;
Missing corner inner coils**





Spring showing sign of fatigue/set

Checking Free Height

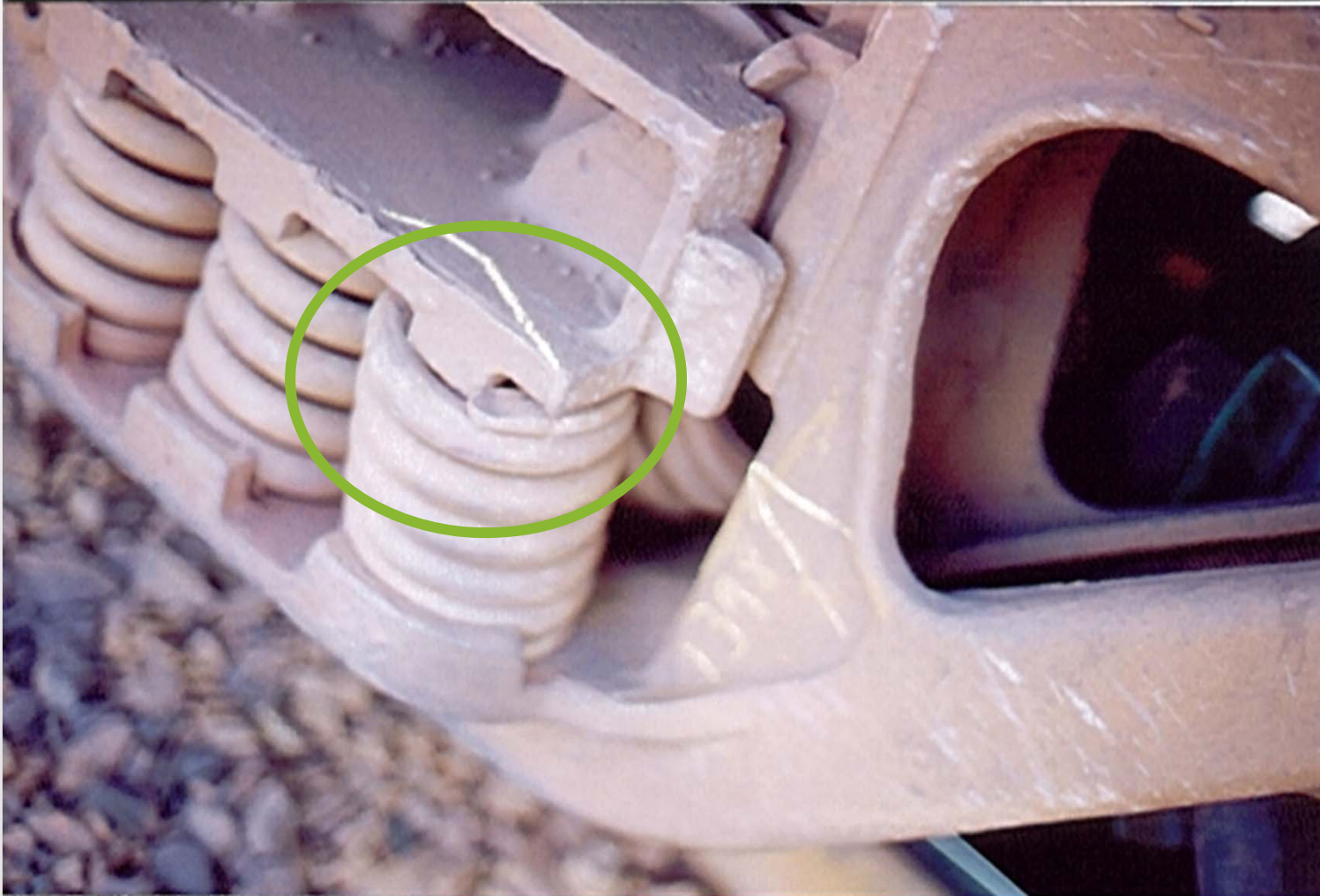






Broken Spring

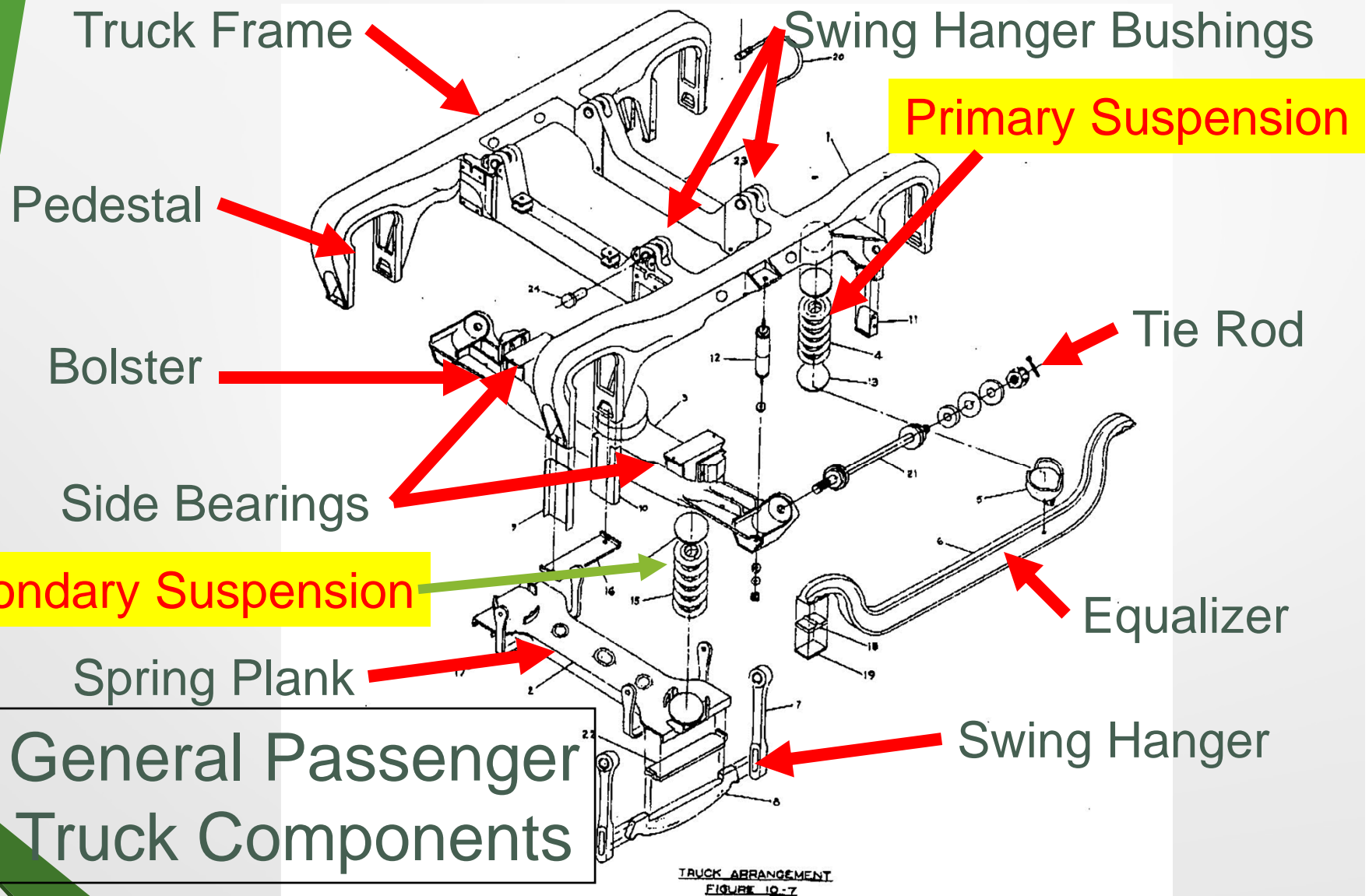


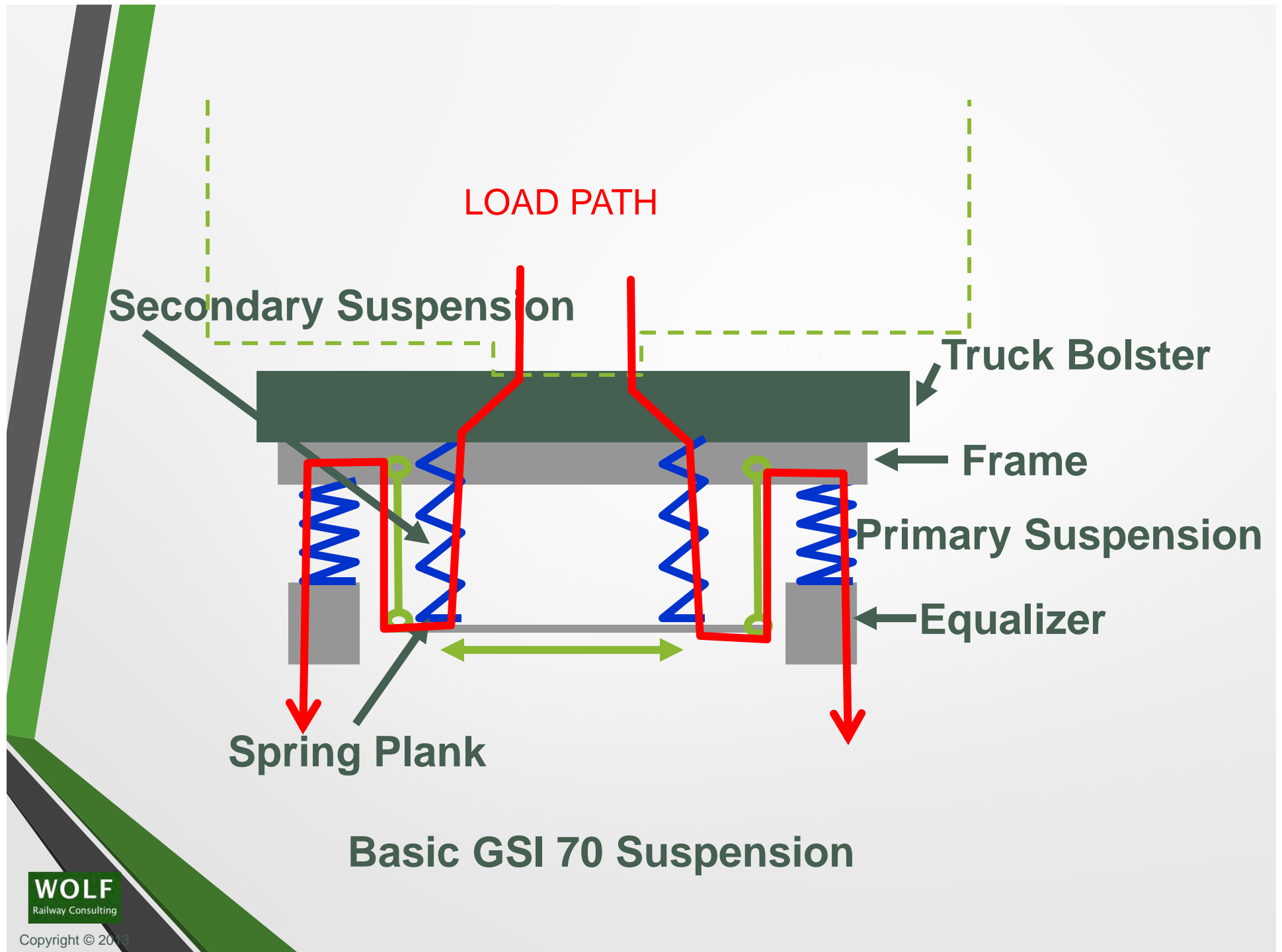


Spring out of Nest



Solid Spring – Indicates Excessive Rock/Roll

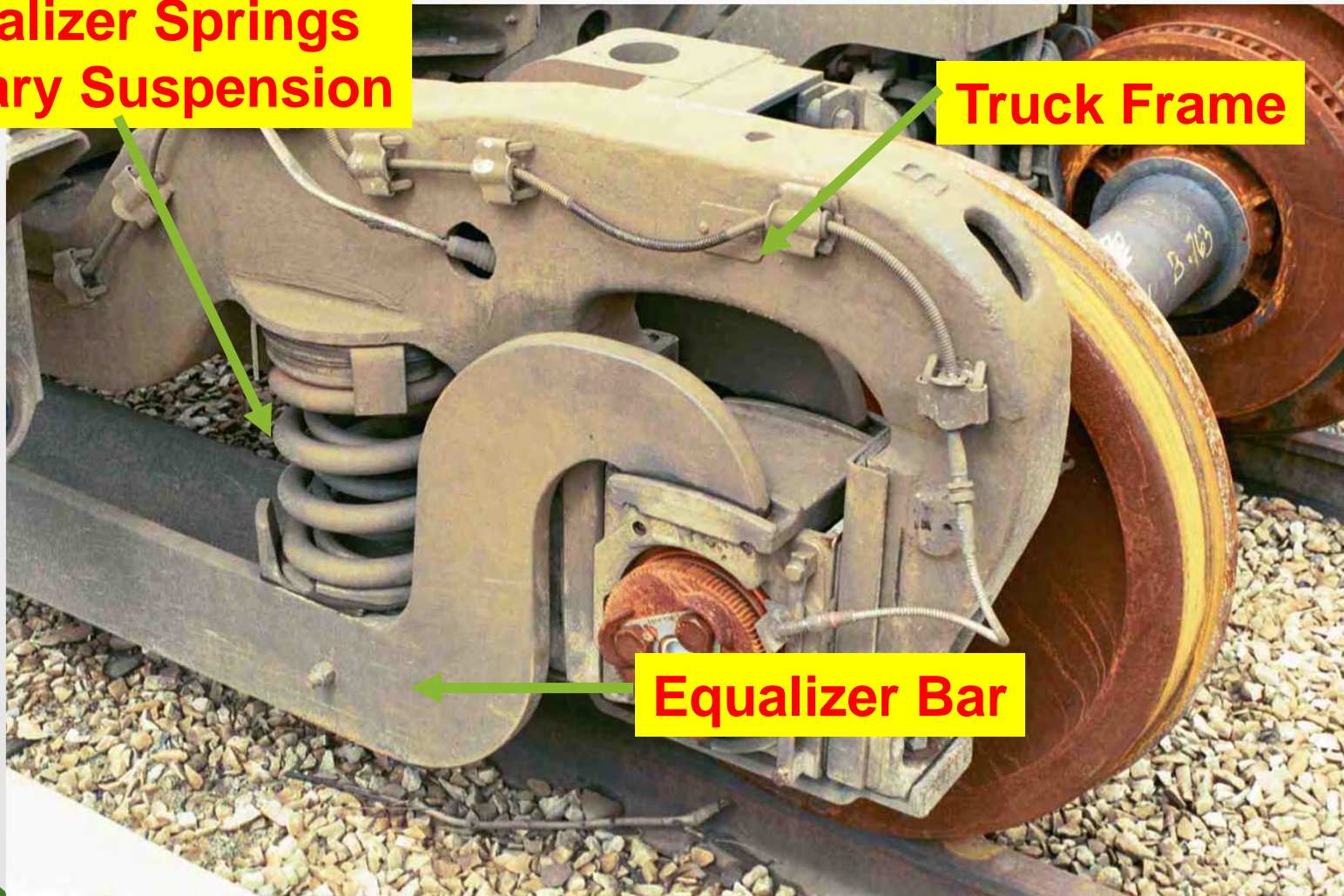




**Equalizer Springs
Primary Suspension**

Truck Frame

Equalizer Bar



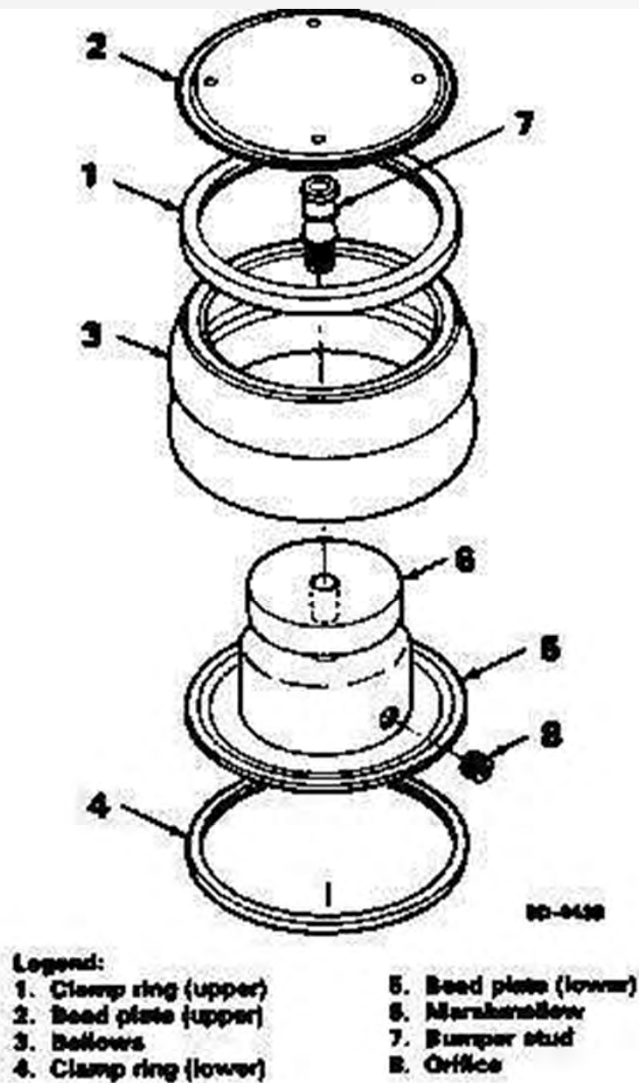


**Secondary Suspension
Spring Plank**

A close-up photograph of a railway vehicle's secondary suspension system. The image shows a complex arrangement of metal components, including a spring plank, equalizer springs, and primary suspension parts. A yellow text box with red text points to the spring plank, and another yellow text box with red text points to the equalizer springs. The components are mounted on a gravel bed.

**Equalizer Springs
Primary Suspension**

Air Spring Secondary Suspension Between Bolster and Car Body



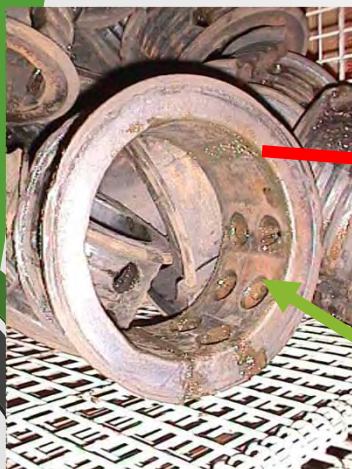
M-3/M-3a Air Spring
Figure 1



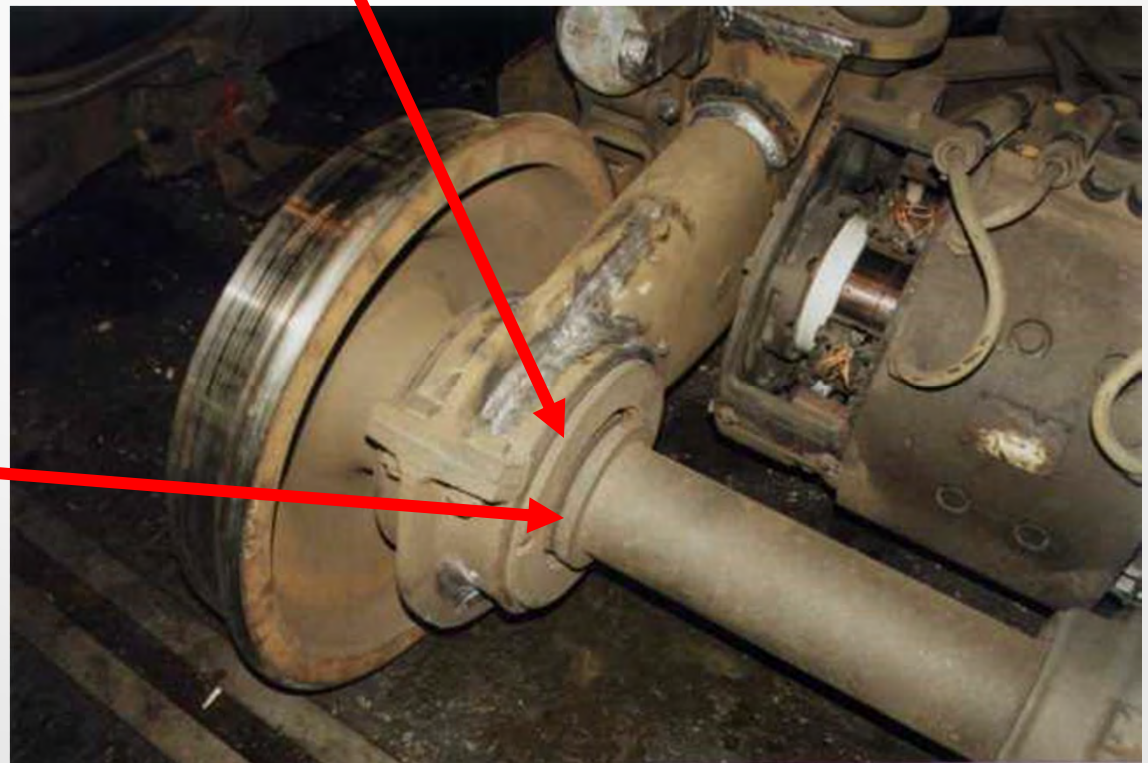
Amfleet Passenger Car Trucks



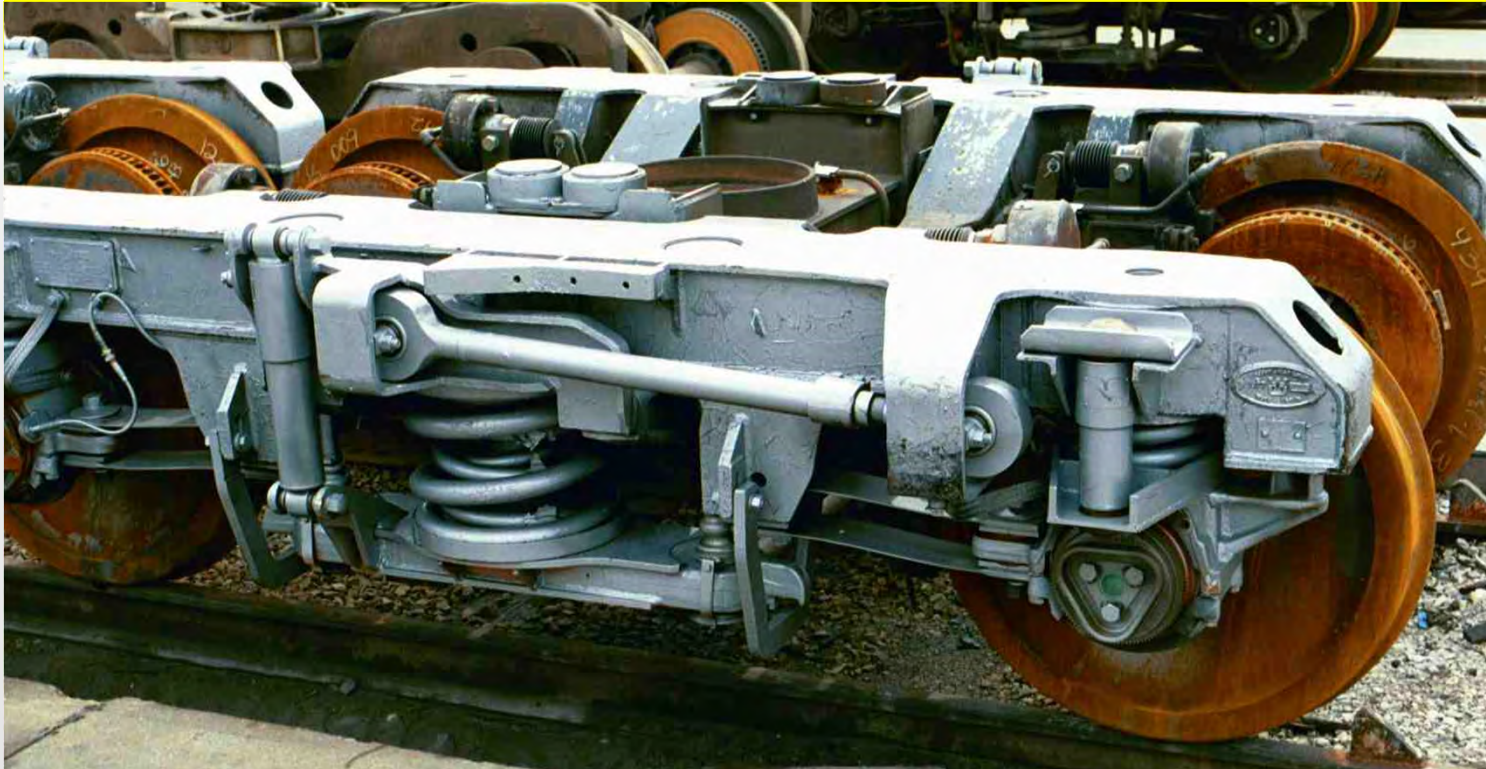
Primary suspension
at each journal



Shock
Ring

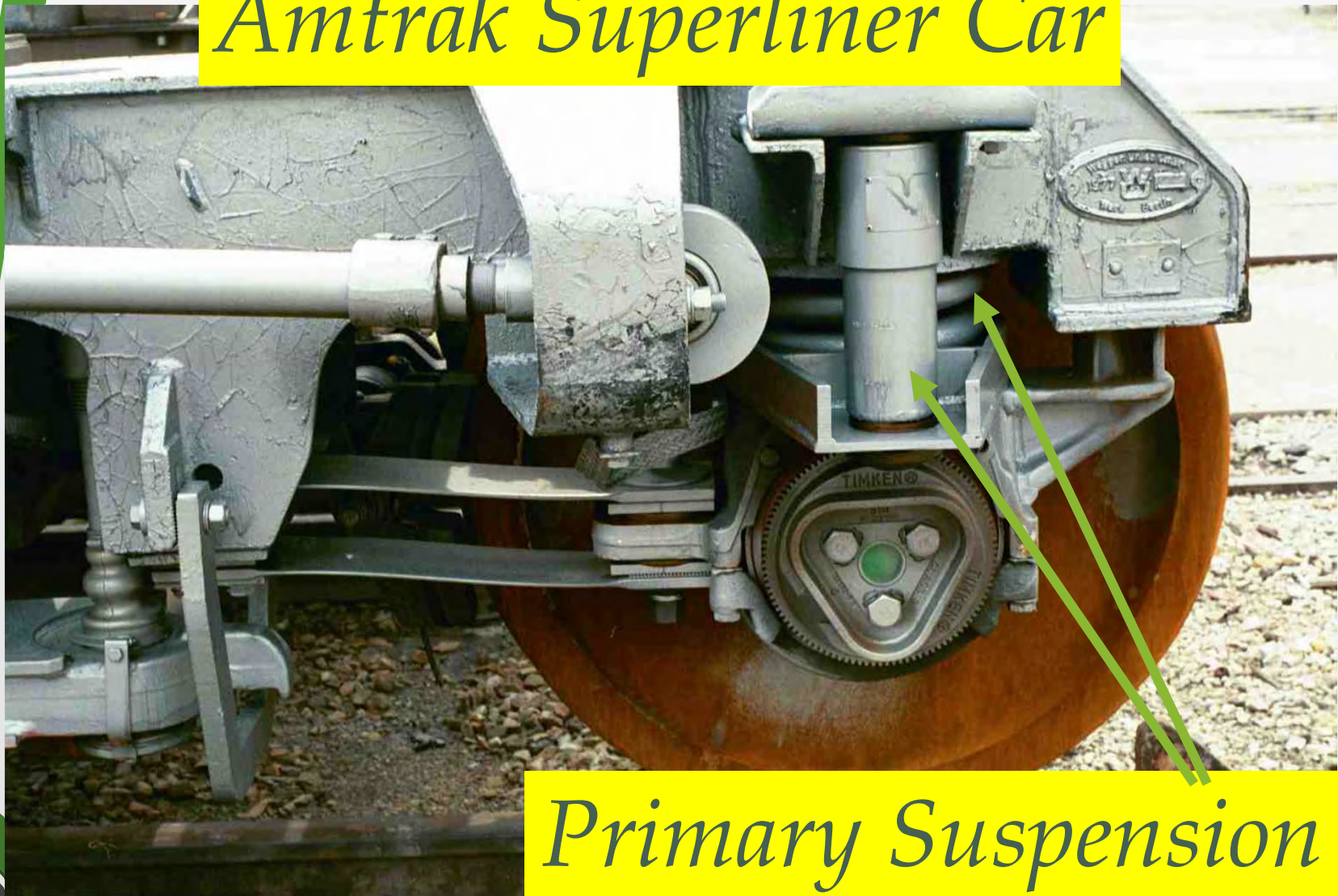


Amtrak Superliner Car



Wagon Union Truck

Amtrak Superliner Car



Primary Suspension

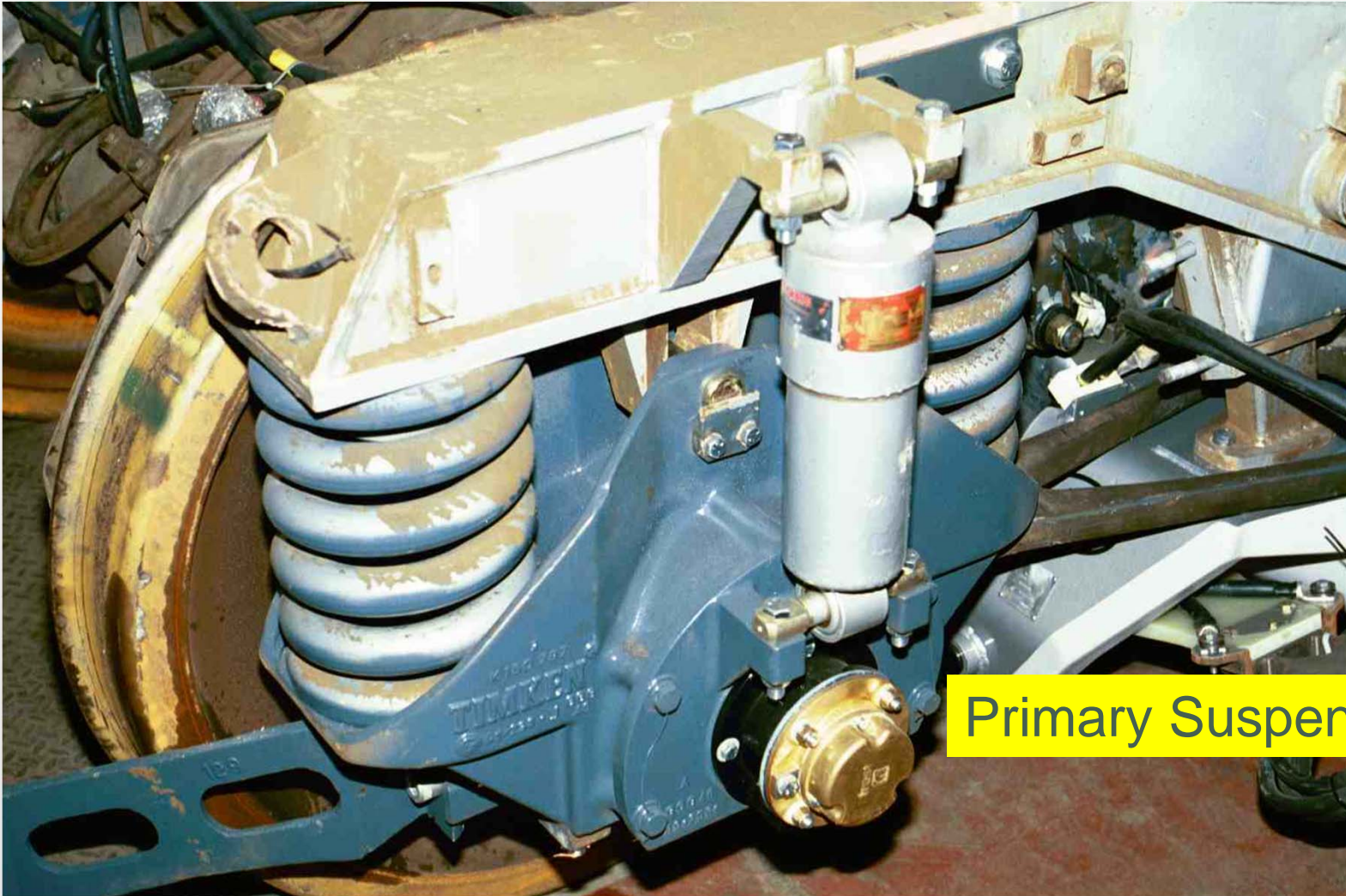


Secondary Suspension

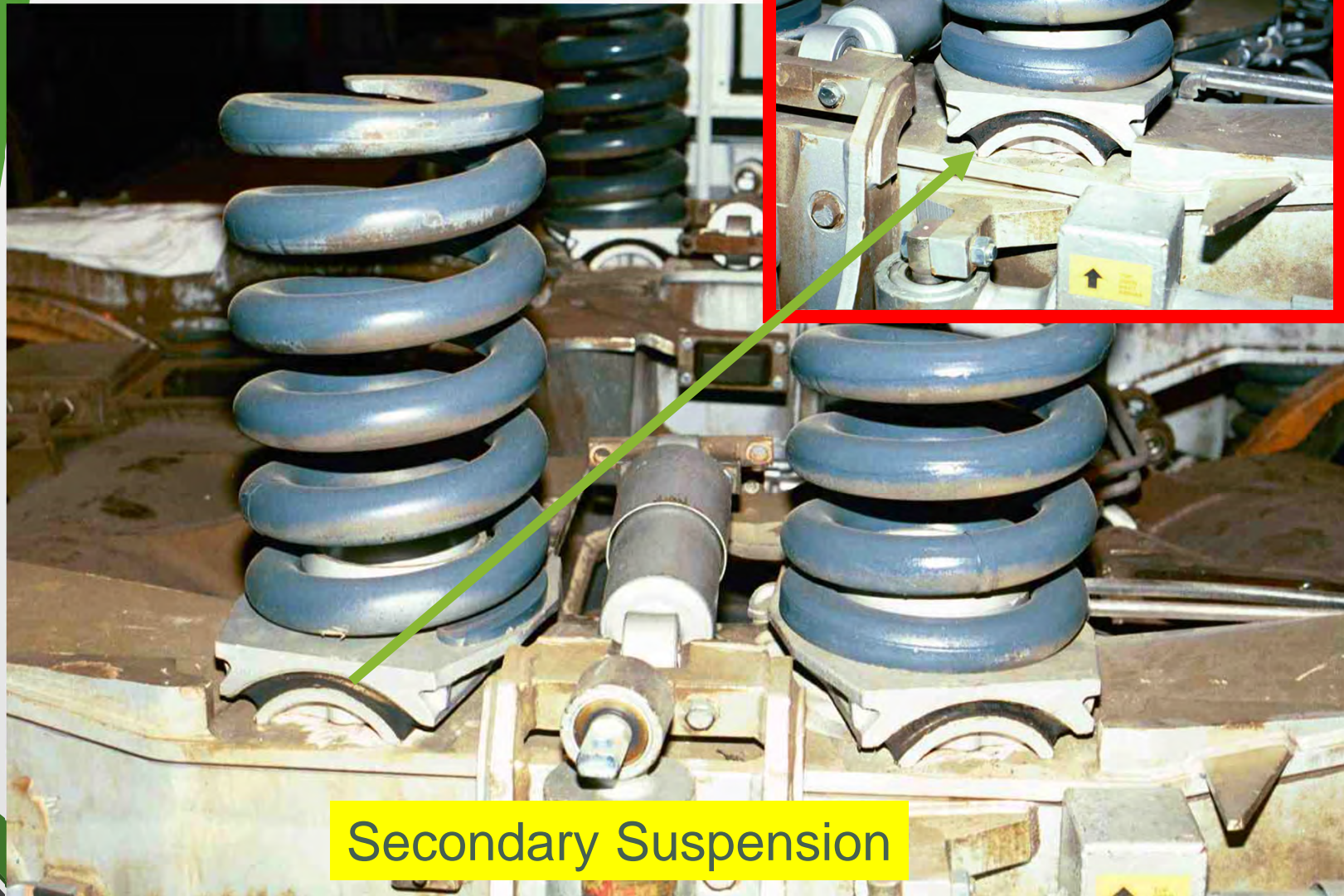
Amtrak Superliner Car

Locomotive Suspensions

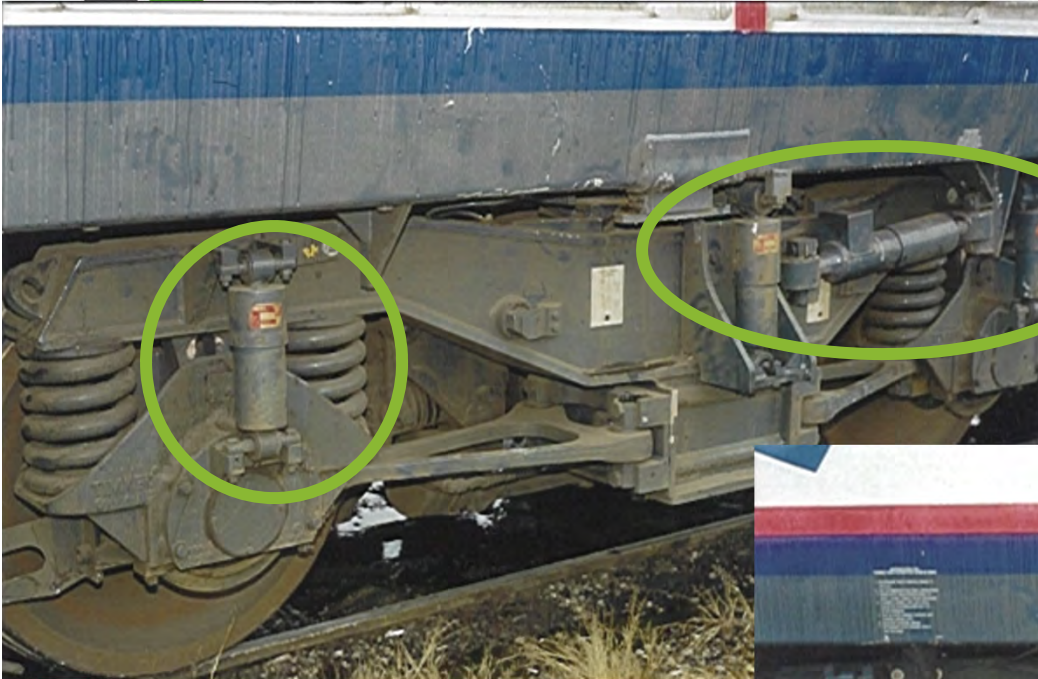




Primary Suspension

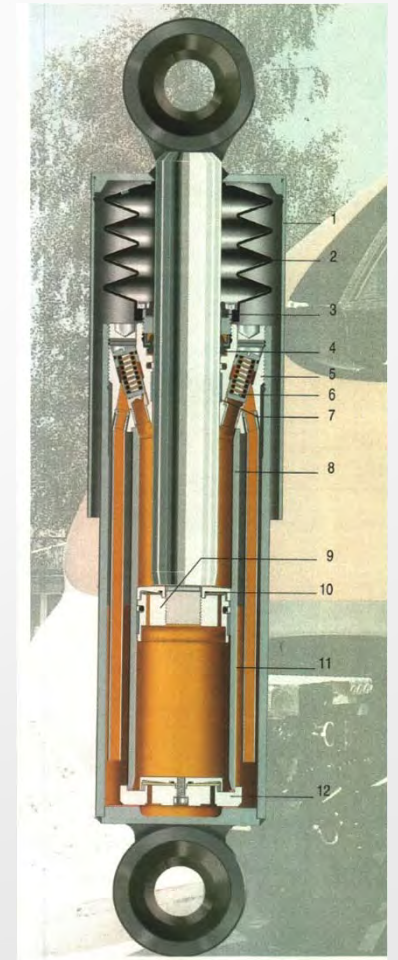


Genesis Trucks



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



Courtesy Koni Company

Hydraulic Dampers - Construction

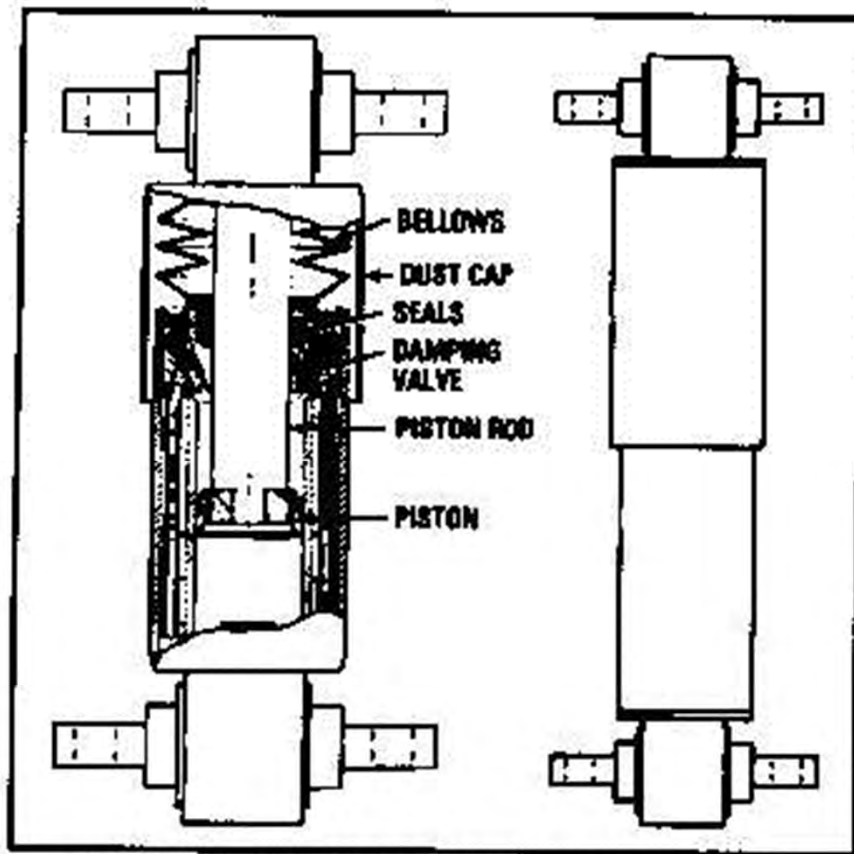
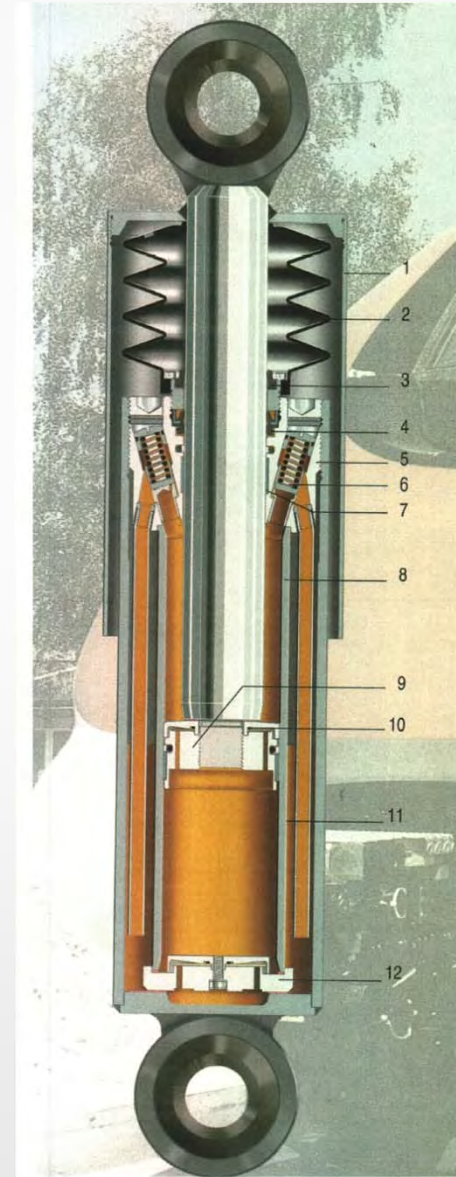
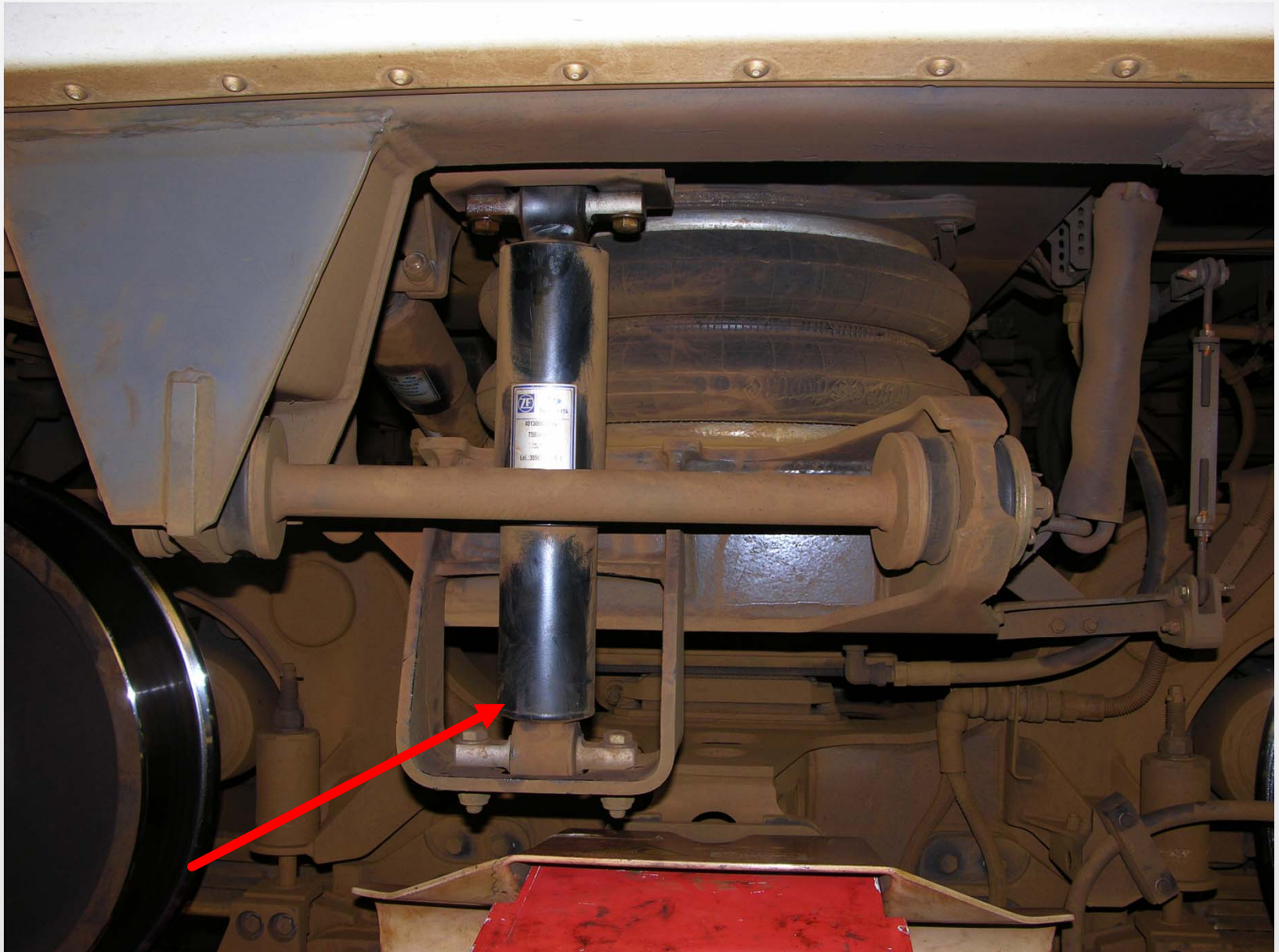


FIG. 4. CROSS SECTION VIEW OF HYDRAULIC SNUBBER (TYPICAL). E-33517.

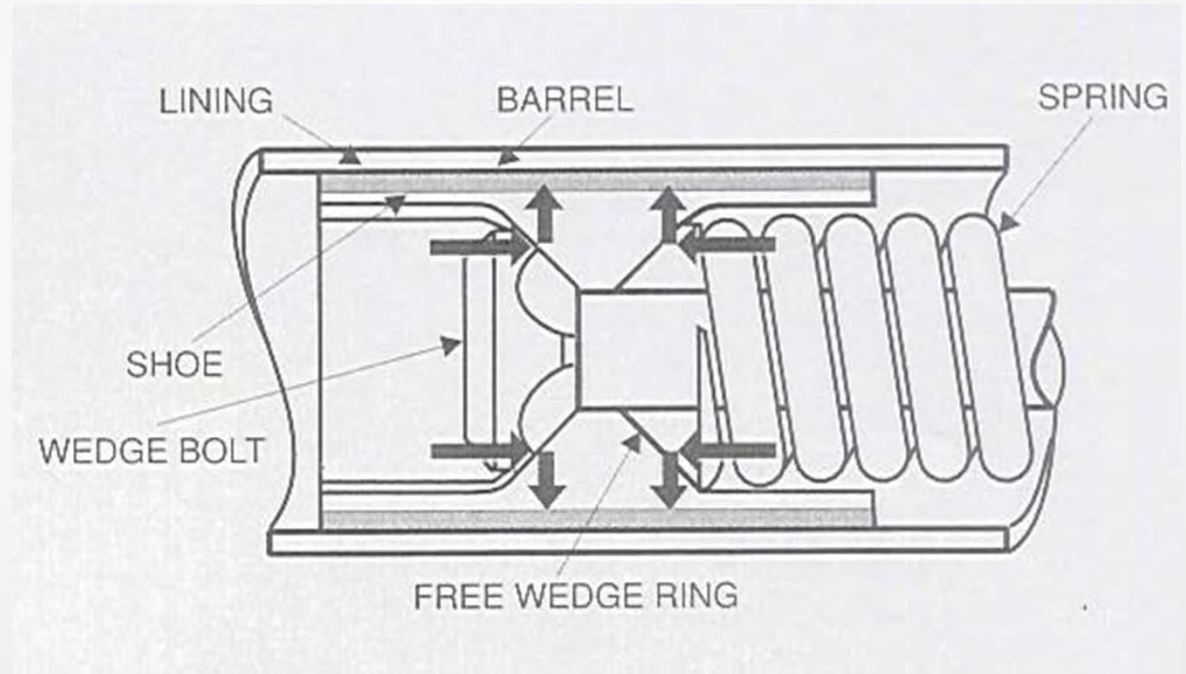
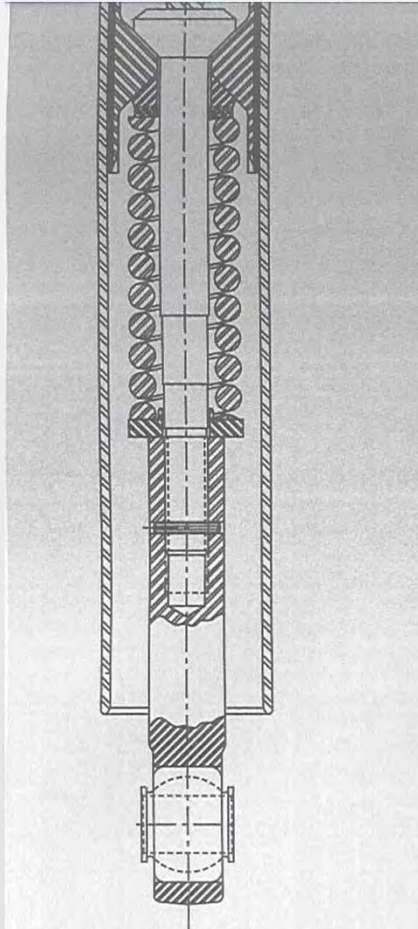


Courtesy Koni Company



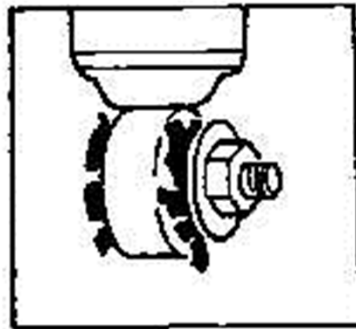
Typical Transit Car Vertical Suspension showing Hydraulic damper in parallel with Air Spring

Friction Dampers

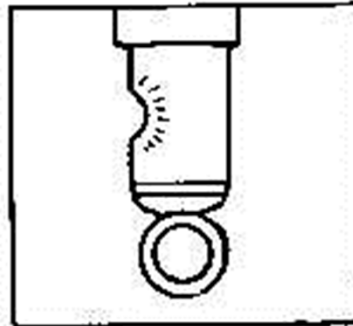


Courtesy Vibratex Company

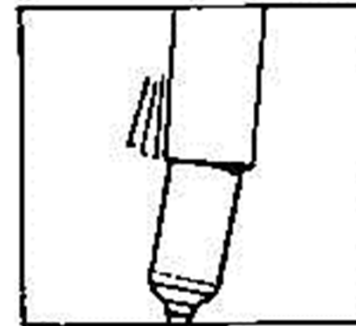
Dampers - Inspection Items



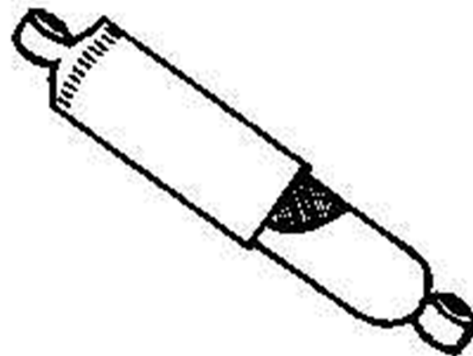
WORN BUSHINGS
Will make shock absorbers noisy and reduce their effectiveness.



BODY DAMAGE
Large dents in the shock absorber will cause the unit to deteriorate.

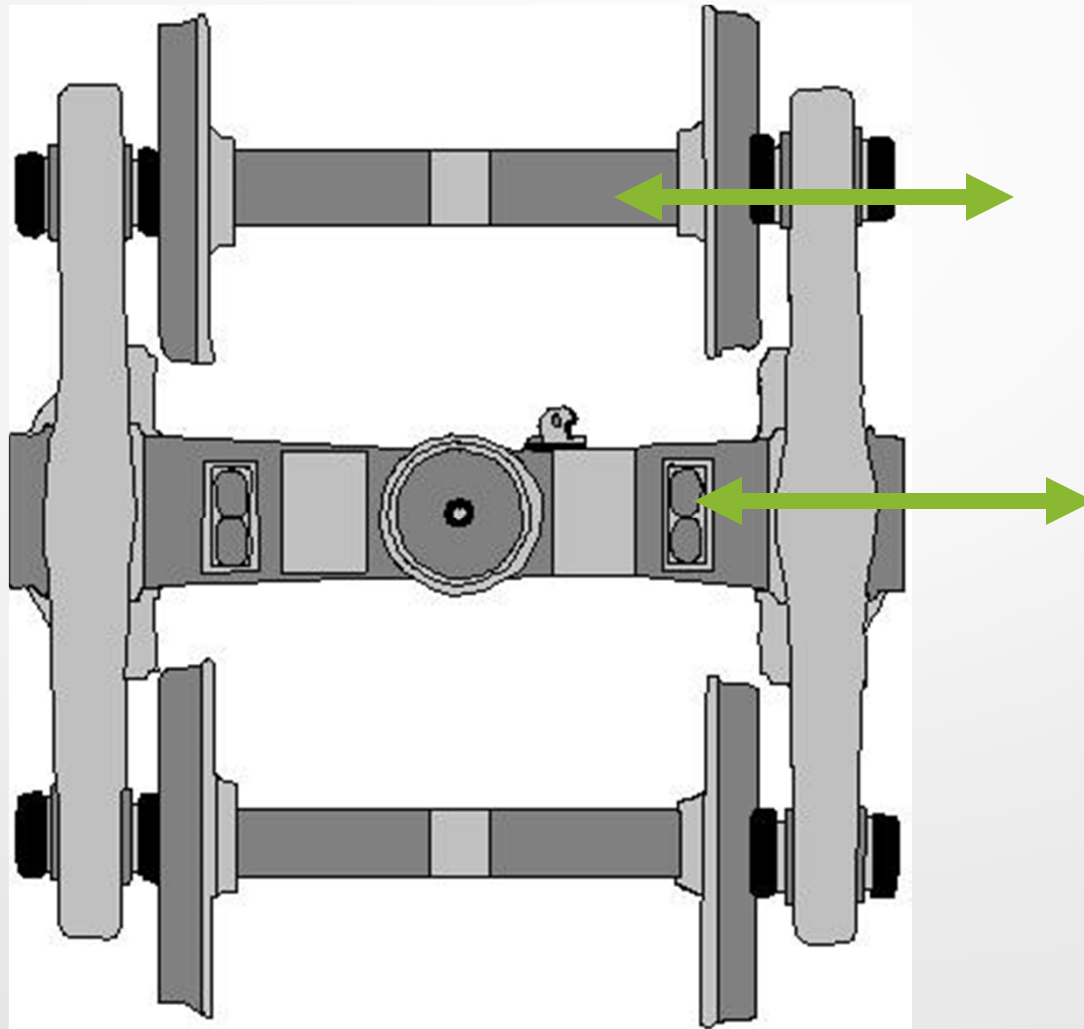


LOOSE DUST SHIELD
Will cause noise and may further damage the unit.



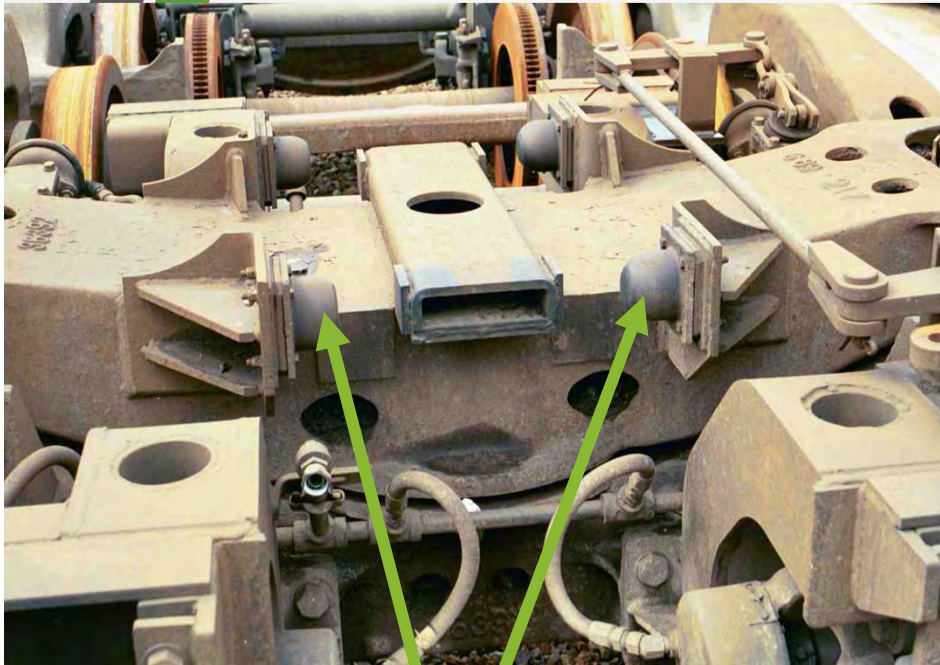
LEAKING FLUID
Will make shock absorber lose effectiveness.

Lateral Suspension



Lateral Suspension

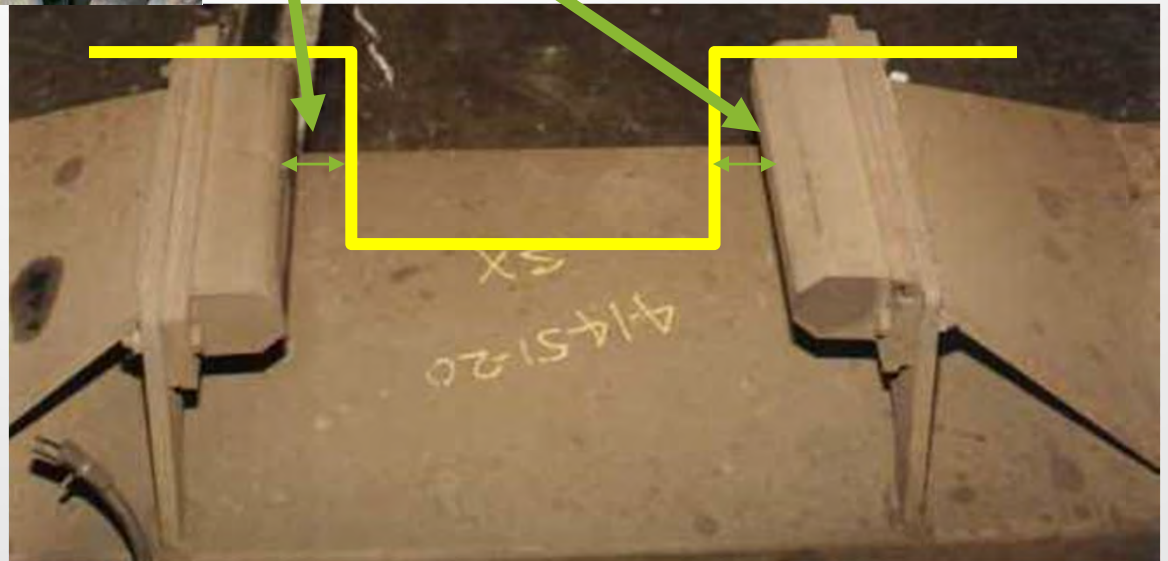
- 3-Piece trucks have relatively poor lateral suspension characteristics, relying primarily on shear stiffness of load springs and friction damping due to wedge motion
- Passenger/locomotive trucks have improved lateral suspension relying on both swing motion of the bolsters, shear of the secondary springs, and bump stops. In addition, lateral shock dampers are used.

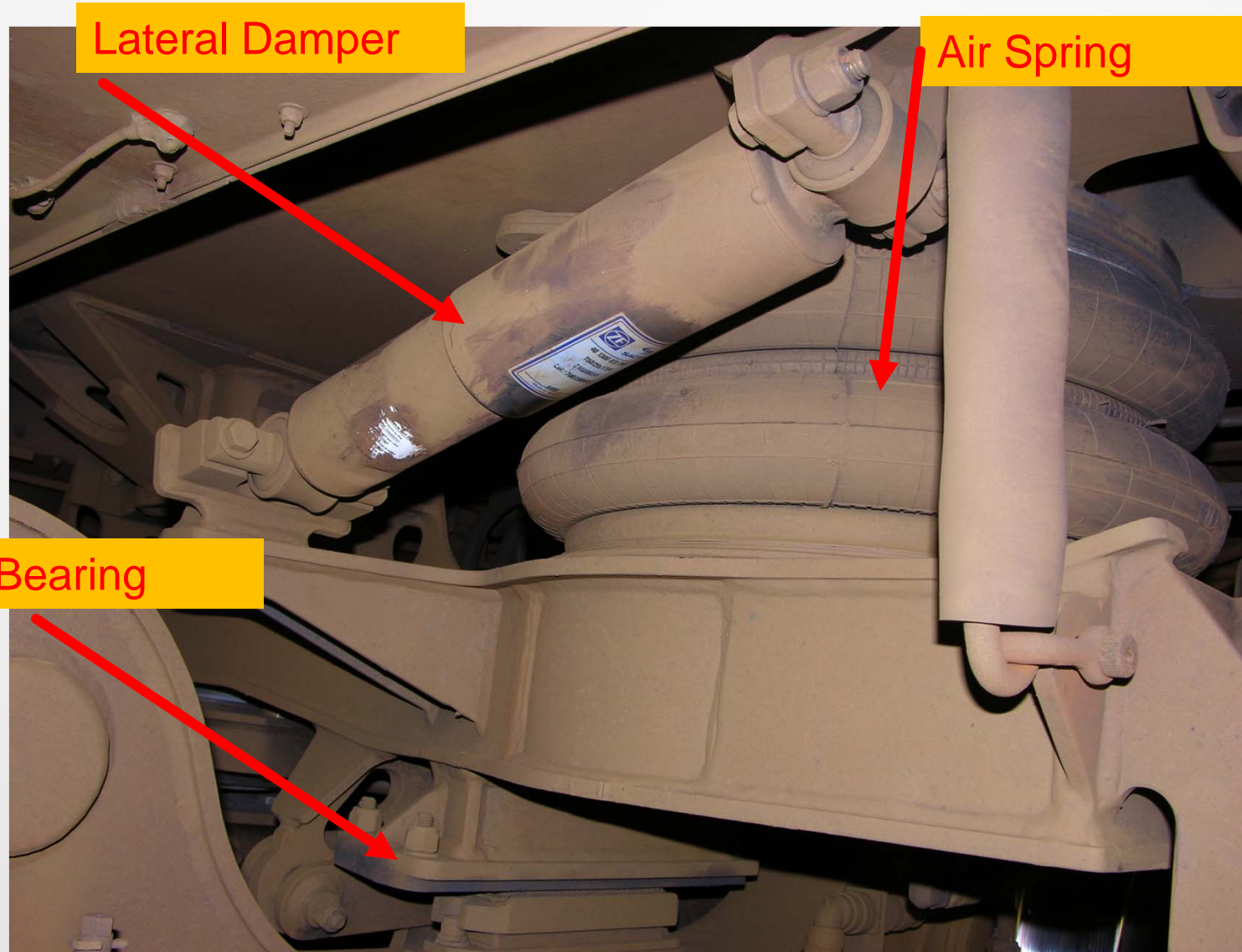


Lateral Bump Stops

Bolster & Lateral Bump Stops

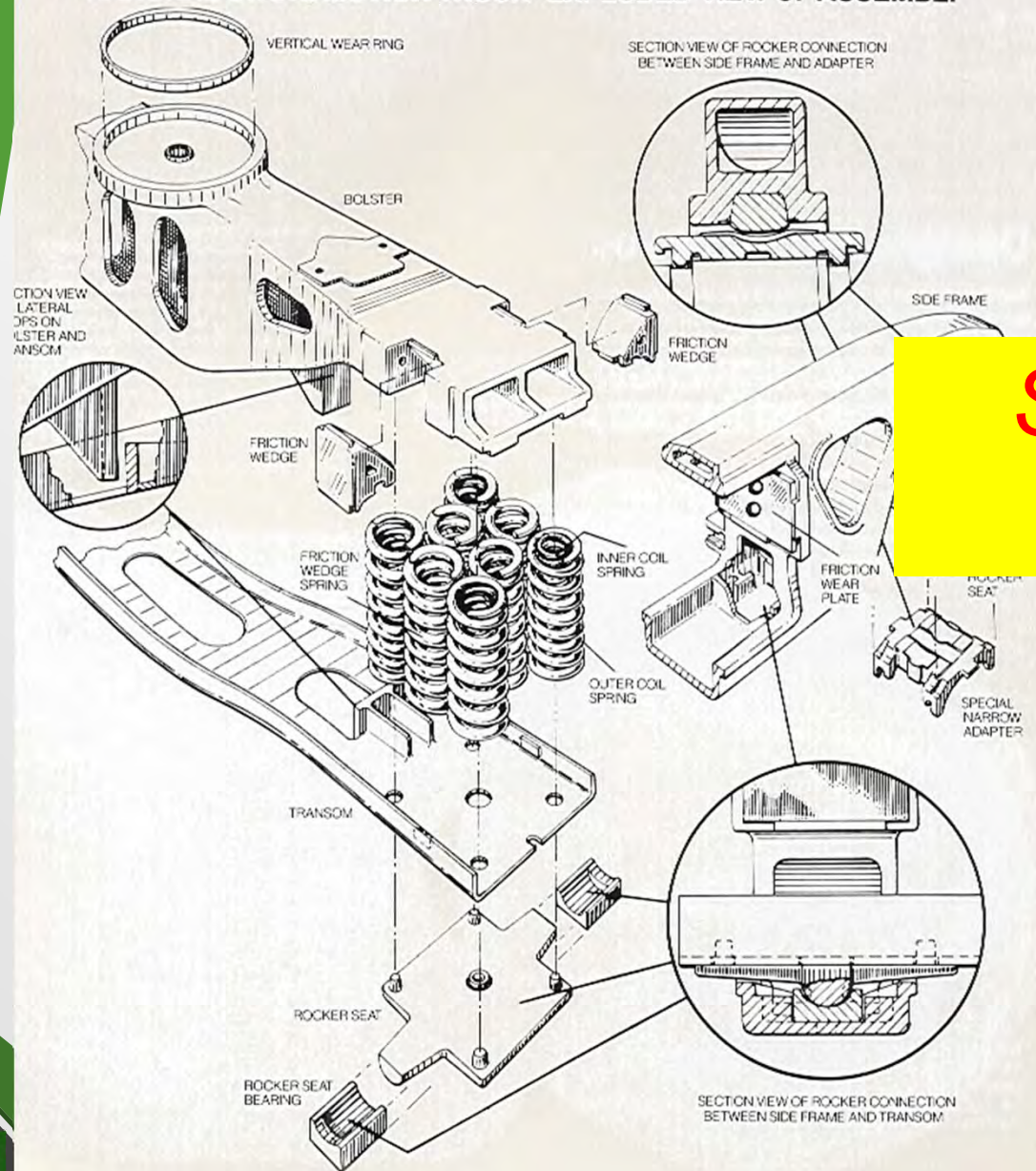
**1" Nominal Bolster Stop to Body
clearance; +1/4", -0" tolerance**





Lateral Secondary Suspension Elements of typical Transit Car showing damper and air spring.

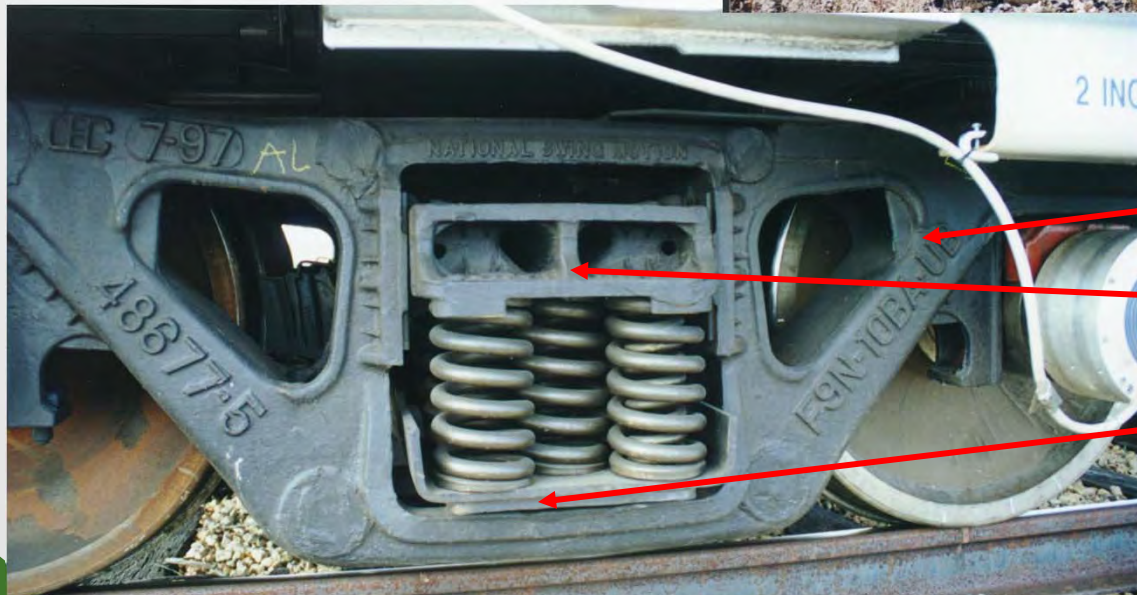
NATIONAL SWING MOTION TRUCK™ EXPLODED VIEW OF ASSEMBLY



Swing Motion Truck



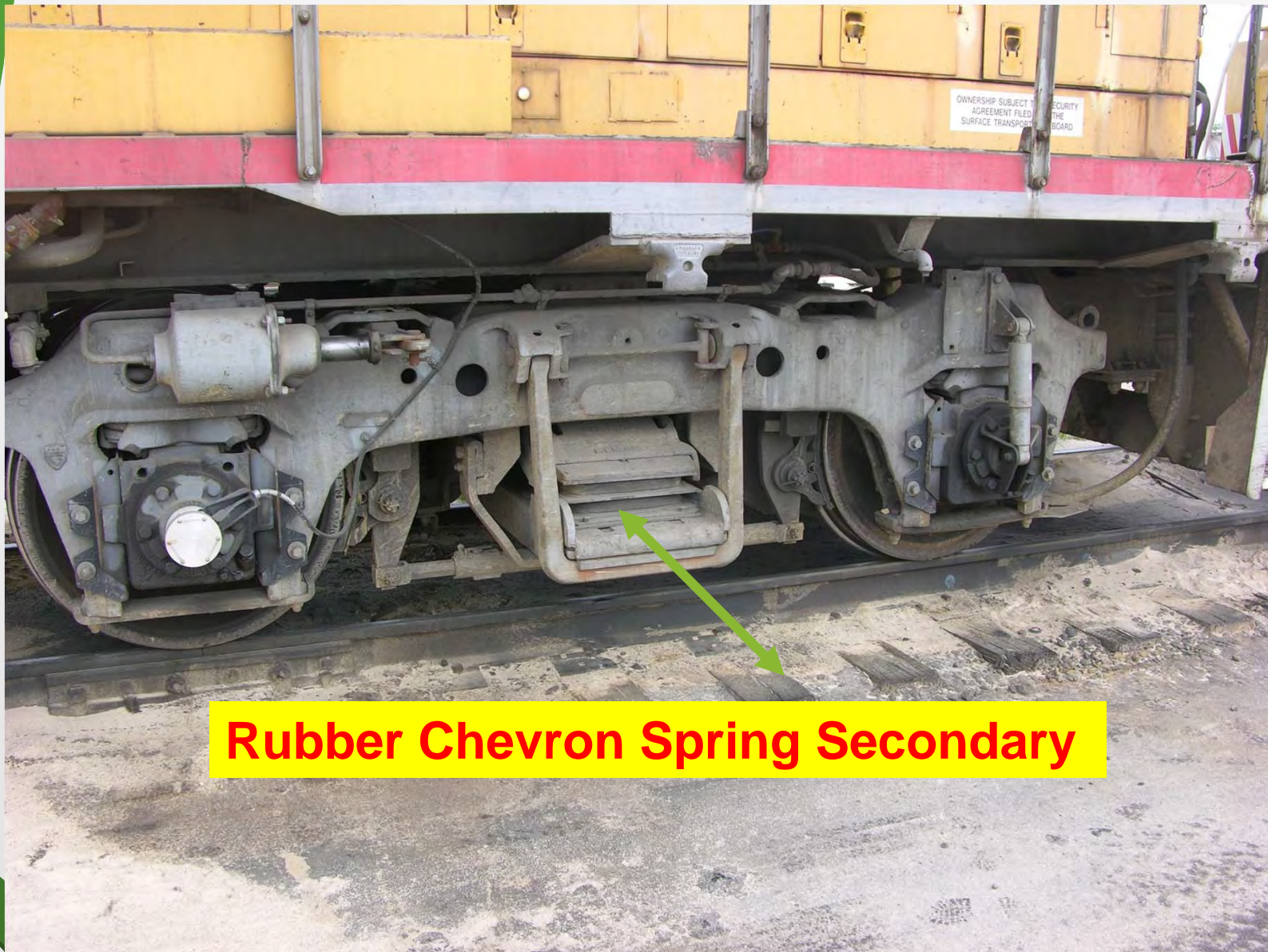
Swing Motion Truck



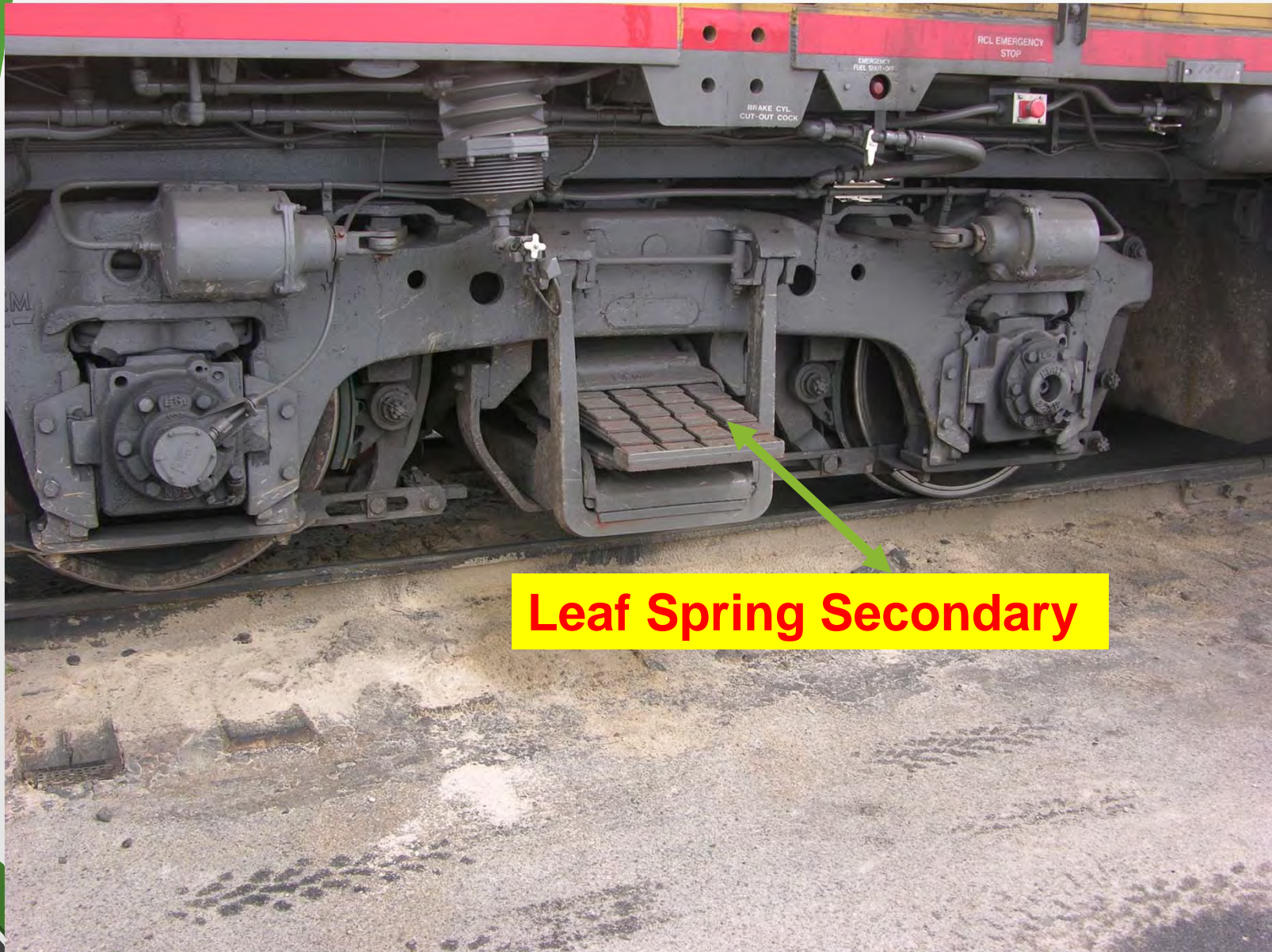
Sideframe

Bolster

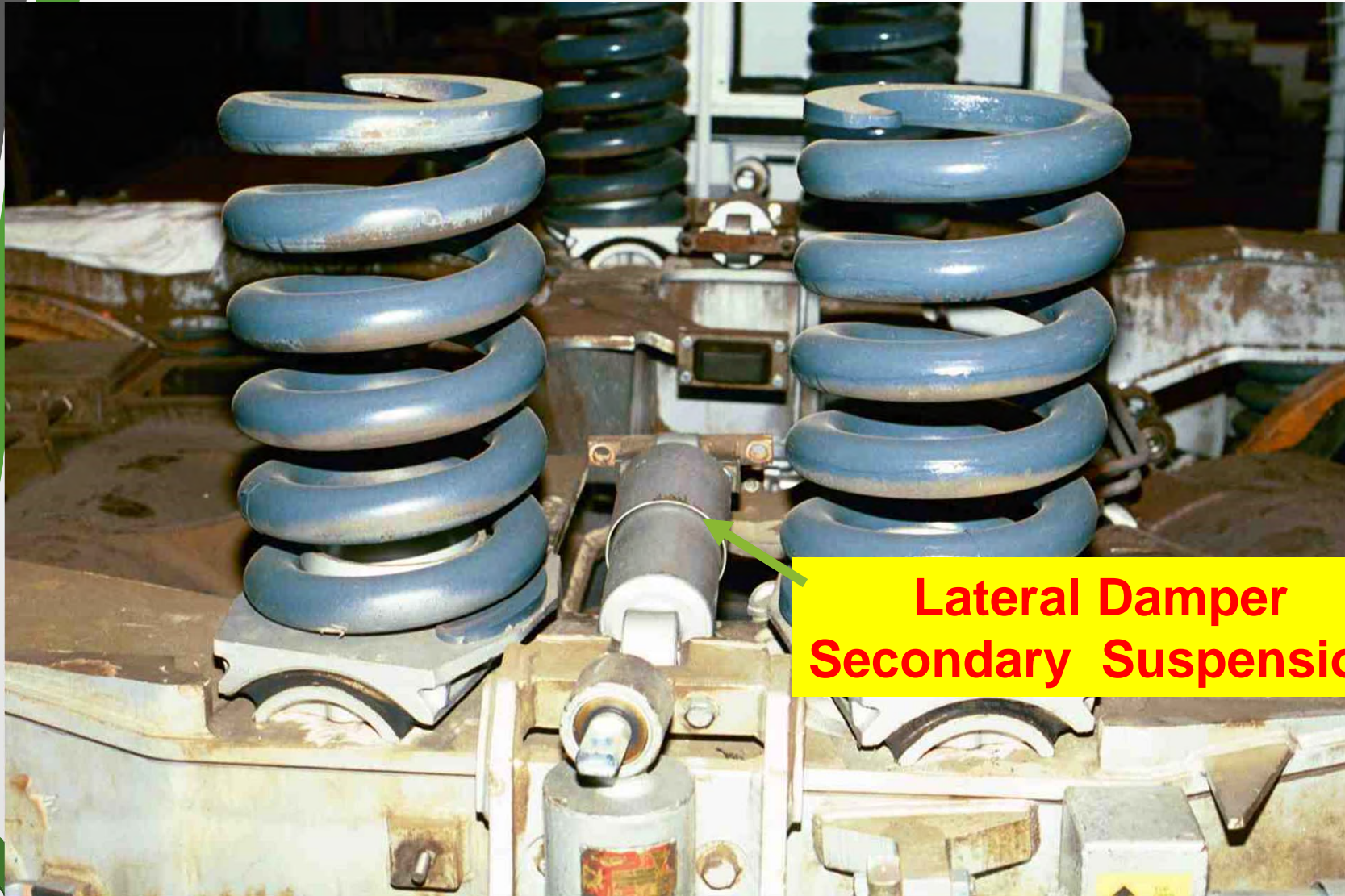
Spring Plank



Rubber Chevron Spring Secondary

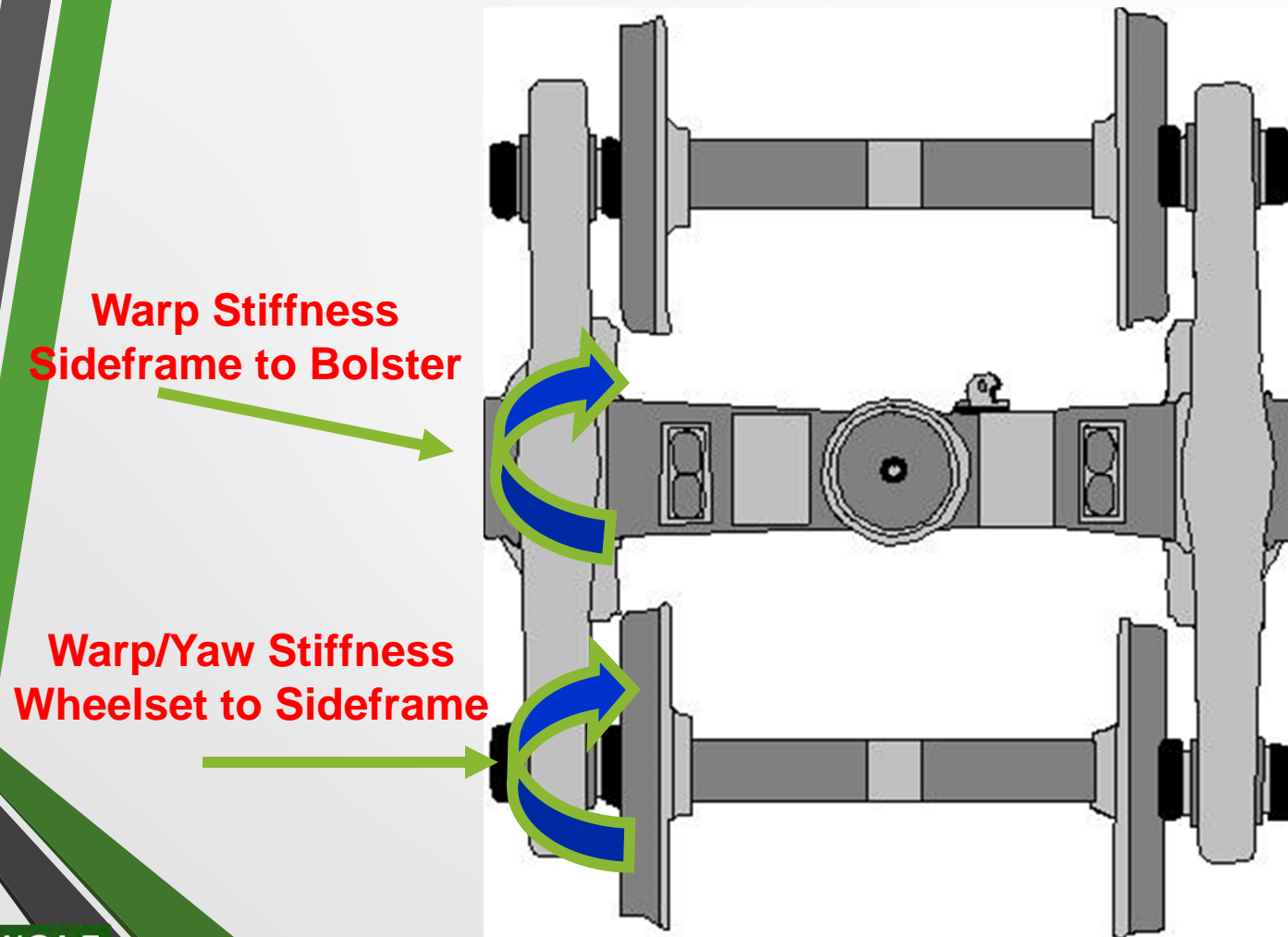


Leaf Spring Secondary



**Lateral Damper
Secondary Suspension**

Yaw/Warp Suspension



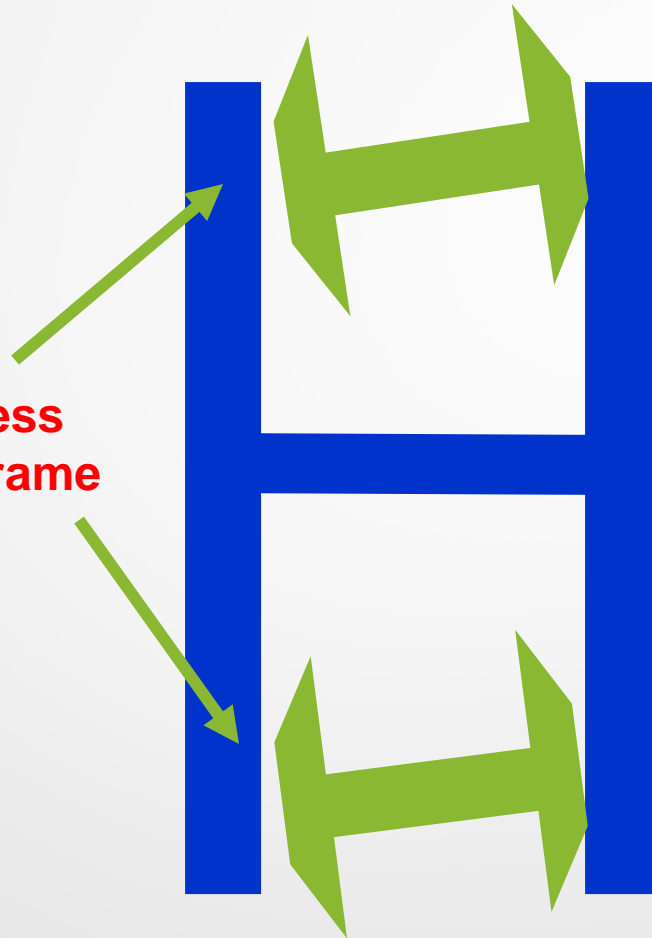
Yaw/Warp Suspension

**Warp Stiffness
Sideframe to Bolster**



Yaw/Warp Suspension

**Warp/Yaw Stiffness
Wheelset to Sideframe**

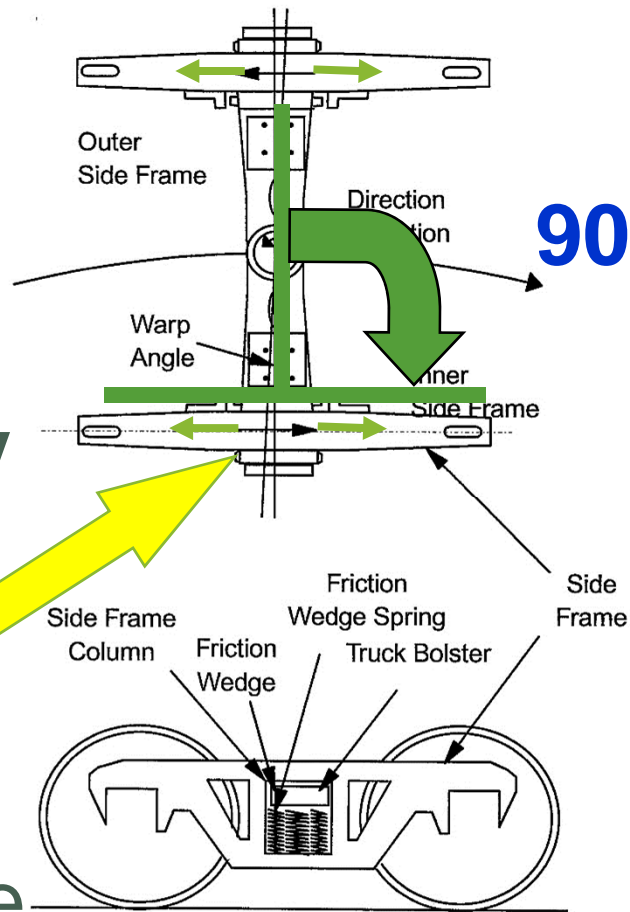


Yaw/Warp Suspension

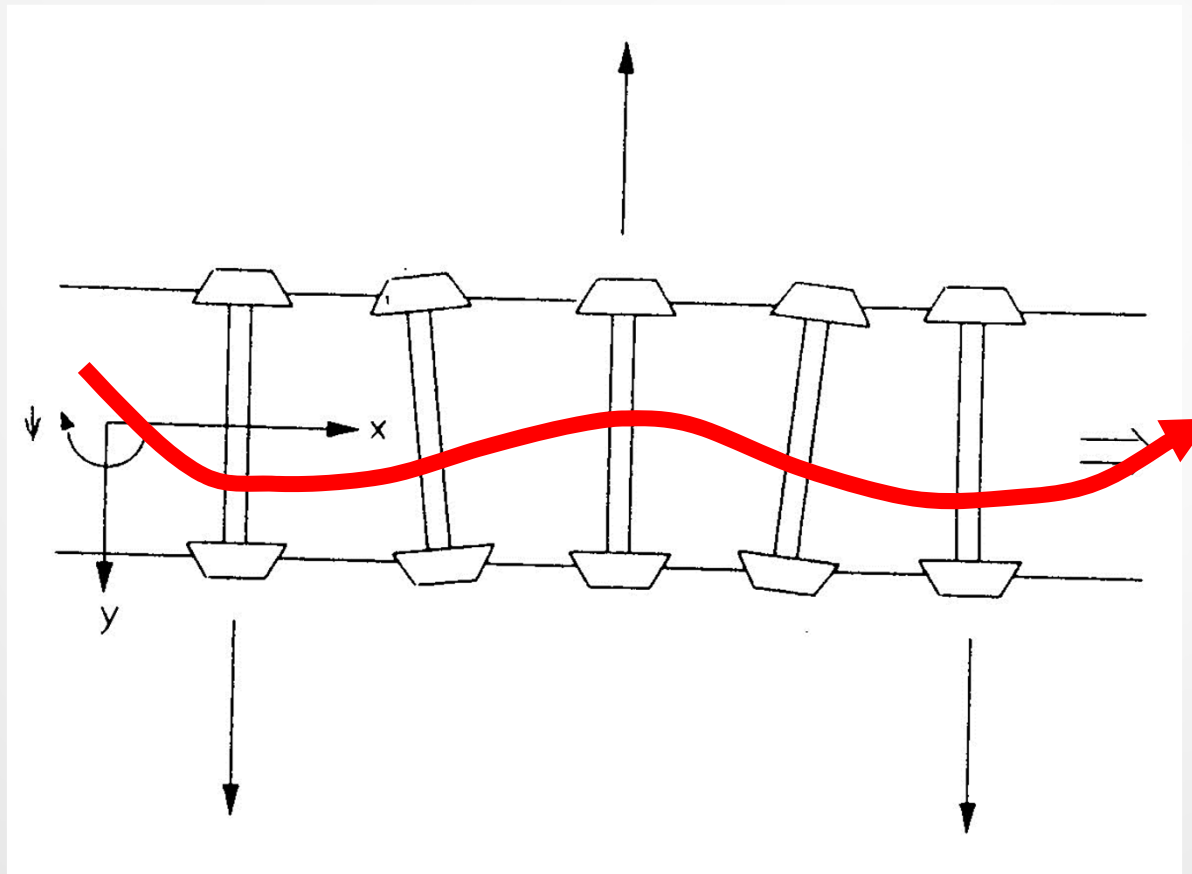
- Yaw/Warp Stiffness influences two primary responses
 - Hunting (high speed stability)
 - Truck Warp (Curving)
- Freight Cars depend on the friction wedge system for warp stiffness
- Passenger cars are normally rigid frame possessing high warp stiffness, but typically possess lower yaw stiffness

Truck Hunting Lateral Instability

Wedges Help to
Keep Truck Square

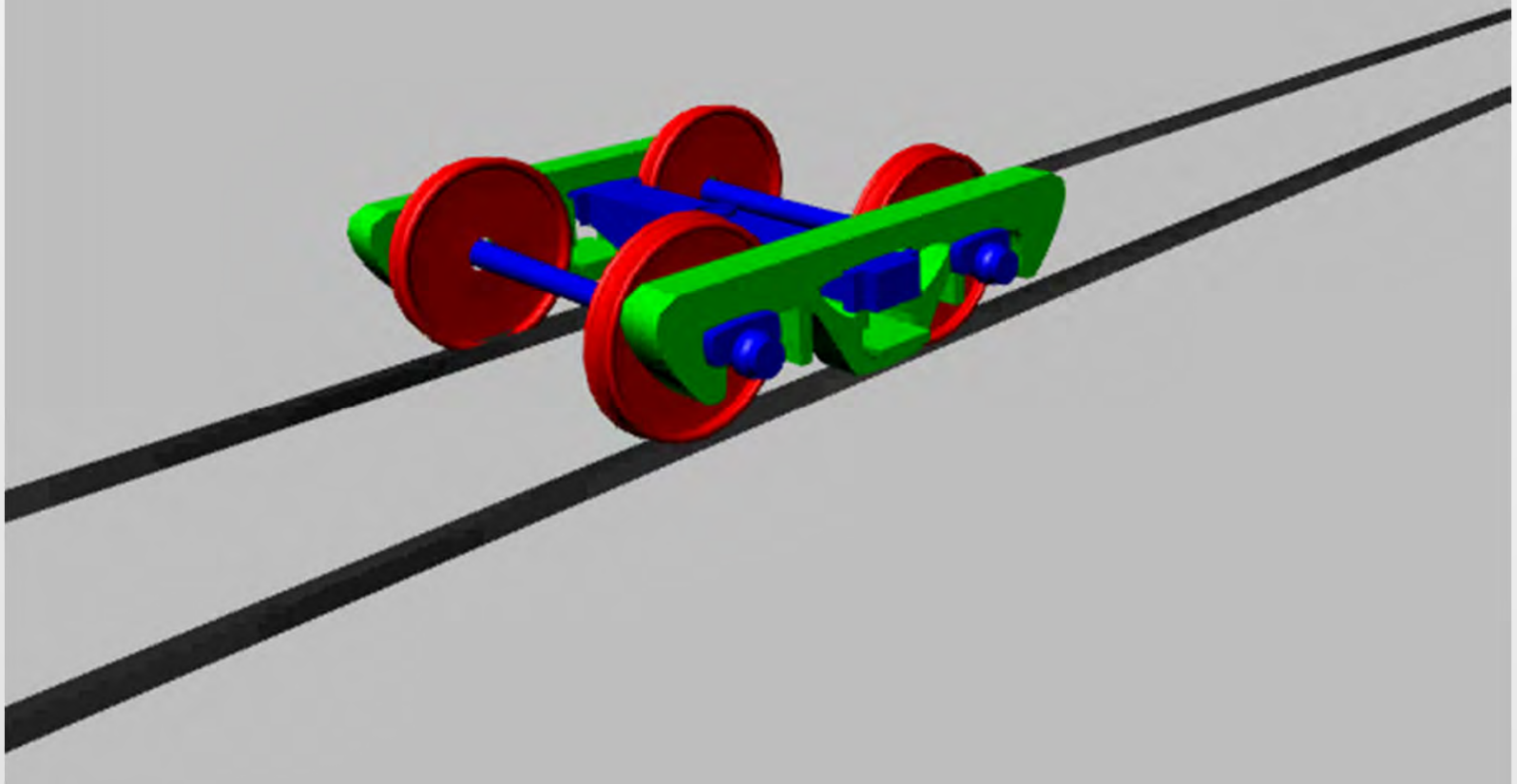


90 Degrees



Hunting Oscillation of a Tapered (Conical) Wheelset

Truck Hunting



Hunting Speed Response

Hunting Severity

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



Lateral
G's

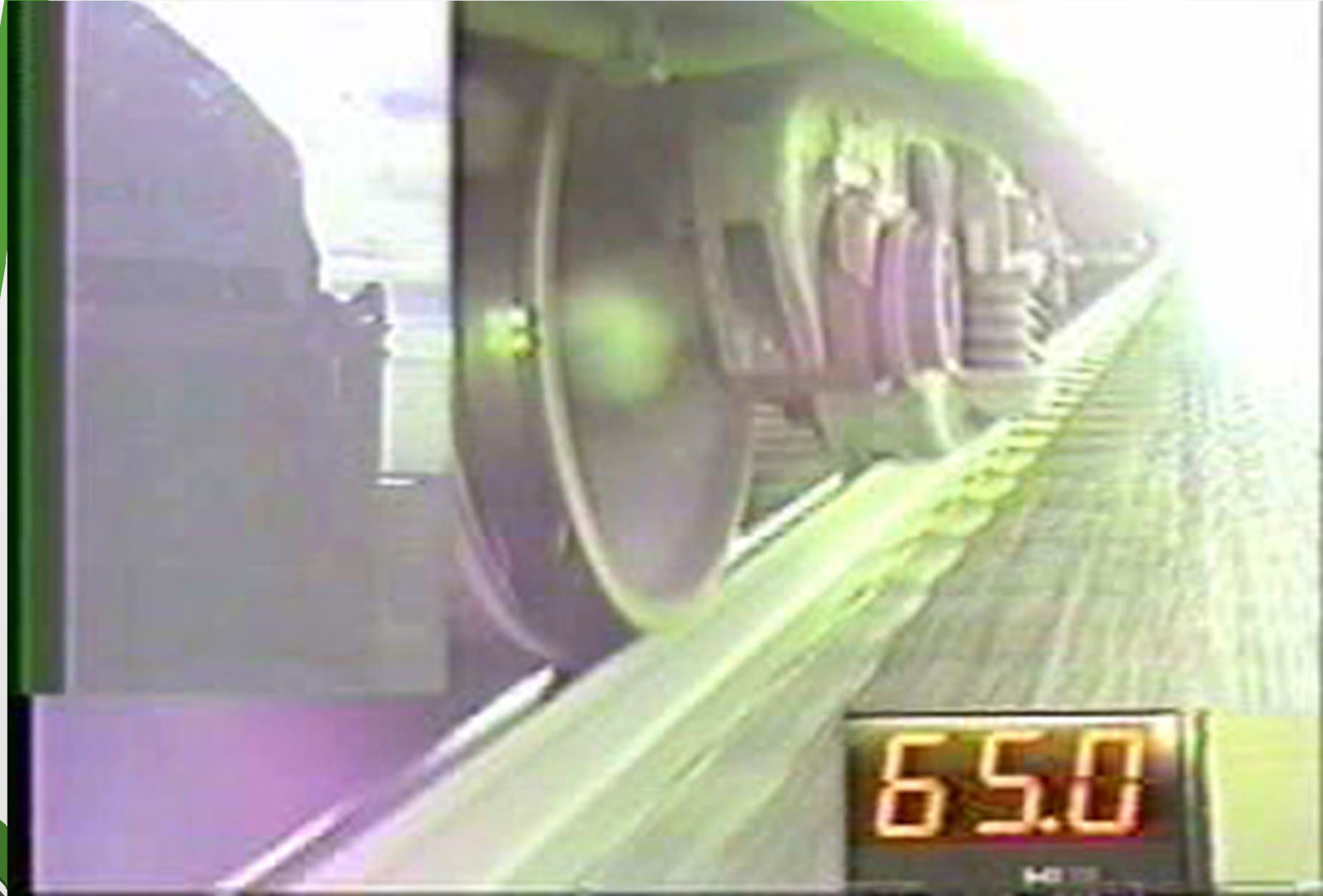
Critical Speed for
Most Cars

Speed MPH

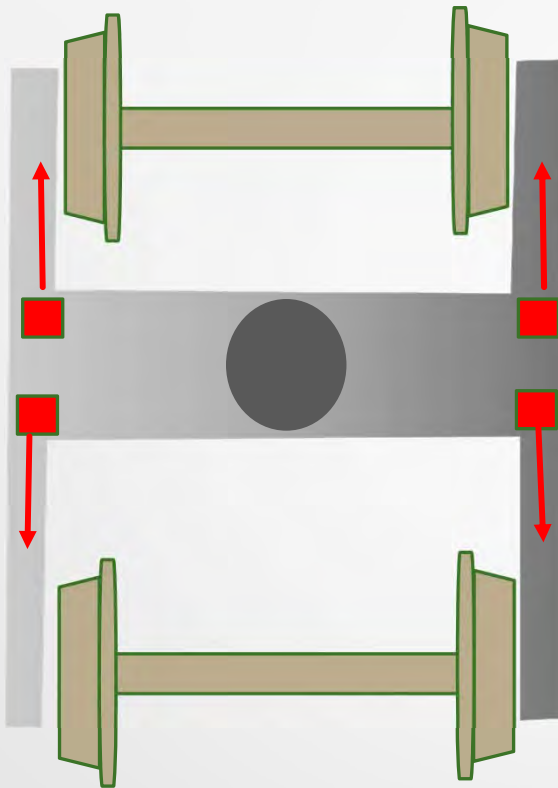
10 20 30 40 50 60 70 80

WOLF
Railway Consulting

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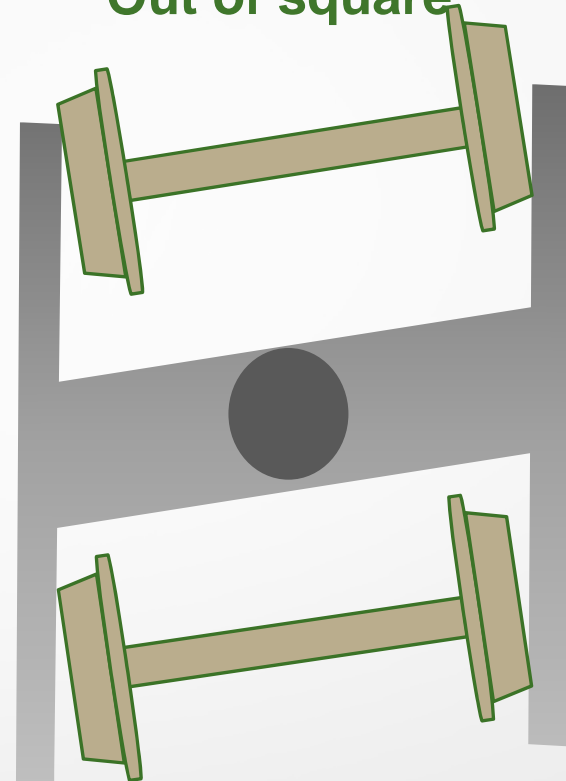


**Truck Stable
Remains Square**



**Friction wedges
Provides squaring
force**

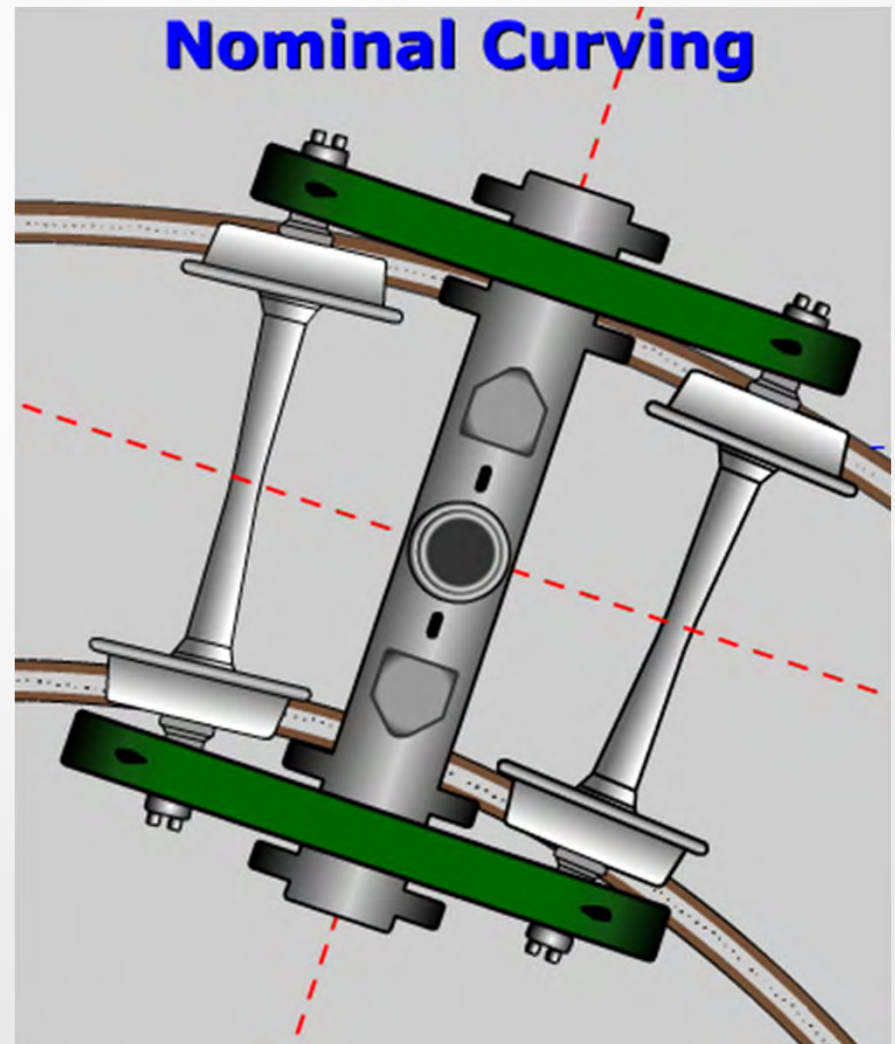
**Truck Hunting
Bolster sideframe
Out of square**



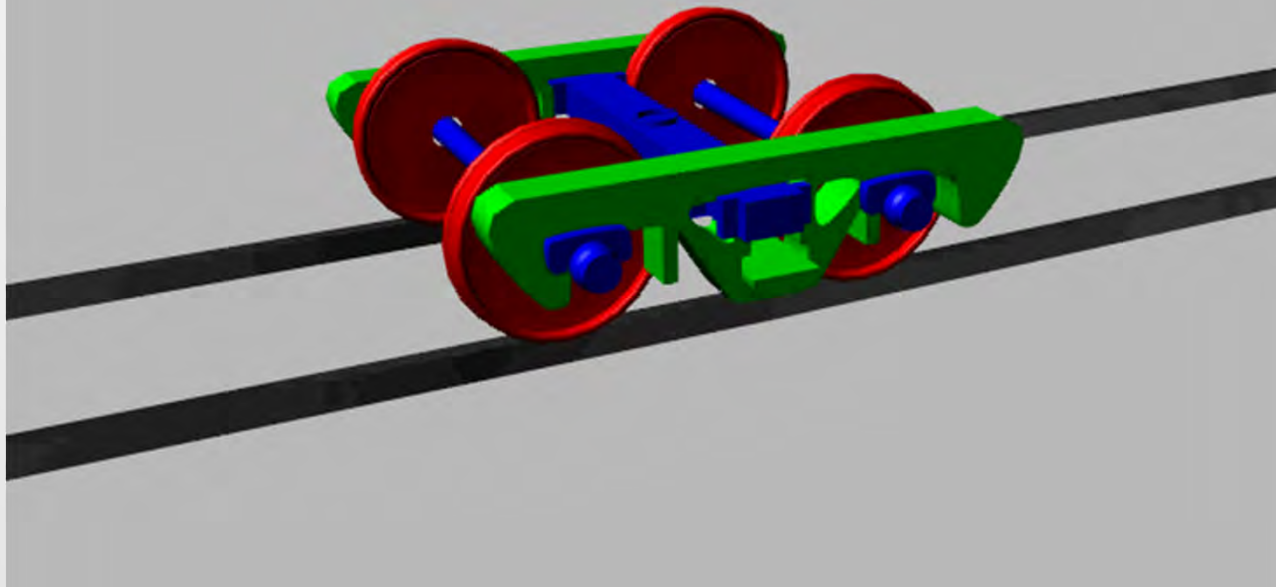
**Friction wedges worn
providing no
squaring force**

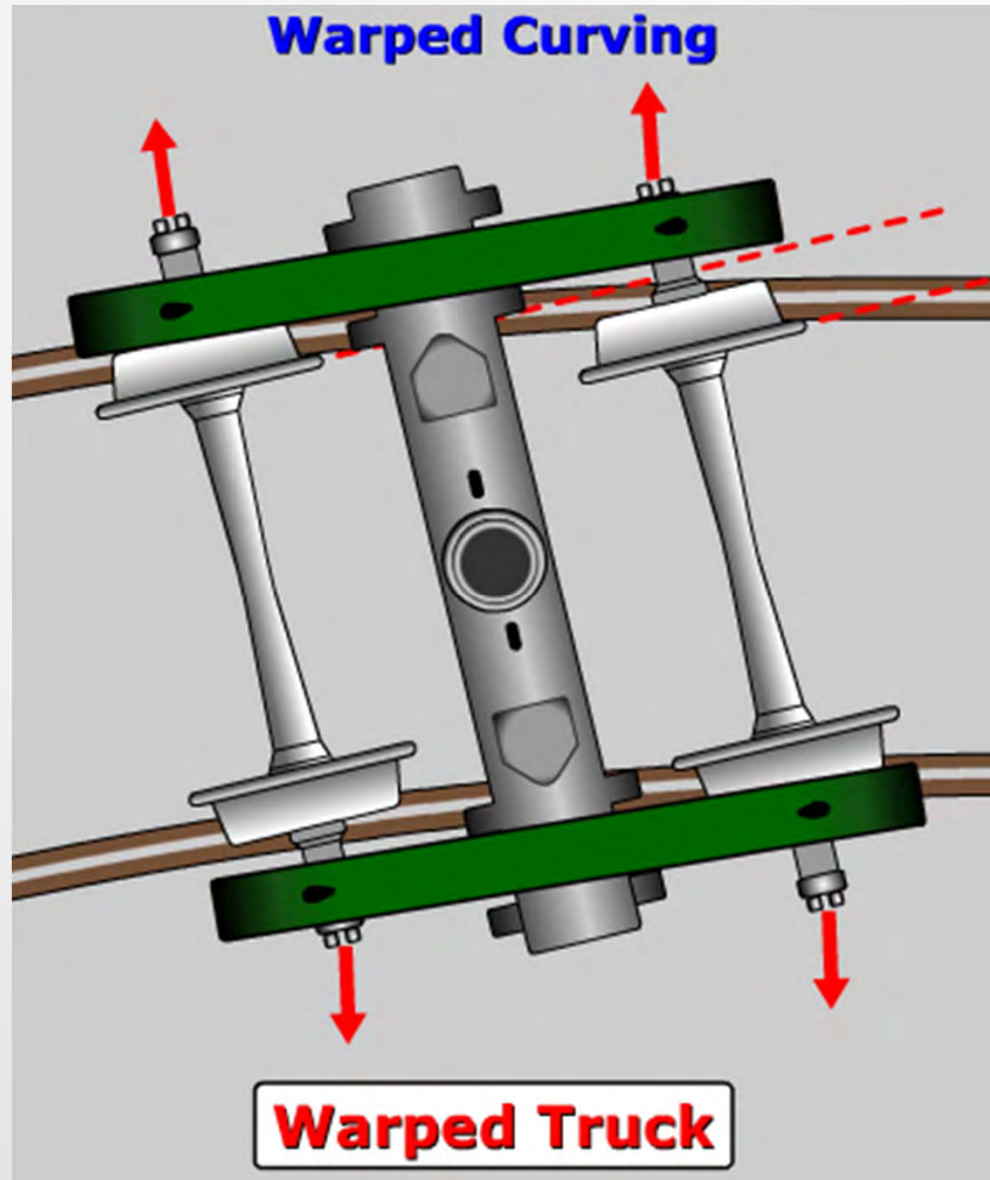
Truck Warp Restraint

Ideally, a truck should remain “Square” during curving to allow radial alignment of wheelsets with curve

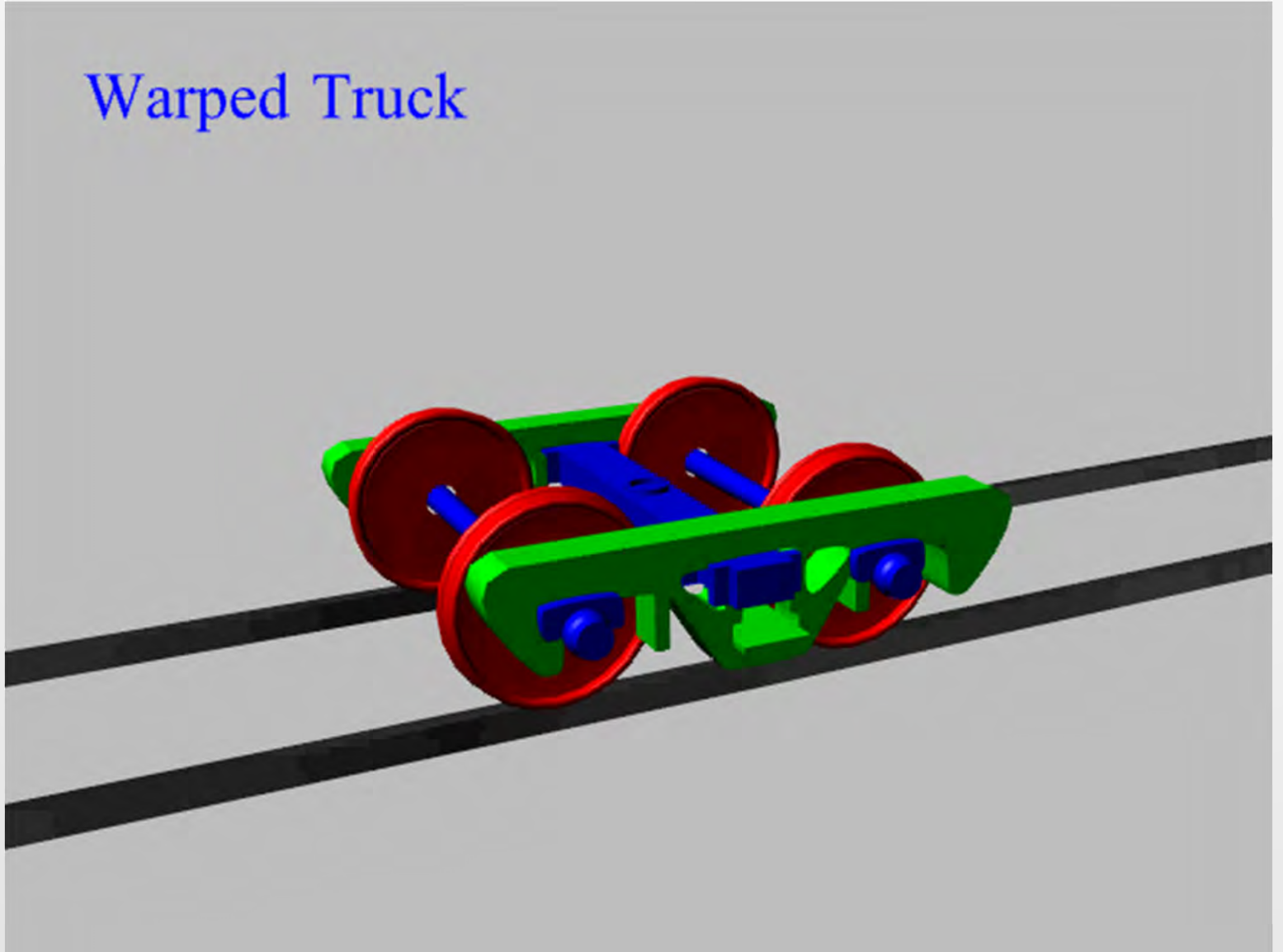


Nominally Curving Truck

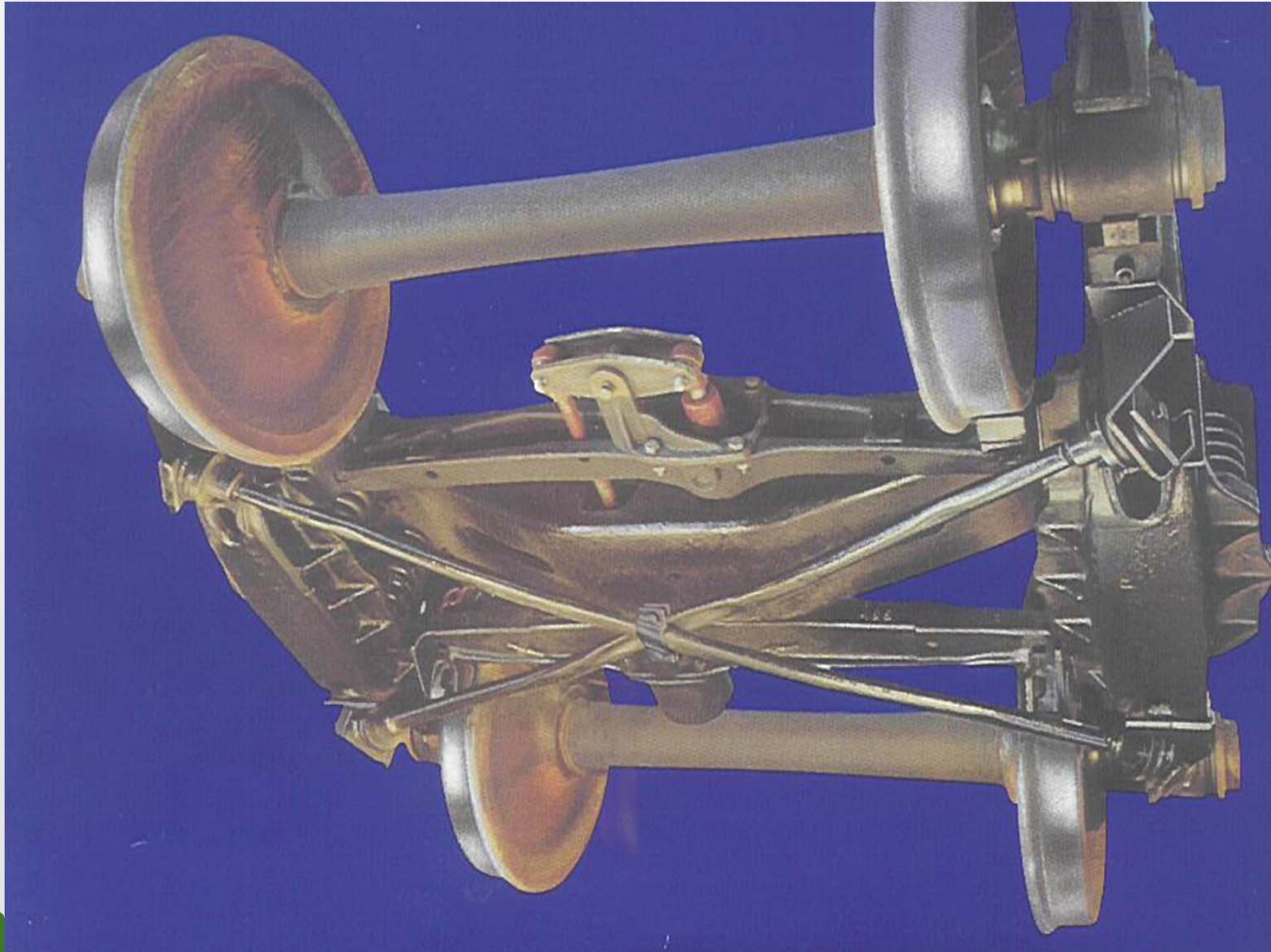




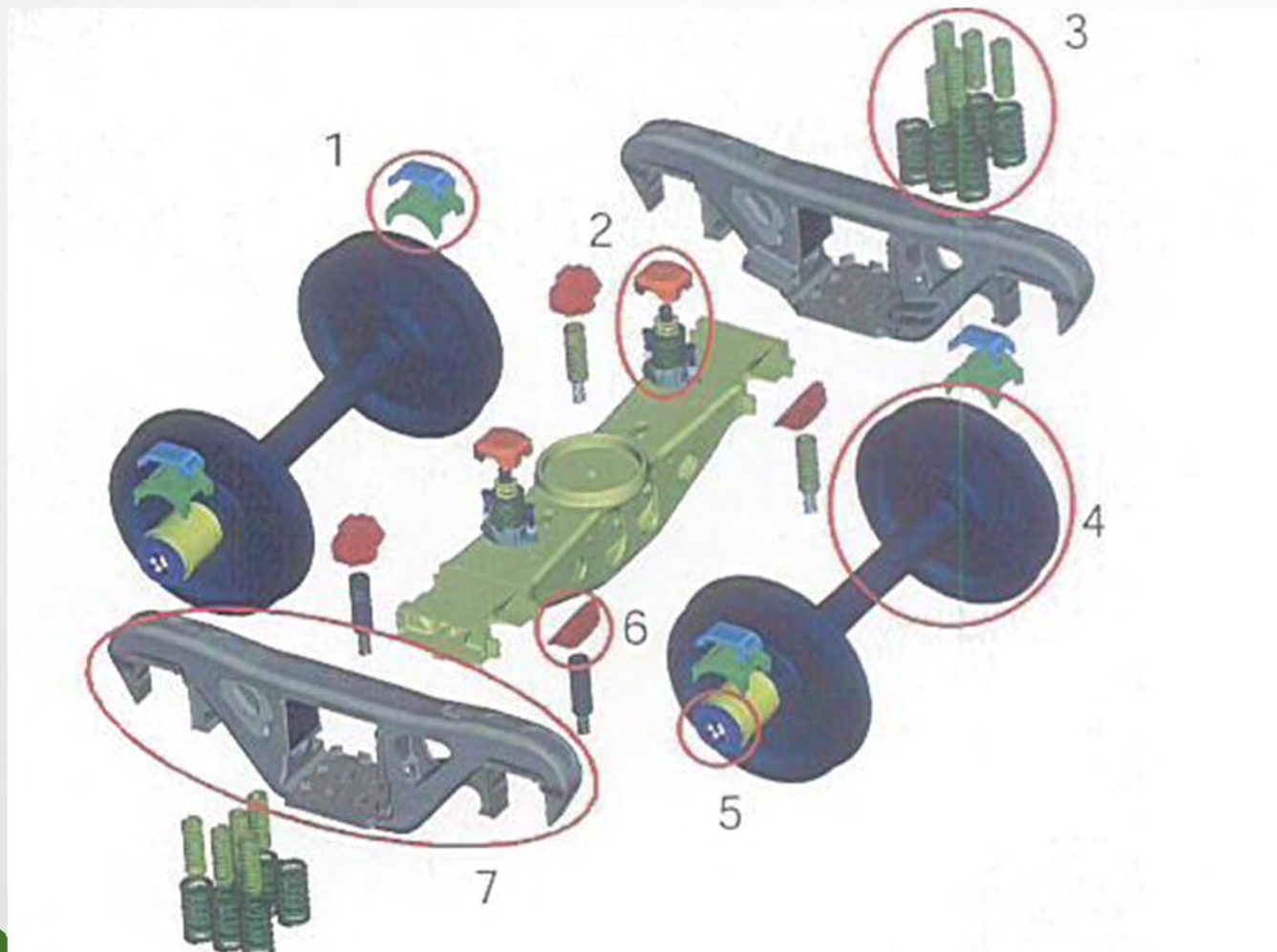
Warped Truck

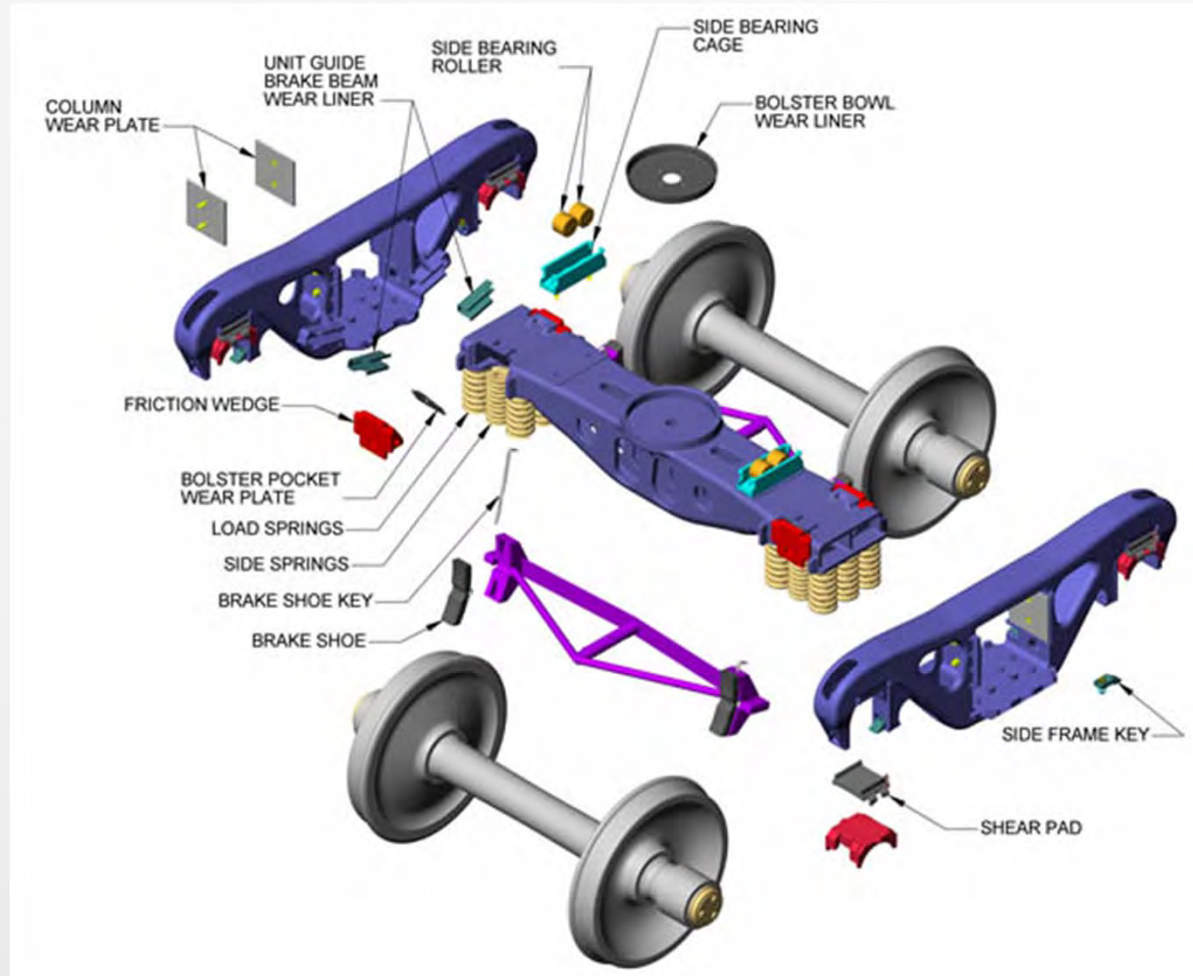


Barber Frame Brace Truck



ASF Motion Control Truck





Barber Stabilized S-2 M976 Truck



The End

Truck Suspension Basics