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## Analysis of Side Bearing Configuration on Lightweight Flatcars

by Corey Pasta and Nicholas Wilson

### Summary

The choice of side bearing design and preload must be made by careful analysis of vehicle steering performance and expected vehicle operating conditions.

In an Association of American Railroads' Strategic Research Initiative, Transportation Technology Center, Inc. (TTCI) studied the importance of side bearing design for a 5-platform lightweight flatcar allocated to high-speed service. Testing conducted at the Transportation Technology Center (TTC), Pueblo, Colorado, showed unacceptable steering performance with the original side bearing design.

As a result, TTCI engineers conducted a comprehensive analysis of side bearing configurations to improve the performance of the vehicle. This effort, which included track tests and NUCARS™ simulations, led to a side bearing selection providing safe performance and acceptable high-speed stability.

The studies conducted in this research offer several general issues that should be addressed for any new vehicle design that includes constant-contact side bearings. Side bearing preloads, functionality, and placement should be chosen such that:

- Side bearings do not "bottom out" in expected operating conditions.
- Side bearing preloads provide a turning moment such that hunting is prevented at design operating speeds, yet still allow safe steering performance.
- Vertical wheel unloading is minimized in standard operation.



**TTCI**  
Transportation  
Technology Center, Inc.

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## INTRODUCTION AND CONCLUSIONS

The Association of American Railroads created a Strategic Research Initiative (SRI) to provide guidelines in the design and operation of special cars. In 2001, the SRI focused on a 5-platform lightweight flat-car designed for high-speed service.

Track testing showed that the original vehicle design had good high-speed stability. However, the vehicle exceeded Chapter XI lateral to vertical (L/V) criteria in curve entry and exit conditions. TTCI engineers investigated various side bearing configurations to find a solution that would improve steering performance while maintaining stability at high speeds.

A combination of track testing and NUCARS™ simulations showed that several factors limited the steering performance of the original design. The level of preload in the side bearings created large truck turning moments that resisted truck rotation and created high axle angles of attack. The large axle angles of attack caused some wheels to develop large lateral forces and high L/V ratios. In addition, the side bearings bottomed out in certain cross-level conditions increasing the turning moments and causing vertical wheel unloading. The arrangement of the side bearing at the articulated joints caused the F-truck to be sensitive to the poor steering.

Steering performance was improved by introducing lower preload side bearings with long-travel capability at critical positions in the vehicle. The revised side bearing design continued to provide acceptable high-speed stability performance.

Although the 2001 testing was specific to the 5-platform flatcar, the following conclusions can be generalized from the study:

- By design, side bearing equipped lightweight vehicles improve high-speed stability at the expense of steering performance.
- Multi-platform (articulated) vehicles will likely require different side bearing performance at the end trucks rather than the intermediate trucks.
- Side bearing selection should prevent the bottoming out of any side bearing in design operating conditions.
- Side bearing preload values should be chosen such that the induced truck turning moments allow for steering under expected operating conditions.

## VEHICLE DESCRIPTION

The test vehicle, shown in Exhibit 1, is a 5-platform intermodal car. The vehicle weighs 130 tons, is approximately 330 feet long, and is designed for high-speed service.

The A- and B-end trucks are a 70-ton design and use two constant-contact side bearings for high-speed stability, up to 100 mph.

The four intermediate articulated trucks are a 100-ton design with four constant-contact side bearings. Two of the side bearings are positioned near the centerbowl to support the platform closest to the B-end. The other two side bearings support the next (adjacent) platform. Exhibit 2 shows the end-trucks and intermediate-truck side bearing configurations, and Exhibit 3 shows the entire vehicle.



Exhibit 1. 5-Platform Test Car

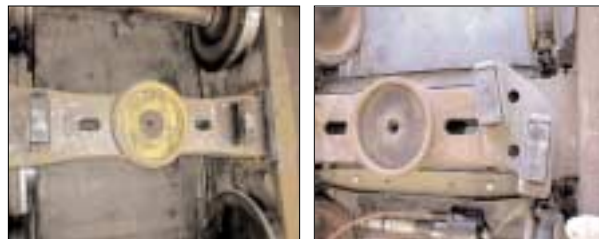


Exhibit 2. End and Intermediate Truck Side Bearing Configurations

### Original Side Bearing Configuration

The original short-travel design specified 5,400-pound preload side bearings at every location.

### Side Bearing Evaluations

A series of side bearing tests were conducted to investigate the impact of turning resistance on steering performance. These tests showed that acceptable steering performance could be achieved on the articulated car with 5,000-to 5,400-pound preload side bearings at the end-trucks and 4,000-to 4,500-pound preload long-travel side bearings at the intermediate trucks.

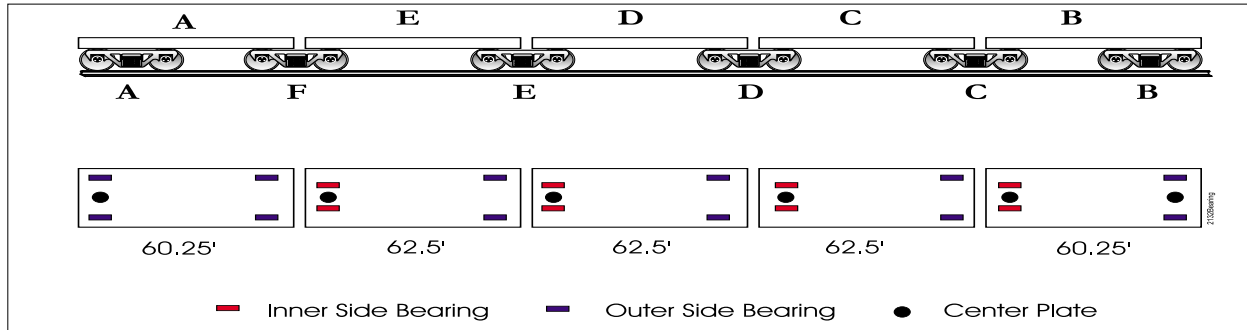


Exhibit 3. Block Diagram of Vehicle

### LIMITING SPIRAL TEST RESULTS

The limiting spiral test measures a car's ability to equalize vertical loads in negotiating curve entry and exit spirals. Exhibit 4 shows that empty- and loaded-case tests with the original side bearing configuration produced maximum 50-millisecond wheel L/V ratios of approximately 2.0. The AAR Specification M-1001 Chapter XI's criterion in the *AAR Manual of Standards and Recommended Practices* for 50-millisecond L/V ratio in a limiting spiral test is 1.0.

The proposed side bearing configuration with 4,500-pound long-travel side bearings reduced the empty-case L/V ratios to approximately 0.5.

### TURNOUT TEST AND NUCARST<sup>TM</sup> RESULTS

The articulated car derailed several times during switching moves at TTC, when traversing a particular switch. This switch is known to have a cross-level defect at the frog-point. The defect is similar to what may be seen in a revenue service rail yard. A short tangent and curve in the opposite direction precede the switch points creating a reverse curve geometry. A comprehensive set of tests and analyses was conducted at this switch to quantify the steering improvement realized by various side bearing configurations.

Steering performance was measured by comparing maximum wheel L/V ratios at the F-truck. Due to the switch geometry and vehicle design, the F-truck showed the most steering resistance of all trucks. As Exhibit 3 shows, the A platform has a higher roll restraint due to being supported by normal side bearings at the A-end and two outer side bearings at the F-truck end. All of the other platforms are supported by more closely spaced inner side bearings at one end. This is accentuated by the "bottoming" and high preloads of the short travel side bearings. This causes the F-truck to be more sensitive to track cross-level varia-

tions than the other trucks. This, in combination with the high-truck turning resistance caused by the side bearings generated large wheel L/V ratios. Reducing side bearing preloads improved the performance as Exhibit 5 shows. The lower section of Exhibit 5 is a key to the different testing configurations.

Test results in Exhibit 5 are ordered by increasing steering resistance. Test 1, with no side bearings, has the least resistance but is unrealistic for revenue service. Test 8, the original side bearing configuration, has the highest steering resistance.

NUCARST<sup>TM</sup> simulations were conducted to evaluate the sensitivity of the F-truck to track cross-level variations. Exhibit 6 compares simulation of the F-truck in its original configuration with 5400-pound pre-load side bearings traversing the turnout. Large L/V ratios are generated when track cross level is included in the simulation, but performance is acceptable with the cross level removed. Note that the cross-level variation was within FRA Class 3 limits.

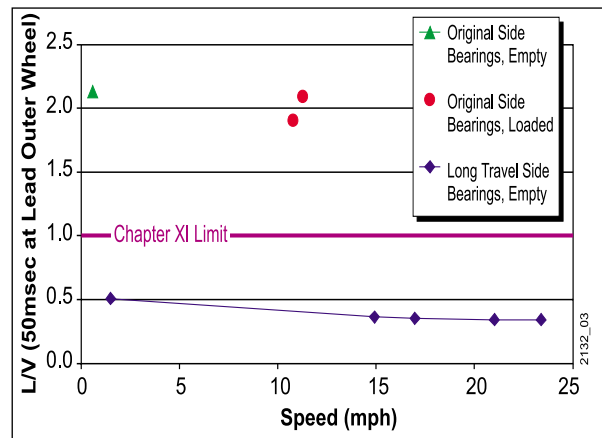
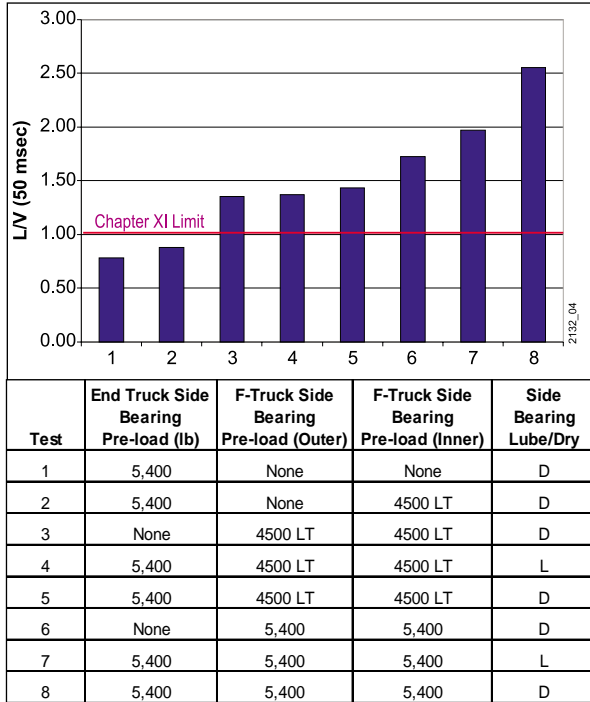


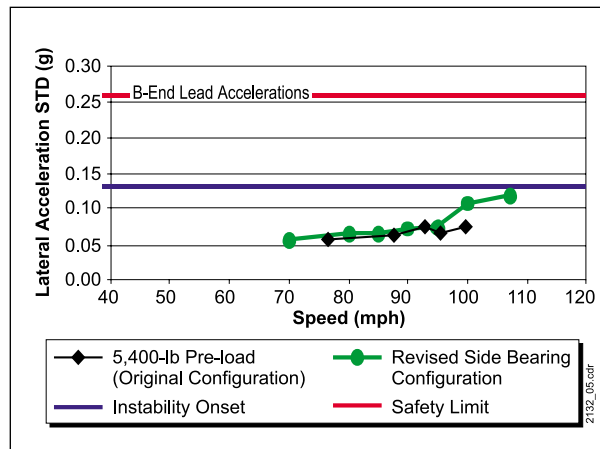
Exhibit 4. Maximum Wheel L/V Ratios in Limiting Spiral Testing



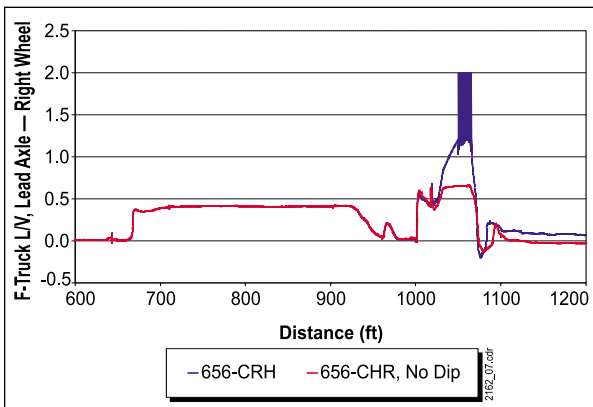
**Exhibit 5. Steering Performance in Turnout Tests**

**HIGH-SPEED STABILITY TEST RESULTS**

High-speed stability tests were conducted to ensure that the empty car did not become laterally unstable at speeds up to and including 100 miles per hour (Exhibit 7). The industry’s recommended lateral acceleration standard deviation threshold is 0.13 g. The original side bearing configuration showed stable performance up to and exceeding 100 miles per hour. The revised side bearing configuration remained stable through 100 miles per hour.



**Exhibit 7. Hunting Performance in High-Speed Stability Testing**



**Exhibit 6. NUCARS™ Simulation of Track Cross Level in Turnout**

**SUMMARY AND FUTURE WORK**

This research demonstrates the need to consider all aspects of vehicle performance when applying constant contact side bearings. The high-speed stability benefit of side bearings must be balanced with the decrease in steering performance.

The SRI discussed in this work will continue into 2002. Future work will focus on the development of a process by which car manufacturers and designers can verify safe performance prior to introducing new designs into revenue service. Input on this process is being solicited from railroads and industry suppliers.

**Note:** Please contact Corey Pasta at (719) 584-0793 with questions or comments about this document.  
 E-mail: corey\_pasta@ttci.aar.com  
 Web Site: www.ttci.aar.com

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