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## Revenue Service Performance Tests of Two Empty Tank Cars

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### Summary

In 2003, Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR), and the Burlington Northern Santa Fe (BNSF) Railway completed an extensive over-the-road test on 4,100 miles of BNSF's revenue service tracks. Two empty tank cars were instrumented to measure vehicle response and track geometry simultaneously. The primary conclusions drawn from the test are as follows:

- The empty tank car equipped with solid-block side bearings experienced significant hunting problems on tangent tracks while operating above 45 mph, whereas the empty tank car equipped with long travel constant-contact side bearings did not experience hunting at speeds up to 55 mph.
- Below 45 mph, the empty tank equipped with long travel constant-contact side bearings performed significantly better than the tank car equipped with solid block side bearings, although the difference in performance was not as large as compared with the difference in hunting performance.
- For vehicle response exceptions found (excluding hunting) in terms of the criteria listed later in the *Technology Digest*, approximately 57 percent occurred in spirals, 31 percent occurred in the body of curves, and 12 percent occurred in tangents.
- For all the locations that produced vehicle response exceptions, only 8 percent had track geometry defects (which were corrected as they were identified) by the current standards. In most cases, combined and multiple track geometry deviations led to poor vehicle response.
- Reduced wheel/rail friction coefficient due to weather (snow or rain) reduced the number of occurrences of poor vehicle responses.

Most vehicle response exceptions (excluding hunting) were recorded with the tank car equipped with solid-block side bearings. They occurred at operating speeds between 35 and 40 mph, although exceptions were also recorded over a speed range from 8 to 45 mph.



## INTRODUCTION AND CONCLUSIONS

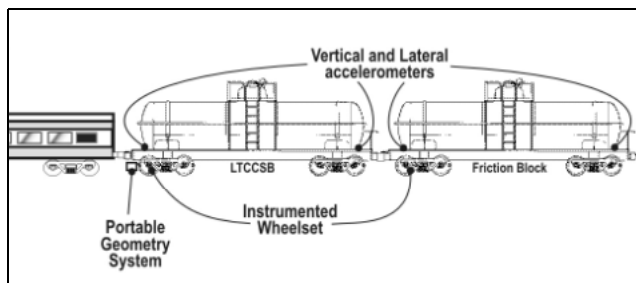
In 2003, the Transportation Technology Center, Inc. (TTCI) and the Burlington Northern Santa Fe (BNSF) Railway performed an extensive over-the-road test on BNSF's revenue service tracks. Two empty tank cars (one equipped with solid-block side bearings, and the other equipped with long travel constant-contact side bearings) were instrumented to measure vehicle response and track geometry simultaneously. The objectives of the test discussed in this *Technology Digest* were:

- To compare the performance of two empty tank cars equipped with two types of side bearings.
- To determine track geometry and operating conditions at locations where tank car responses exceed the pre-determined limits (vehicle response exceptions).

The primary conclusions are listed on the first page of this *Technology Digest*.

## TEST CARS AND INSTRUMENTATION

Figure 1 shows the test train. BNSF selected two empty tank cars for the test. Both have a car length (coupler-to-coupler) of 61 feet and a truck center spacing of 45 feet, 9 inches. All the trucks are Barber S-2 type. However, one tank car was equipped with long travel constant-contact side bearings (LTCCSB), the other was equipped with solid-block side bearings (or friction blocks).



**Figure 1. Test Train and Instrumentation**

The following instrumentation was used to measure vehicle responses and track geometry conditions simultaneously:

- Instrumented wheelsets to measure wheel/rail lateral and vertical forces, from which single wheel lateral over vertical (L/V) ratio and axle sum L/V ratio were determined.
- Eight accelerometers (four lateral and four vertical) were used to measure car body accelerations. A

pair of lateral and vertical accelerometers was installed at each end of each test car.

- A track geometry system measured track geometry conditions.

More than 4,100 miles of track were tested, covering a wide range of track and operating conditions (including those lines that had historic tank car performance issues).

## VEHICLE RESPONSE LIMITS

To identify track locations that produced poor vehicle responses, the following limits were selected to determine vehicle response exceptions:

- Single wheel L/V ratio greater than 1.0 (50-millisecond window), wheel climb limit.
- Axle sum L/V greater than 1.5 (50-millisecond window), wheel climb limit.
- Vertical wheel load V less than 10 percent of static wheel load (50-millisecond window), wheel lift limit.
- Car body lateral acceleration greater than 1.5 g (peak-to-peak), hunting limit.

These limits were selected based on AAR's Chapter XI criteria found in the *AAR Manual of Standards and Recommended Practices*.

## HUNTING PERFORMANCE

Measurements were taken at operating speed up to 55 mph for several lines covered during this test. Above 45 mph, however, the tank car equipped with solid-block side bearings experienced significant hunting on tangent tracks. Comparatively, the tank car equipped with LTCCSB did not experience hunting within the operating range of 55 mph.

Figure 2 shows performance comparison between the two cars. For the test line shown in this example, the worst value of each track segment (1 to 3 miles depending on operating speed) was plotted for single wheel L/V ratio and car body lateral acceleration, combined with operating speed. As shown, just above 45 mph, the recorded lateral accelerations for the car equipped with friction block side bearings exceeded 1.5 g (i.e., the hunting limit) numerous times, whereas the car equipped with LTCCSB did not experience hunting.

The results for single-wheel L/V ratio also indicate that the car equipped with LTCCSB performed better than the one equipped with friction blocks — reflecting the difference in hunting tendency.

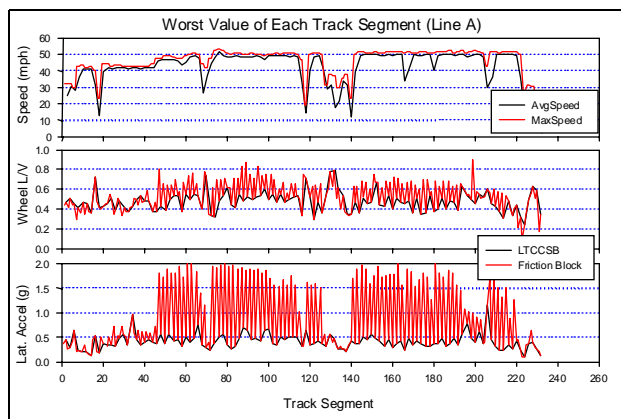


Figure 2. Hunting Performance Comparison of Two Tank Cars

**COMPARISON WHILE NOT HUNTING**

Figure 3 shows a comparison similar to Figure 2, with operating speed below 45 mph for a different line tested. As shown, no hunting occurred for either car at less than 45 mph. Nevertheless, the car equipped with LTCCSB still performed better than the car equipped with friction-block side bearings, based on measured single-wheel L/V ratios and car body lateral accelerations.

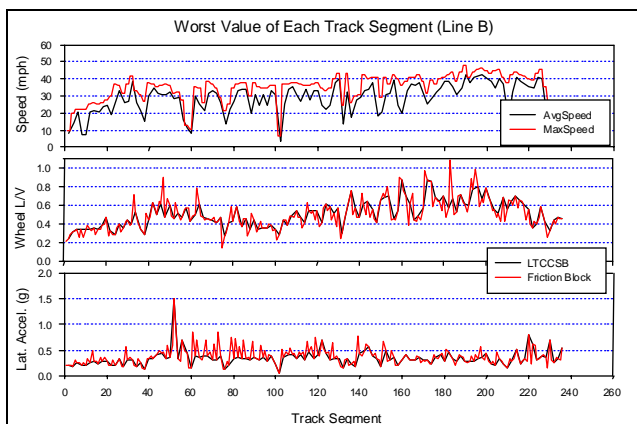


Figure 3. Performance Comparison of Two Tank Cars, No Hunting

**EXCEPTIONS DUE TO TRACK GEOMETRY**

For the rest of this document all vehicle response exceptions discussed are those related to wheel climb or wheel lift, as defined by the first three vehicle response limits.

During the entire test, a total of 336 exceptions (excluding hunting) were recorded, which corresponded to 123 track locations. Most of these exceptions were recorded on the empty tank car equipped with solid-block side bearings. In addition, most of those exceptions were related to the L/V criteria. A location

could produce multiple vehicle response exceptions, depending on the criteria used and number of wheels or axles that produced exceptions.

**Distribution of Exceptions Over Speed**

Figure 4 shows the distribution of response exceptions with operating speed. As shown, most of the exceptions occurred at operating speeds between 35 and 40 mph. However, this distribution may also indicate the frequency of various train operating speeds.

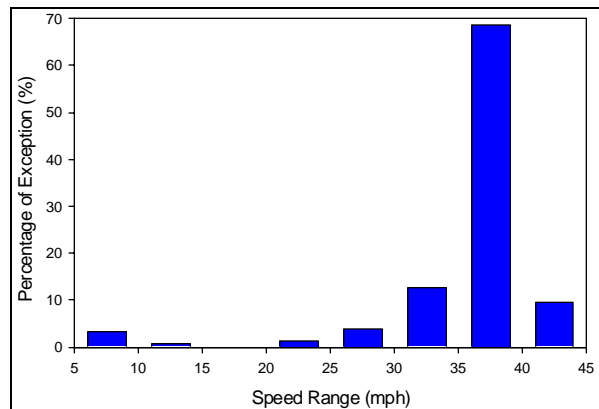


Figure 4. Distribution of Exception Over Speed

**Distribution of Exceptions over Curvature**

Figure 5 shows the distribution of response exceptions with curvature. As illustrated, exceptions occurred at various curvatures from tangent to 6-degree curves, although 3-degree curves were ranked the highest in terms of number of exceptions (again, the highest bar at or near 3-degree curves may indicate that these curves are the most common).

In addition to the breakdown shown in Figure 5, the following distribution is obtained:

- 57 percent of exceptions occurred in spirals
- 31 percent of exceptions occurred in body of curves
- 12 percent of exceptions occurred in tangents

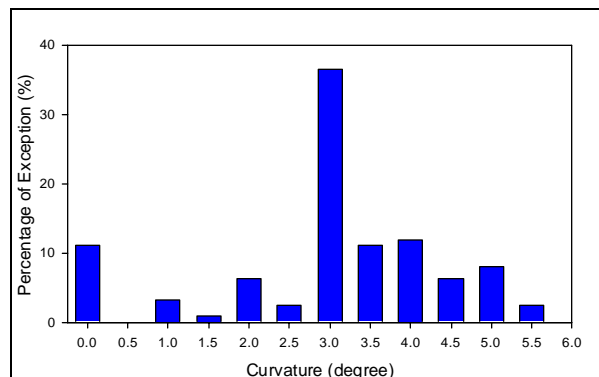


Figure 5. Distribution of Exception over Curvature

Moreover, the test results did not support a popular opinion that the leading axle of the lead truck would produce more exceptions in entry spirals than in exit spirals, whereas the leading axle of trailing truck would produce exceptions in an opposite trend.

## Effects of Track Geometry on Vehicle Performance

For all vehicle response exceptions found, only a small number (8 percent) of locations had track geometry defects as defined by the current standards. Wide gage was identified eight times, narrow gage was identified once, cross-level defect was identified once, and another exception involved the combined defects in alignment and narrow gage. Maintenance actions were taken on all defects identified.

Frequently, it was a combination of track geometry conditions, rather than a single geometry defect, that led to poor vehicle response. Figure 6 shows an example of two recorded vehicle response exceptions (L/V ratio greater than 1.0) and the corresponding track geometry condition. As illustrated, none of individual track geometry parameters had deviations exceeding Federal Railroad Administration (FRA) geometry standards (indicated by the vertical arrows).

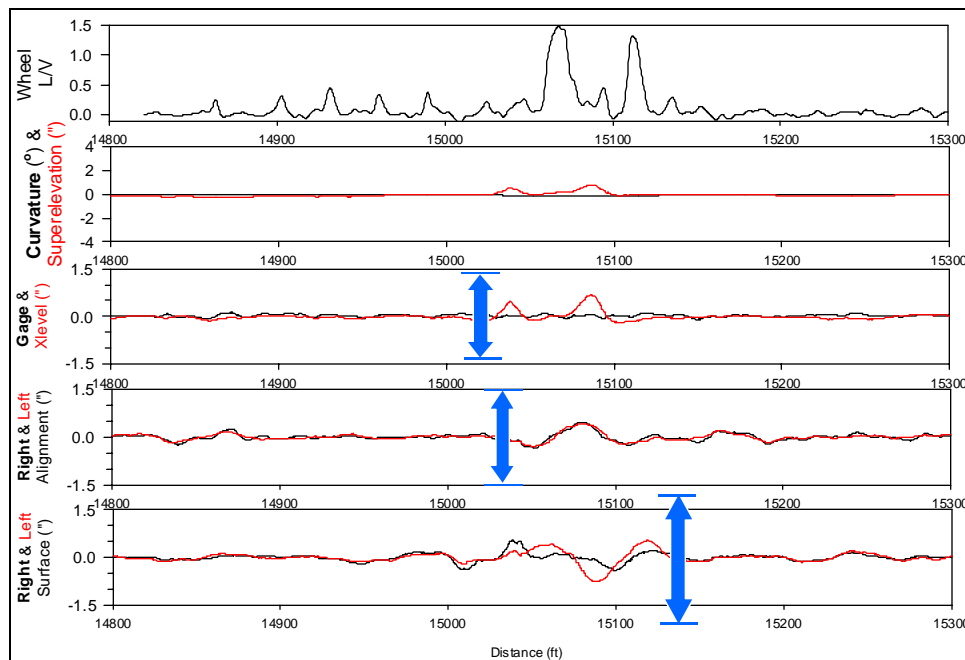
combined track geometry deviations that led to two vehicle response exceptions at this location.

## Wheel/Rail Friction

During the test, one line was tested several times and produced a number of different response exceptions between various runs. Weather was one of the main factors that affected vehicle response. Conditions for runs conducted under snow or rain led to wet wheels and rails, resulting in a much lower wheel/rail friction coefficient. As past AAR research has shown, a reduction of wheel/rail friction coefficient reduces wheel/rail lateral forces significantly. The effect of reduced wheel/rail friction coefficient on tank car performance was obvious during this test. That is, the run conducted under wet weather recorded much lower lateral wheel loads (leading to fewer vehicle response exceptions for the same line tested) than the runs conducted under dry, sunny weather.

## ACKNOWLEDGEMENTS

The following BNSF and TTCI personnel were instrumental in this project and made significant contributions to the successful completion of this large-scale revenue service vehicle-track interaction test: Lisa Stabler, Rick Harbuck and his track geometry car crew, Mike Mischke, Ron Bidwell, and Jerry Malone.



**Figure 6. Example of Exception Recorded at 43 mph on Tangent due to Combined Effect of Cross Level, Alignment, and Surface Deviations**

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