

The background features a red and white globe with a grid pattern. A black horizontal band is positioned across the middle of the slide. The Firestone logo is written in a stylized, red, serif font. Below the logo, the text "World's Number 1 Air Spring." is written in a white, sans-serif font. To the right of this text is a small icon of an air spring. Below the icon, the text "FIRESTONE INDUSTRIAL PRODUCTS COMPANY" is written in a small, white, sans-serif font.

Firestone

*World's Number 1
Air Spring.*



FIRESTONE INDUSTRIAL PRODUCTS COMPANY

Advantages of Incorporating Air Springs into Hotchkiss-style Suspension

Brad Hayes
Light Duty Engineering Manager
Firestone Industrial Products
23 October 2008

BRIDGESTONE

Bridgestone Europe



Bridgestone Japan

Bridgestone Firestone North American Tire, LLC

BFS Retail & Commercial Operations, LLC

Firestone
DIVERSIFIED PRODUCTS

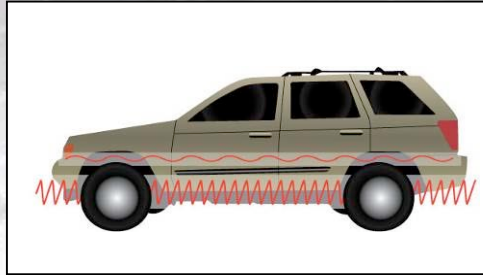
Bridgestone Firestone Latin America

Bridgestone Americas Center of Research and Technology, LLC



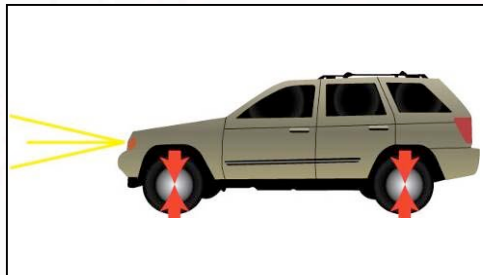
Air Suspension Advantages

Truck/SUV Rear Axle Leveling System



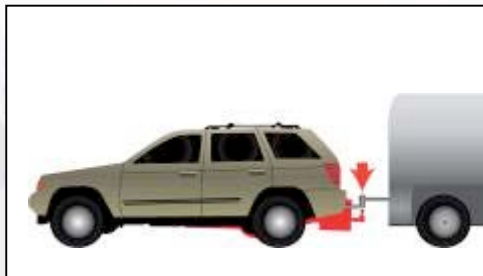
RI DE COMFORT

- Full suspension travel (load independent)
- Body always at ride-height
- Allows softer spring rate



LOAD LEVELING

- Ride-height
 - Improved headlight aim
 - Driveline angles
- } Independent of Load



TRAILER TOWING

- Constant, level height
- Coupling mode
- Towing mode

Firestone

World's Number 1
Air Spring.



FIRESTONE INDUSTRIAL PRODUCTS COMPANY

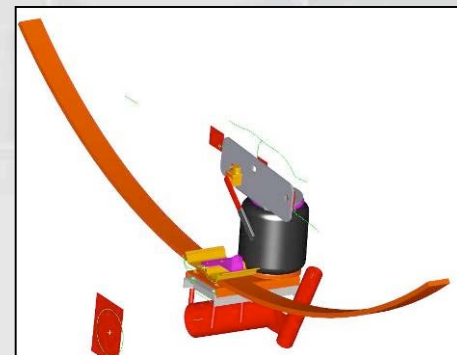
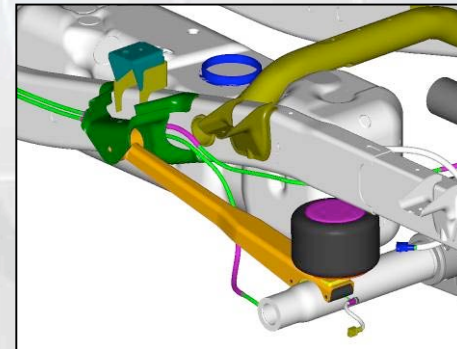
Light & Medium Duty Market Segment

Light and Medium duty trucks are utilized in a wide range of loading conditions

- From unloaded daily driving to heavy load 5th wheel towing
- It is difficult to optimize steel suspension ride and handling for such a wide range of load cases
- This market segment is ideal for further air suspension penetration

Why has air suspension not reached this market at the OE level?

1. Complexity of full air suspension
 - This makes it difficult to offer an air suspension option at the OE level (cost, capital investment, validation requirements, etc...)
2. Minimal benefit of adding air springs to traditional Hotchkiss suspension
 - Compromised between ride improvement and axle control



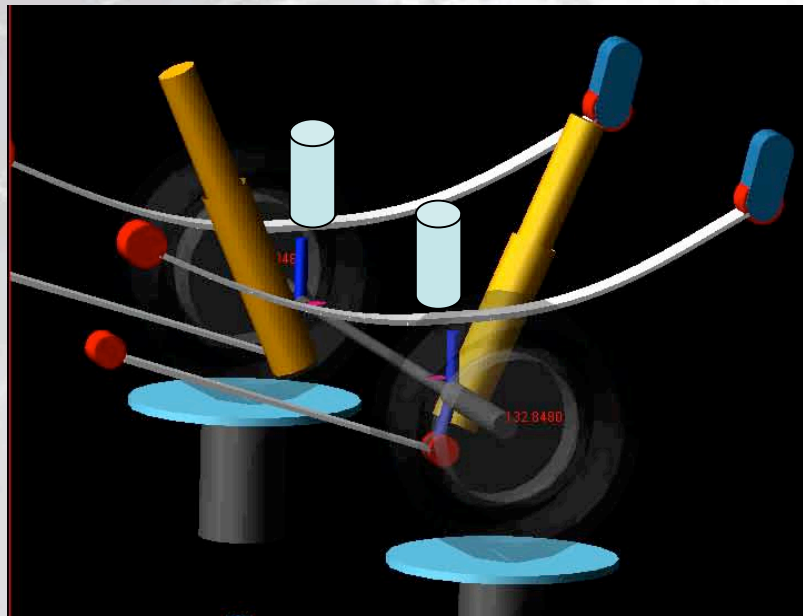
Firestone
World's Number 1
Air Spring.

FIRESTONE INDUSTRIAL PRODUCTS COMPANY

Firestone & SANLUI S Rassini Collaboration



+



To address the challenges of incorporating air suspension into a traditional Hotchkiss suspension, Firestone collaborated with SANLUI S Rassini to apply air springs to the R4Tech suspension

The Result → AIR4Tech



AIR4Tech Functional Objectives

The AIR4Tech suspension system was developed to meet the following objectives:

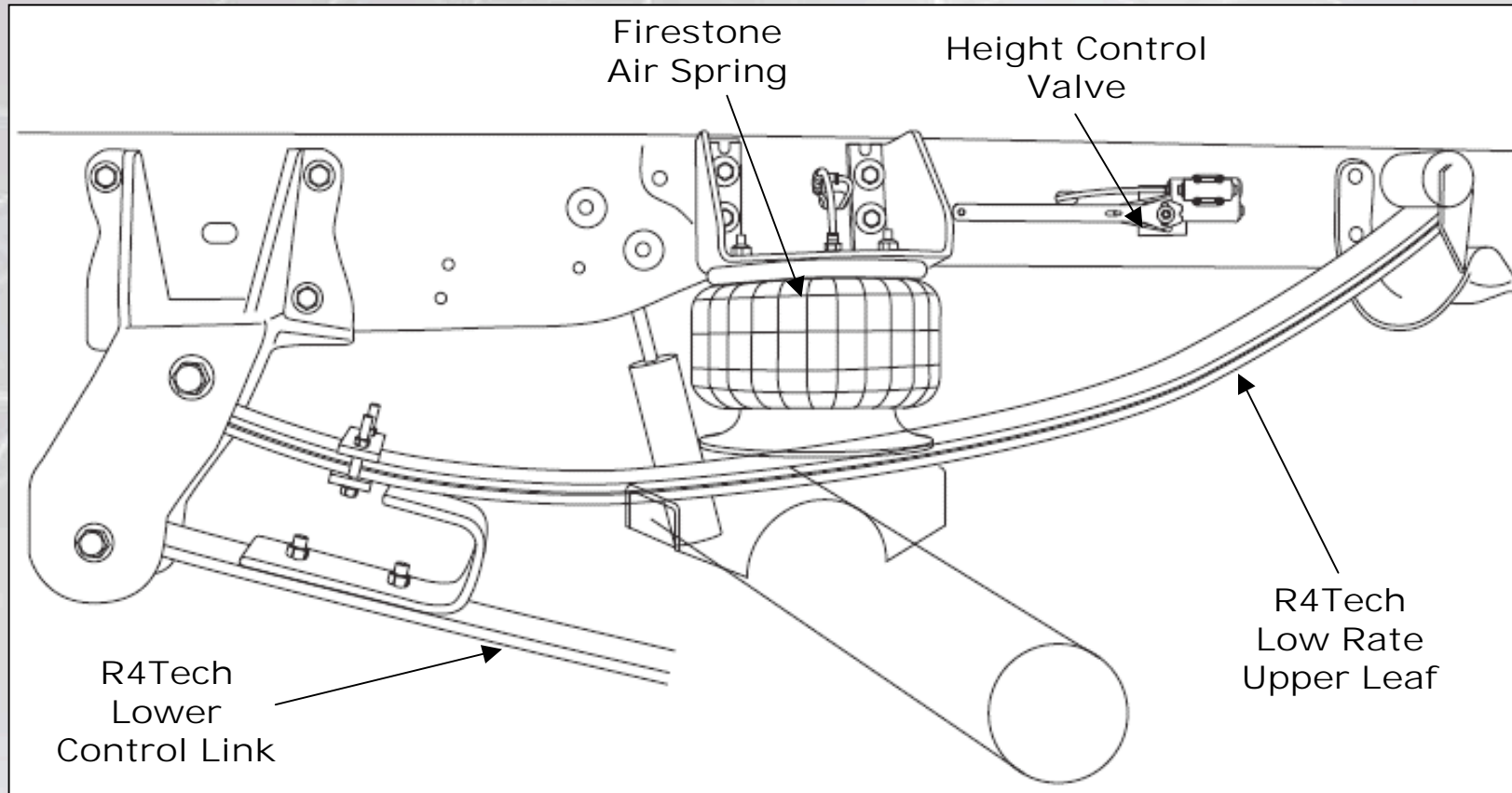
1. Fit air leveling suspension into OEM leaf spring envelope
2. Improve unladen ride quality
3. Maintain (or improve) laden ride quality
4. Maintain (or improve) axle windup control
5. Implement rear-leveling and rear-kneel functionality
6. Reduce weight
7. Potential to increase payload
8. Maintain safety (limit handling, evasive maneuvers)

Firestone

World's Number 1
Air Spring.

FIRESTONE INDUSTRIAL PRODUCTS COMPANY

AI R4Tech Suspension



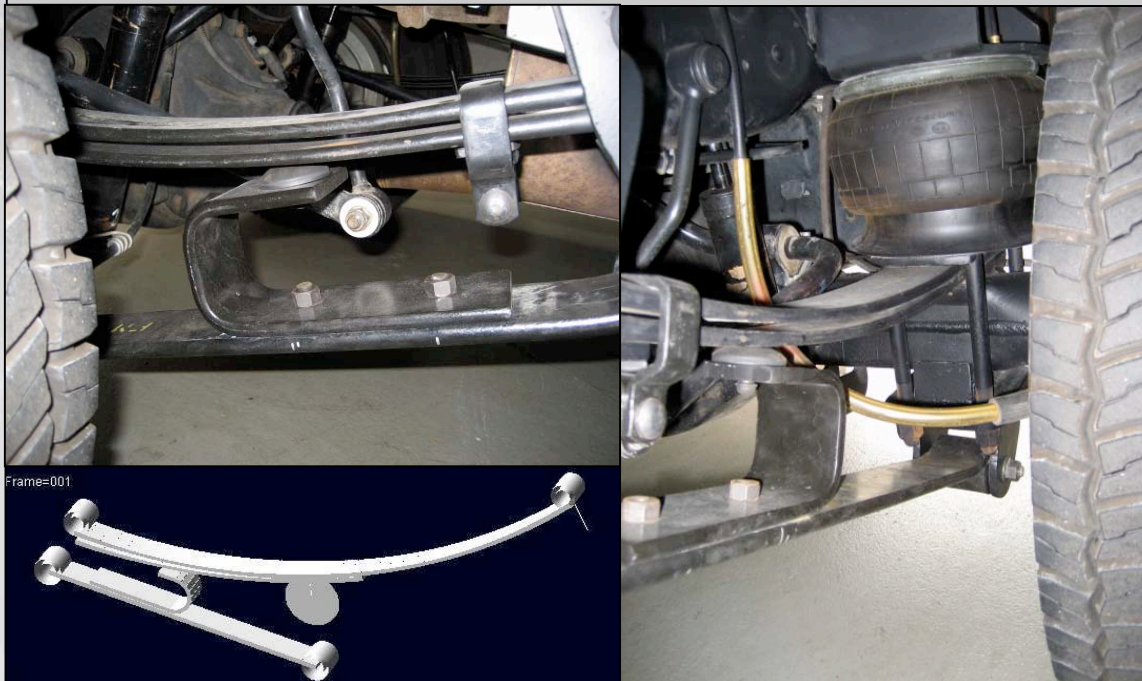
Firestone
World's Number 1
Air Spring.

FIRESTONE INDUSTRIAL PRODUCTS COMPANY

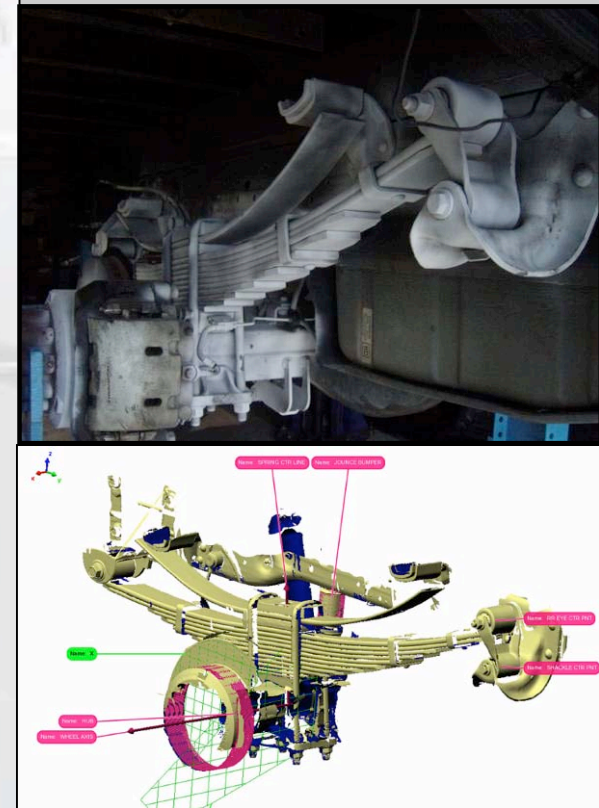
AIR4Tech Suspension Packaging

Initial development has been done on 1 ton and 1½ ton pickup truck and chassis cab applications

AIR4Tech Air Suspension



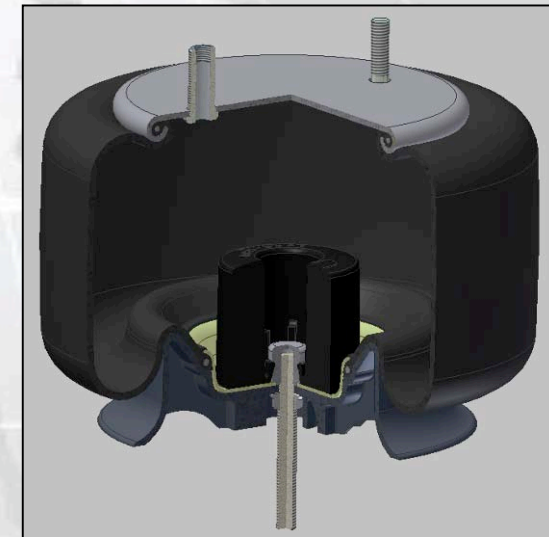
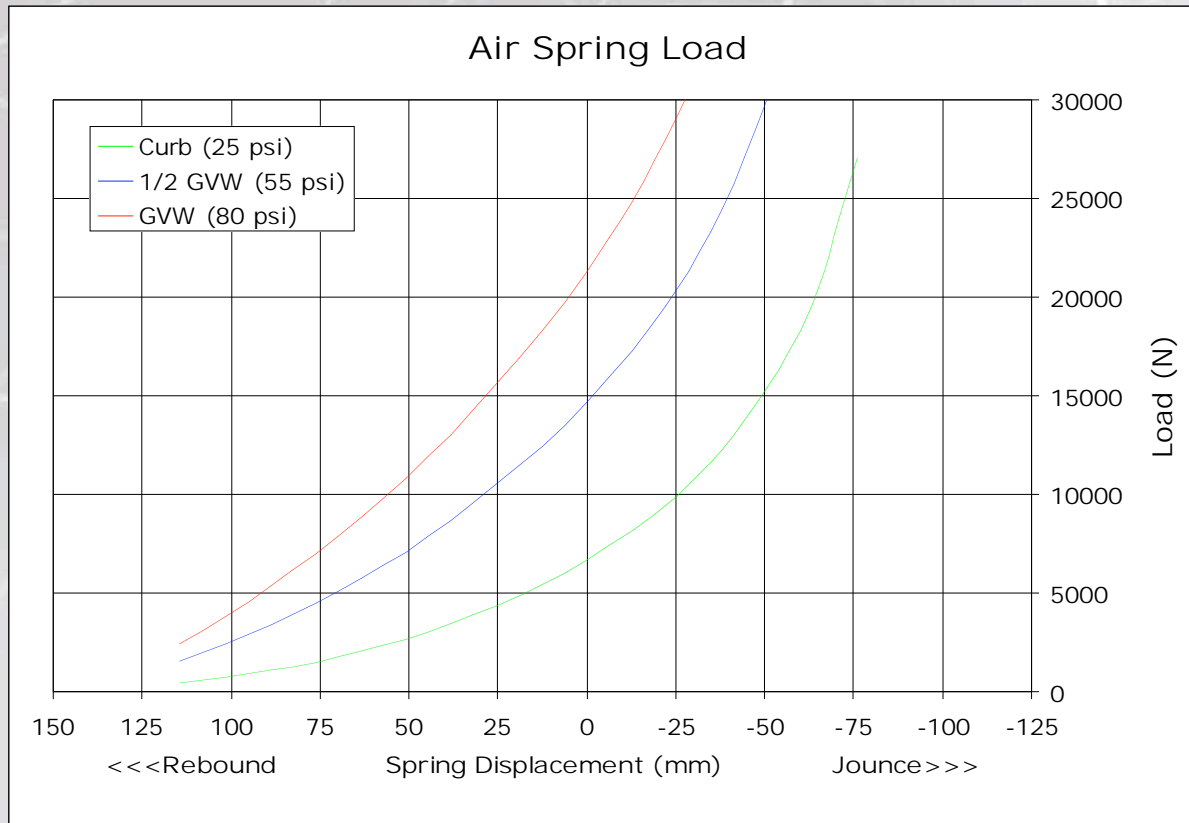
OE Suspension



Firestone
World's Number 1
Air Spring.

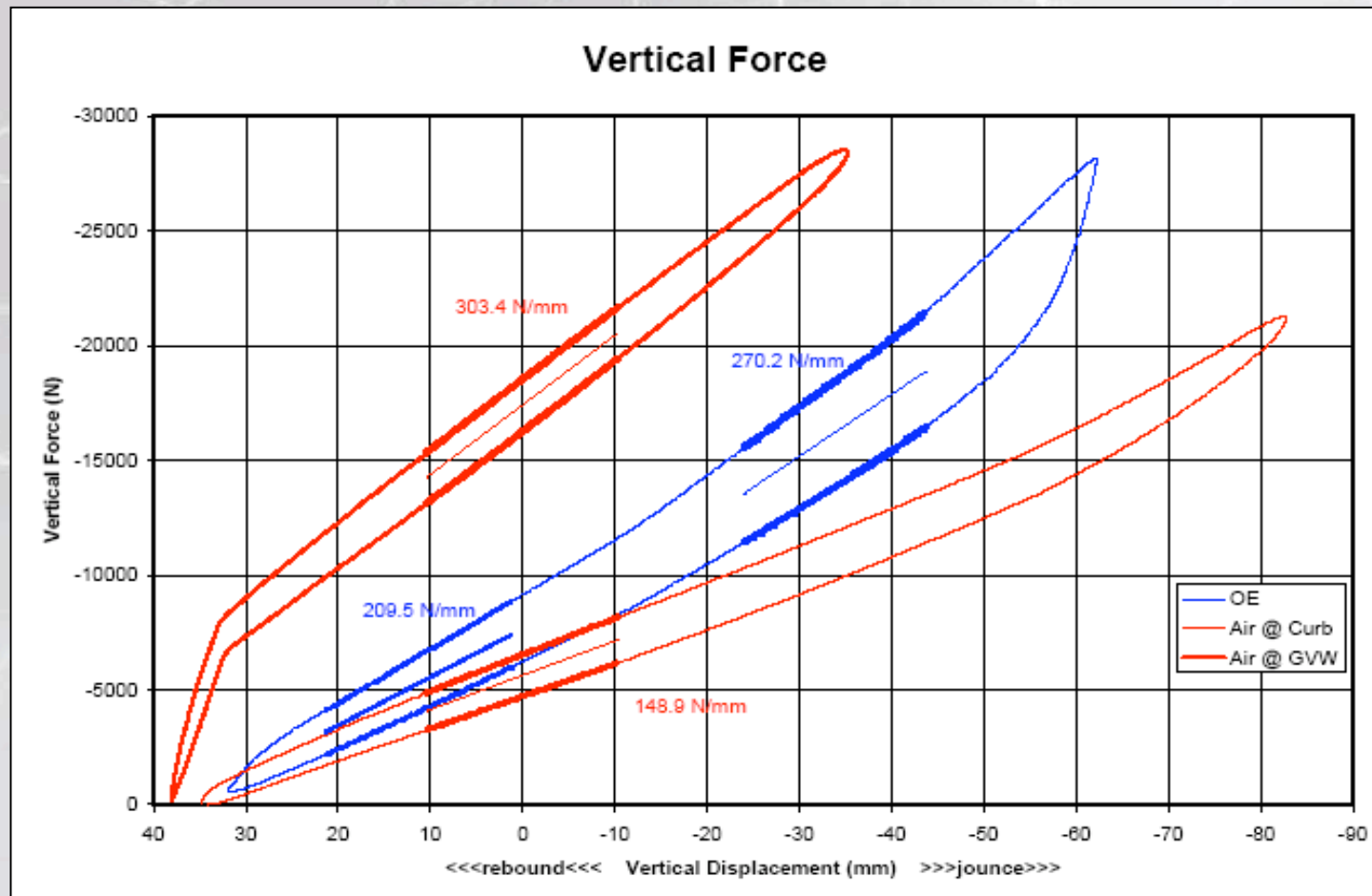
FIRESTONE INDUSTRIAL PRODUCTS COMPANY

Air Spring Load Contribution



Air spring provides increased spring rate with increased load

System Spring Rate Comparison

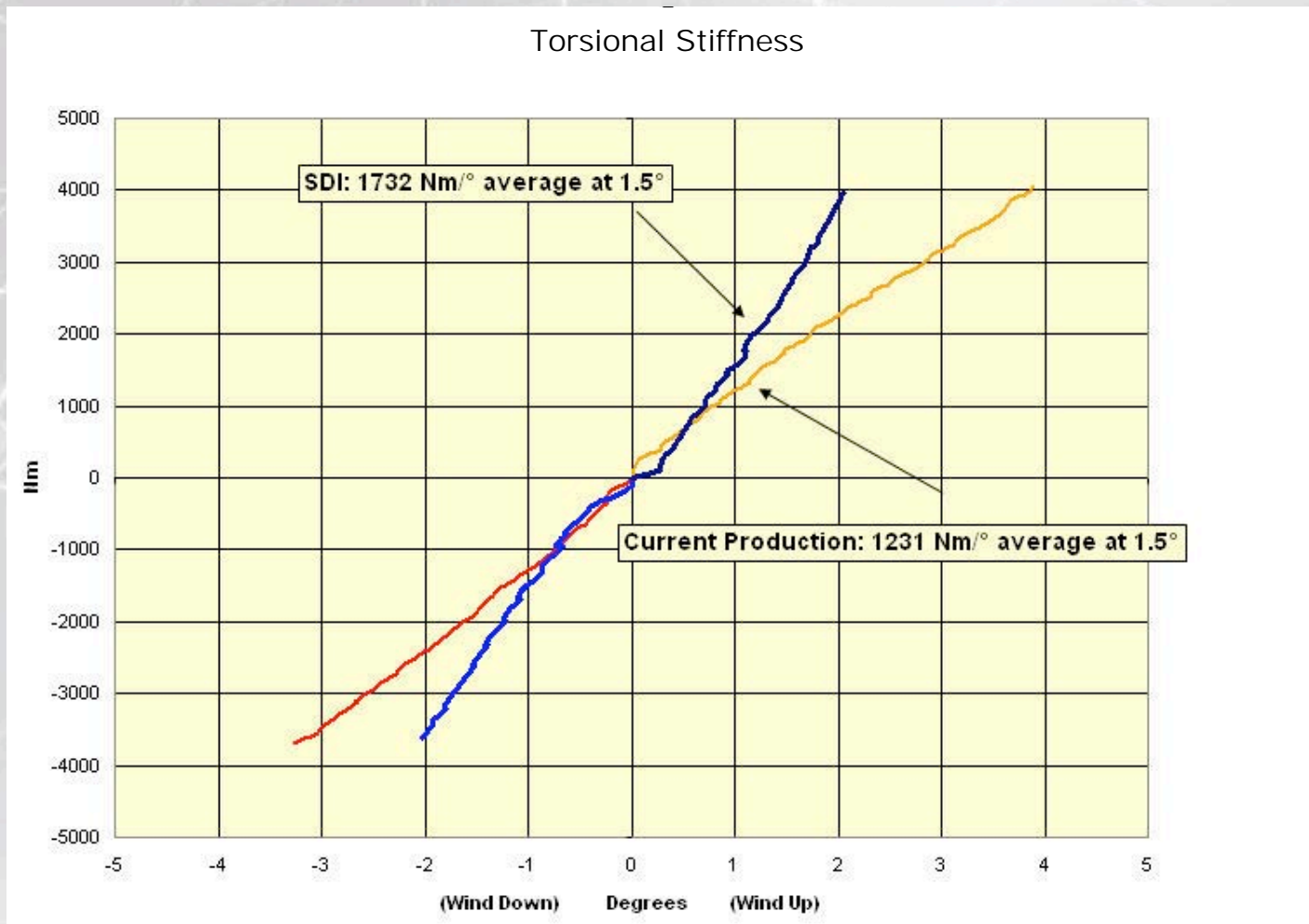


Air spring provides increased spring rate with increased load

More consistent ride frequency over a wide range of load conditions

Firestone
World's Number 1
Air Spring.
FIRESTONE INDUSTRIAL PRODUCTS COMPANY

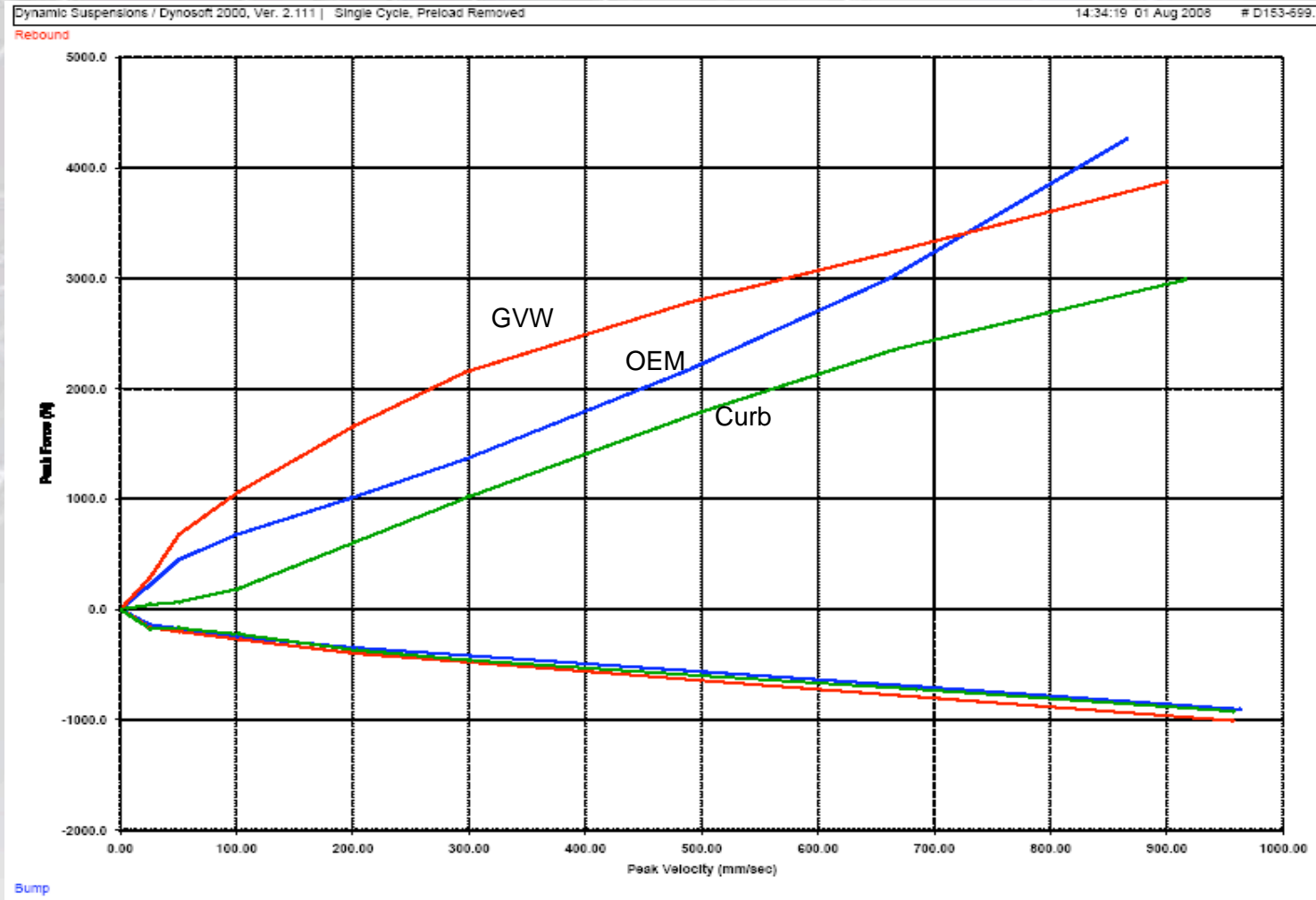
Axle Windup Control



Firestone
World's Number 1
Air Spring.
FIRESTONE INDUSTRIAL PRODUCTS COMPANY

40% Improvement in
Windup Stiffness

Load Adaptive Damping



Firestone
World's Number 1
Air Spring.
FIRESTONE INDUSTRIAL PRODUCTS COMPANY

Damping increases with air spring pressure, allowing more optimized damping at both curb and GVW loads

Qualitative Ride Evaluation

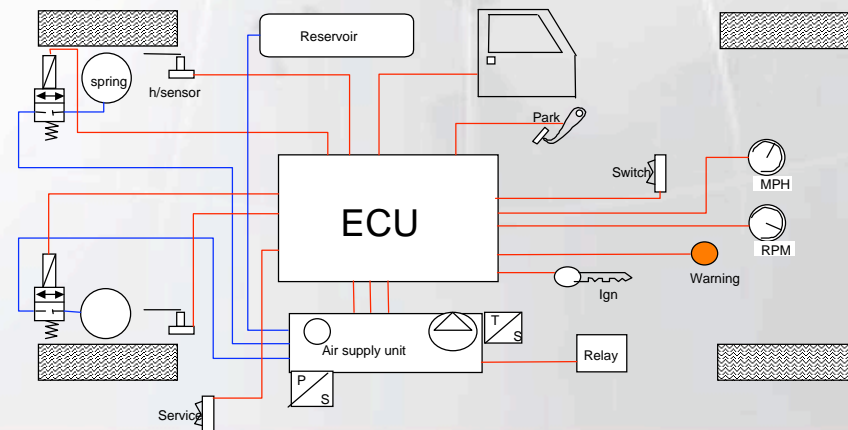
Load		CURB + 2pass		50% GVW	
Suspension		OEM Leaf	AIR4Tech	OEM Leaf	AIR4Tech
Evaluation Item					
<i>Impact</i>	25 mph	6	8	6.5	7.75
<i>Harshness</i>	50 mph	6.5	8	7	7.75
<i>Impact</i>	25 mph	7	7.5	7	7
<i>Boom/Noise</i>	50 mph	7	7.5	7	7
<i>Pitch Balance</i>		7	7.5	7	7.5
<i>Damping</i>		7	8	7	8
<i>Shake</i>		6	6.5	7	7
<i>Pothole</i>		5	7.5	6	7
<i>Plushness</i>		5	7	6	7.5
<i>Beaming</i>		6	8	7	8.5
<i>Crashthrough</i>		8	8	8	8
<i>Spring Slap</i>		6	9	5	9
Overall Rating		6.5	8	7	7.5

Ride evaluation conducted by:



Control System Options

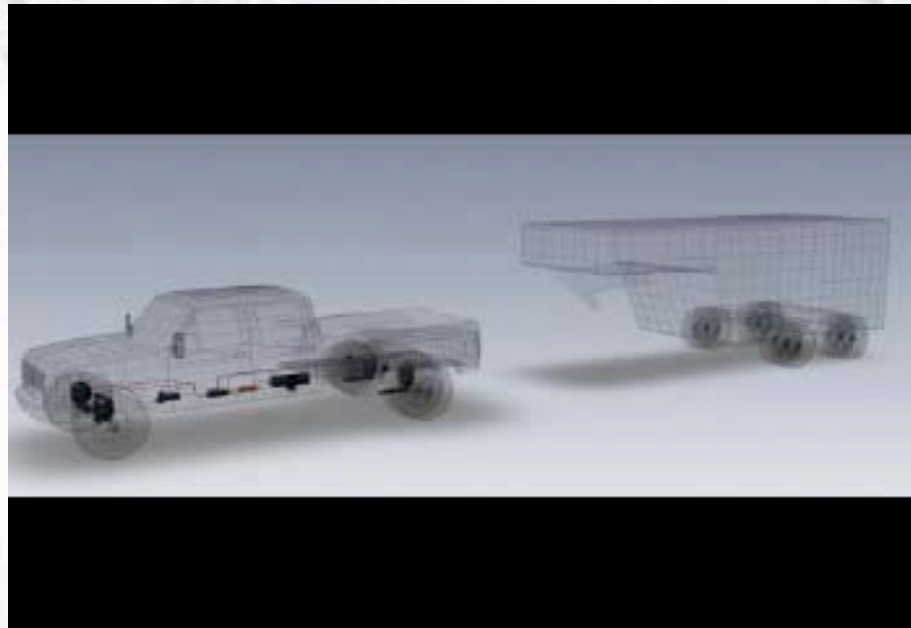
Features	Mechanical Valve	Mechanical Valve with Dump	Electronic System
Rear Load Leveling	•	•	•
Rear Kneel		•	•
Driver Interface		•	•
Communication Over Vehicle Network			•
Safety Features			•
Multiple Heights			•
Load Sensing ($\pm 5\%$)			•



Firestone
 World's Number 1
 Air Spring.
 FIRESTONE INDUSTRIAL PRODUCTS COMPANY

Kneeling Feature

By “dumping” air pressure from springs, rear of vehicle can kneel for easy trailer hitching...



Firestone

World's Number 1
Air Spring.



FIRESTONE INDUSTRIAL PRODUCTS COMPANY

Kneeling Feature

...or for easy loading in ambulance or delivery vehicle applications



Firestone

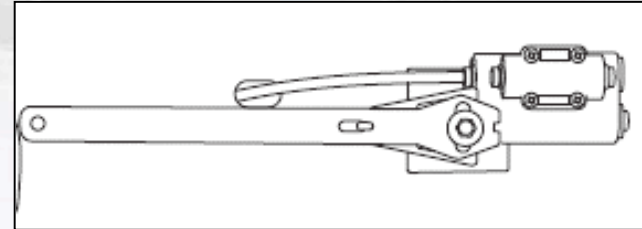
World's Number 1
Air Spring.

FIRESTONE INDUSTRIAL PRODUCTS COMPANY

Control System Components

Mechanical Valve Control System

- Mechanical Height Control Valve
- Air Supply Unit
- Reservoir



Electronic Control System

- ECU
- Air Supply Unit
- Reservoir
- 2 Height Sensors
- Valve Block
- Control Panel



Control System Details

As applied to 1½ ton truck application

- Electronic suspension control system
 - Continuously monitors suspension height
- Multiple vehicle inputs
 - Two user-selectable heights
 - Lowered height aids loading and trailering (-60mm at axle)
- Unique load measuring software
 - Provides real-time user feedback of vehicle weight
 - Allows user to efficiently utilize full cargo capacity
 - Alerts driver of overload conditions
 - Data can be recorded for warranty evaluation purposes
 - Data can feed back to ESC systems
- Electric Compressor with integrated exhaust valve and air dryer
- Air reservoir for rapid height change response
- Load Adaptive dampers enable ride tuning at various load conditions

Firestone

World's Number 1
Air Spring.



FIRESTONE INDUSTRIAL PRODUCTS COMPANY

Mass Reduction

AIR4Tech Air Suspension Saves Considerable Mass Compared to Full Steel Suspension

	OE Suspension	AIR4Tech Air Suspension
Leaf Spring Components	130.9	57.9
Air Springs	-	7.2
Pneumatic Components	-	18.1
Total System Mass (kg)	130.9	83.2

47.7 kg Mass Reduction on typical 1½ ton truck

Vehicle Dynamics Advantages



- Lower CURB ride frequencies possible
- Ride frequency nearly constant over load range
- More wheel travel at GVW, less input to frame through jounce bumpers
- Roll stiffness automatically increased with load
- Roll centers do not move vertically with load
- Potential for progressive, linear or digressive spring rates
- Reduced unsprung mass

Results vs. Objectives

1. Fit air leveling suspension into OEM leaf spring envelope
 - *Air springs fit in to existing vehicle space*
 - *R4Tech components mount to existing hangers*
2. Improve unladen ride quality
 - *Overall +1.5 pts*
3. Maintain (or improve) laden ride quality
 - *Overall +0.5 pts*
4. Maintain (or improve) axle windup control
 - *40% Improvement*
5. Implement rear-leveling and rear kneel functionality
 - *Can achieve -60 mm kneel height*
 - *Maintains height regardless of load*
6. Reduce suspension system mass
 - *Reduced by 47.7 kg*
7. Maintain safety

Items for further consideration:

1. Loaded roll under-steer characteristics
2. Optimization of spring load inputs to frame
3. Optimization of wheel travel

Firestone

World's Number 1
Air Spring.



FIRESTONE INDUSTRIAL PRODUCTS COMPANY

The Bottom Line!!

- Improved ride characteristics under all loading conditions
- Level ride under all loading conditions
- Lower loading height capability with kneel feature
- Lighter suspension weight



Firestone
World's Number 1
Air Spring. 
FIRESTONE INDUSTRIAL PRODUCTS COMPANY