

### "EFFECT OF TRACK TWIST ON VEHICLE DYNAMIC PERFORMANCE"

by Huimin Wu and Dave Read  
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#### Summary

Tests conducted by the Association of American Railroads (AAR) at the Transportation Technology Center, Pueblo, Colorado, show that vehicle response to track twist varies significantly with car type. Important response variables include car body torsional stiffness, truck spacing, track alignment (tangent or curve), track geometry, and wheel/rail friction coefficient.

The test program investigated the influence of track twist on wheel unloading and wheel climbing tendencies of stiff, unloaded freight cars as a function of speed and track curvature. Three vehicles—a 100-ton, 89-foot center beam flatcar, a 100-ton covered hopper car, and a 70-ton tank car—were tested over cross level and combined cross level/alignment perturbations installed in tangent, 7.5-degree curve, and 12-degree curve test zones. No derailments were experienced, even with combinations of irregularities and speed much greater than those allowed by the current FRA Track Safety Standards.

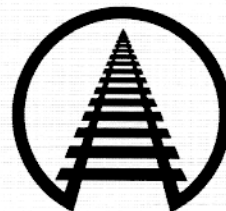
All vehicles negotiated tangent track cross level perturbations ranging from 2.25 inches to 3 inches (FRA Class I) at speeds up to 48 mph without exceeding AAR Chapter XI limits of wheel unloading (90 percent of static load) or L/V ratio (single wheel ratio of 1.0 or axle ratio of 1.5). The addition of a 1.75-inch misalignment (FRA Class III) to the cross level deviation increased the tendency for partial wheel unloading at slightly lower speeds. However, all vehicle types negotiated the combined cross level and alignment perturbation at the 30-mile per hour limit for Class III track without exceeding Chapter XI limits.

Operating over a 2.5-inch cross level perturbation installed on the 7.5-degree and 12-degree curve test zones, the covered hopper produced wheel L/V ratios greater than 1.0 at less than 10 mph at both locations. In the same 2.5-inch cross level deviation, the tank car operated to the maximum curve speed of 30 mph in the 7.5-degree curve and exceeded 1.0 wheel L/V ratio in the 12-degree curve at less than 10 mph. The flatcar operated to 30 mph over a 3-inch cross level deviation in the 7.5- and 12-degree curves without exceeding limits. All car types produced wheel L/V ratios exceeding 1.0 at less than 10 mph over the cross level/1.75-inch alignment perturbation located in the 7.5-degree curve.

Wheel/rail friction coefficient and use of locomotive sand significantly influenced L/V ratios and wheel climb tendencies of all vehicles in the curved zones.

#### Suggested Distribution:

- Planning & Analysis
- Track Maintenance
- Engineering Dept. - Safety
- Research & Development



Association of American Railroads  
Railway Technology Department

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## INTRODUCTION AND CONCLUSIONS

The Association of American Railroads (AAR), in conjunction with the Volpe National Transportation Systems Center (VNTSC), has investigated the effect of track twist on vehicle performance at the Transportation Technology Center (TTC), Pueblo, Colorado. The project was jointly funded by the Federal Railroad Administration (FRA) and AAR as part of the Vehicle/Track Interaction Program.

Track twist is defined as a change in cross level between two points along the track. Track twist in the transition from tangent to curved track is designed into the spiral as superelevation. Track twist can also occur as a track geometry defect. Change in cross level causes redistribution of vertical wheel loads. In an extreme twist condition, the wheels on one side of the car can approach an unloaded condition. This situation may result in wheel climb if sufficient lateral force is present.

Vehicles described in Exhibit 1 were tested in an empty load condition over the following: cross level and combined cross level/alignment perturbations in tangent and 7.5-degree curve test zones, a cross level perturbation in a 12-degree curve zone, and through the Chapter XI bunched and limiting spirals. The cross level perturbations included a 3-inch change in 20 feet for the flat car tests, a 2.25-inch change in 20 feet for the covered hopper car tests, and a 2.5-inch change in 20 feet for the tank car tests. The alignment perturbation was a 1.75-inch amplitude misalignment added to the cross level perturbation. Two instrumented wheel sets with AAR1B wheel profiles were installed in the leading truck of each test vehicle. AAR Chapter XI minimum performance guidelines of 90 percent wheel unloading, 1.0 single wheel L/V ratio or 1.5 axle sum L/V ratio were used during the test. Results and conclusions are listed below.

- ▶ Vehicle response to track twist varies significantly with car body torsional stiffness, truck spacing, track curvature, track geometry, and wheel/rail friction coefficient.
- ▶ Track twist tests showed that similar geometry defect amplitudes cause much higher wheel L/V ratio on curved track than on tangent track.
- ▶ Wheel/rail friction coefficient and use of locomotive sand significantly influenced the

L/V ratios and wheel climb tendencies of the vehicles tested in the curved zones.

- ▶ Wheel unloading over 90 percent of the static load was recorded during dynamic tests, compared to 57 percent to 68 percent in the static laboratory tests.

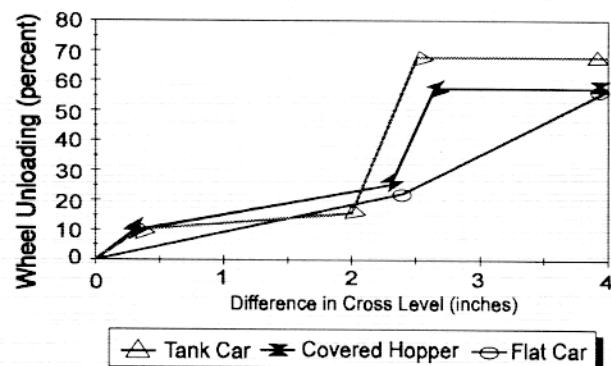
Exhibit 1. Description of Test Vehicles

Vehicle	Truck Spacing	Empty Weight (pounds)	Trucks
Center beam flat car	59', 10"	64,000	100-ton constant damped
Covered hopper	40', 6"	61,800	100-ton constant damped
Tank Car	29', 9"	56,400	70-ton variable damped

## STATIC JACKING TESTS

Jacking tests were performed prior to track testing to measure vertical wheel load redistribution as both wheels at one corner of the car were raised a total of 4 inches. Results were used to establish the cross level perturbation amplitudes to be used during the track tests.

Exhibit 2 shows wheel unloading increased sharply to 57 percent for the covered hopper and 68 percent for the tank car between 2 inches and 2.6 inches cross level difference. The separation of the car body and truck at the center plate occurs with no additional wheel unloading when the difference in cross level between truck centers exceed 2.5 inches. The center beam flatcar showed more torsional flexibility between trucks and less wheel unloading (about 35 percent at a cross level difference of 3 inches).



Relationship of Static Wheel Unloading and Cross Level Difference



Exhibit 3. Maximum Operating Speed Without Exceeding Chapter XI Limits on Tangent Track

	Center Beam Flatcar (3-inch cross level) Speed (mph)		Covered Hopper (2.25-inch cross level) Speed (mph)		Tank Car (2.5-inch cross level) Speed (mph)	
	Unloading (90 percent)	L/V(W) (1.0)	Unloading (90 percent)	Hunting	Unloading (90 percent)	Hunting
Cross Level	48	N	N	60	N	52
Cross Level & Alignment	N	30	50*	N	40	N

L/V(W) is Chapter XI wheel L/V limit (1.0) and Unloading is the wheel unloading limit (90 percent of static load). N indicates the limit was not exceeded at the top speed. \*The L/V limit was exceeded below 15 mph.

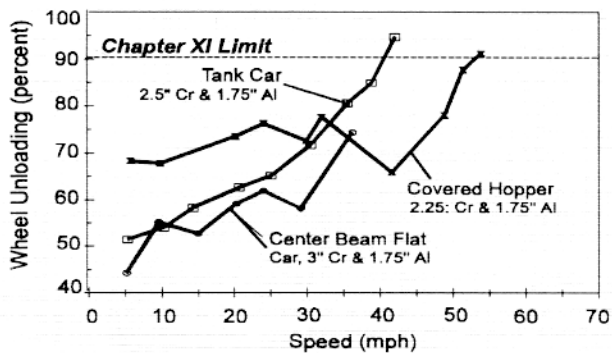


Exhibit 4. Wheel Unloading on Tangent Track with Cross Level/Alignment Perturbations

### RESULTS OF TANGENT TRACK TESTS

Exhibit 3 shows the maximum operating speed of each car over perturbations in the tangent zone without exceeding Chapter XI limits. Maximum speed of the covered hopper and tank car was limited by vehicle hunting rather than wheel unloading or high L/V ratios when operating over the cross level perturbation. Adding the alignment perturbation caused wheel unloading on the covered hopper and tank cars (Exhibit 4) and an L/V ratio in excess of 1.0 on the flatcar.

### RESULTS OF CURVED TRACK TESTS

Exhibit 5 shows the maximum operating speed without exceeding Chapter XI limits on the curved track zones. Exhibits 6 through 8 show wheel L/V ratio as a function of speed for each test vehicle. The flatcar operated to 30 mph in all five curve test zones with peak wheel L/V ratios close to or slightly above the Chapter XI limit of 1.0. Except on the limiting spiral, wheel L/V ratios were all above 1.0 on the covered hopper. Ratios above 2.0 were recorded at the bunched spiral and the 7.5-degree curve with cross level/alignment perturbation. The wheel L/V ratio for the tank car was above 1.0 at both the 7.5-degree curve with cross level/alignment perturbation and the 12-degree curve.

Maximum wheel unloadings were all below 90 percent of static load. However, vertical wheel unloading at the top of the cross level perturbation was the cause of high L/V ratios.

There was no derailment during the test, despite wheel flange climb observed on the high rail of the 12-degree curve for both the covered hopper and tank cars.

Exhibit 5. Maximum Operating Speed Without Exceeding Chapter XI Limits on Curved Track

	Center Beam Flatcar (3-inch cross level) Speed (mph)		Covered Hopper (2.25- inch to 2.5-inch cross level) Speed (mph)		Tank Car (2.25-inch to 2.5-inch cross level) Speed (mph)	
	L/V (W)	L/V (A) (1.5)	L/V (W)	L/V (A) (1.5)	L/V (W) (1.0)	L/V (A) (1.5)
Chapter XI Limits						
7.5-degree Cross Level	25*	30	5(E)	15*	30	30
7.5-degree Cross Level & Alignment	5(E)	30	5(E)	5(E)	5(E)	5(E)
12-degree Cross Level	30*	30*	5(E)	5(E)	5(E)	17
Bunched Spiral	30	30	5(E)	5(E)	30	30
Limiting Spiral	30	30	30	30	30	30

E indicates the Chapter XI limit was exceeded. L/V (W) and L/V (A) are Chapter XI wheel L/V limit (1.0) and Chapter XI axle sum L/V limit (1.5). \*Only one point exceeds the Chapter XI limit below 10 mph.



Test results also show that locomotive sand significantly influenced the L/V ratio and wheel climb tendency of the vehicles tested on the curved zones. Exhibit 9 shows the effect of sanding on the tank car wheel L/V ratios in the 7.5-degree curve.

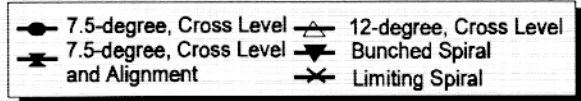
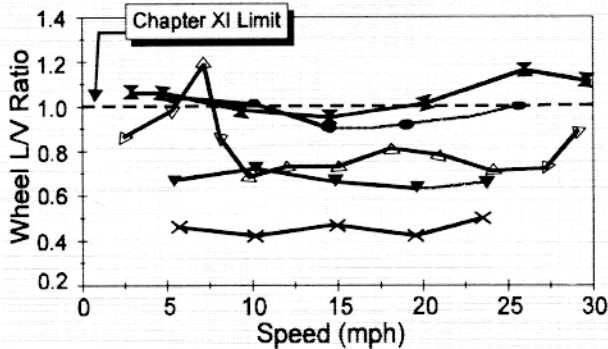


Exhibit 6. Maximum Wheel L/V Ratio on Curved Track—Flatcar

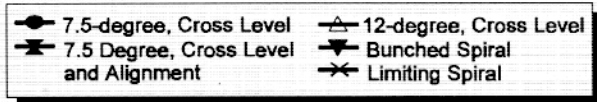
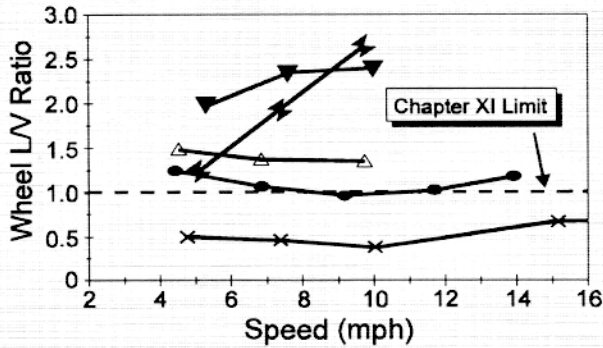


Exhibit 7. Maximum Wheel L/V Ratio on Curved Track—Covered Hopper

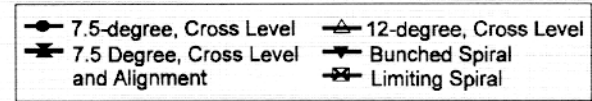
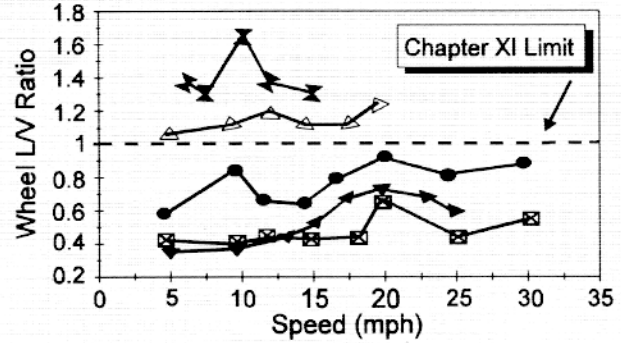


Exhibit 8. Maximum Wheel L/V Ratio on Curved Track—Tank Car

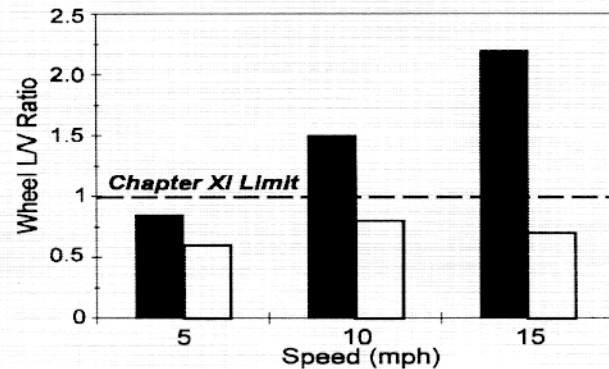


Exhibit 9. Effect of Applying Sand: Tank Car, 7.5-degree Curve

Note: Contact Huimin Wu (719) 584-0533 or Dave Read (719) 584-0559 with questions or comments concerning this document.

E-mail: huimin\_wu@aar.com or david\_read@aar.com

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