TECHNOLOGY DIGEST
Timely Technology Transfer — 98-006

DISTANCE REQUIRED FOR FLANGE-CLIMB DERAILMENT

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Summary

Tests at the Federal Railroad Administration's (FRA) Transportation Technology Center by researchers from the Transportation Technology Center, Inc., a subsidiary of the Association of American Railroads (AAR), have indicated that a distance-based standard to assess the potential peak forces before flange climb may be a better predictor of derailment than the current time-duration criterion. The time-duration criterion to predict lateral-to-vertical wheel-force ratios prior to derailment is outlined in Chapter XI of AAR's *Manual of Standards and Recommended Practices*. In this project jointly funded by the AAR and FRA, the AAR's Track Loading Vehicle (TLV) was used to measure the time or distance required for flange climb to occur on the test tracks. The primary objective of the test program was to provide data that could be used to examine the validity of the current 50-millisecond criterion that is used in Chapter XI for determining the acceptable duration of L/V (lateral-to-vertical) ratio. Furthermore, the results showed that distance to climb was strongly dependent on angle of attack of the wheel set.

The test results were compared with predictions from AAR's NUCARS general rail vehicle dynamics simulation program. This permitted a wider range of conditions to be evaluated than could be examined during the track test program. This comparison indicated that there was general agreement between the simulation results and the test data, even though the test data had considerable scatter.

In order to accurately measure the wheel-climb trajectory during the track tests, the forward motion of the TLV had to be carefully controlled at a very low speed. This was accomplished by winching the test consist at 0.25 mph.

Considerable scatter in the test data has precluded any determination of the effect of rail profile on the distance to climb, although the NUCARS simulation results do indicate some differences between rail profiles. In addition, the effect of coefficient of friction of the rail on the distance to climb was not investigated experimentally. Both the effect of rail profile and rail coefficient of friction on distance to climb should be the subjects of future research.

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Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads
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INTRODUCTION AND CONCLUSIONS

A recently completed test program using the Association of American Railroads' (AAR) Track Loading Vehicle (TLV) indicates that a distance-based, rather than a time-based, standard is more appropriate for evaluating the acceptable duration of L/V (lateral-to-vertical) ratio before flange-climb derailment occurs. The primary reason for this investigation was to determine the validity of the 50-millisecond rule currently used during Chapter XI tests.

This digest summarizes the results of the derailment tests that were performed with the TLV at the Federal Railroad Administration's (FRA) Transportation Technology Center (TTC) and comparison of the results of these tests with predictions of distance to climb using AAR's NUCARS vehicle dynamics simulation program.

Test and analysis results indicate the following:

- Wheel climb depends on distance rather than time.
- Distance to climb is strongly influenced by angle of attack.
- Distance to climb depends on the maximum value reached by the flanging wheel L/V.
- The fixed value of 50 milliseconds used in Chapter XI should be re-evaluated based on these results.
- NUCARS predictions were in general agreement with the experimental data.

FLANGE-CLIMB TEST DESCRIPTION

The location used in the Distance to Climb experiments was the TTC's Precision Test Track (PTT). Two tangent test zones with AREA 119RE rail were used. The first zone was made up with essentially a new rail section while the second zone consisted of a straightened curve-worn rail.

The test consist included a locomotive, instrumentation car (AAR100) and the TLV. The direction of travel was south and the direction of the lateral loading was always to the west. A bulldozer's winch was used to pull the consist at a controlled rate of about 0.25 mph, as a very low speed was required in order to permit accurate measurement of the wheel-climb trajectory.

The data collected for these tests consisted of the vertical and lateral loads applied to the TLV bogie wheel set (see Exhibit 1). Vertical, lateral, and longitudinal forces, as well as wheel-contact lateral position measurements from the instrumented wheel set — a proven technology for measuring forces at the wheel-to-rail interface — were also collected. Angle-of-attack settings and rail-contacting positions also were collected to accurately determine the angle of attack of the axle while in motion. The forward speed of the vehicle was collected using a rotary encoder.

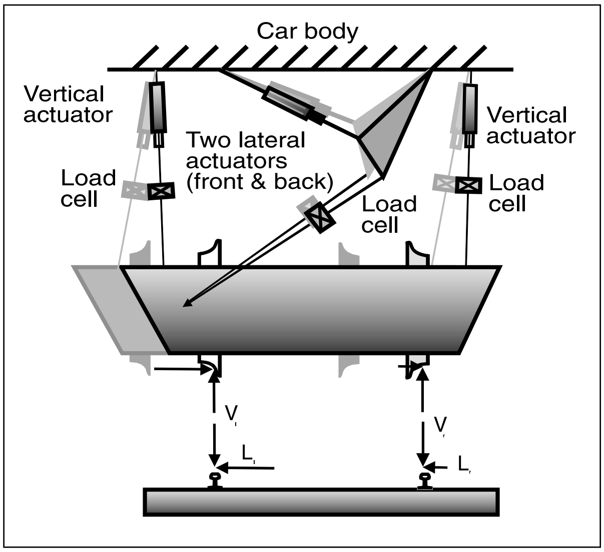

Exhibit 1. TLV Loading Kinematics

The desired axle angle of attack and 10-kip vertical axle load were set before forward movement. Once at a constant 0.25 mph, an initial lateral force was applied at either 50 percent or 80 percent of the predicted steady-state climb L/V ratio. This initial load level was held for 5 feet of travel to ensure equilibrium. The lateral force was then stepped up (at a rate of 30 to 60 kips/second) to the final desired L/V ratio. This higher load was held until flange climb occurred or for 20 feet of forward travel (see Exhibit 2).

These tests were done on new- and worn-rail profiles with initial L/V ratios of both 50 percent and 80 percent of the predicted steady-state climb L/V. Each load combination was run with the

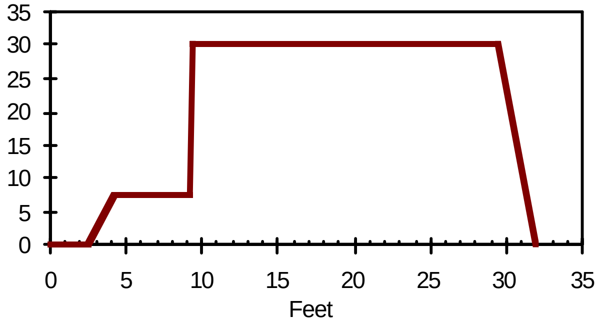

Exhibit 2. Typical TLV Lateral Load Profile (Vertical Command Held Constant)

angle of attack set to (+30, +10, +5, 0, -2.5) milliradians respectively. Before a test series, the rails were cleaned and sanded, and the coefficient of friction on the rail was measured at each test zone using a portable tribometer. Also, the wheel and rail profiles were taken before and after testing using a Miniprof™ Profilometer.

NUCARS DISTANCE PREDICTIONS

TTCI researchers simulated transient wheel-climb behavior using NUCARS before the track tests. Exhibit 3 shows results using +20 milliradians axle angle of attack, and friction coefficients of 0.5, 0.4, and 0.3. Vertical dashed lines show Nadal's theoretical steady-state wheel-climb L/V ratios. The solid line NUCARS predictions vertically converge to these asymptotes for large angles of attack of the axle. However, for small and negative angles of attack, these L/V vertical asymptotes will be larger than Nadal's solution. Also, as L/V further increases above the steady-state wheel-climb threshold, changes in friction do not appear to influence climb distances. Therefore, all three curves approach the same horizontal asymptote.

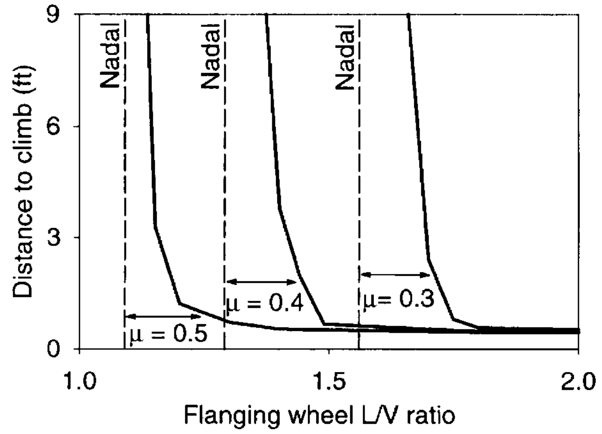

Exhibit 3. NUCARS Predictions of Distance to Climb for Three Friction Values (Axle Angle of Attack = +20 mrad)

These curves help interpret TLV test results. They show that test derailments near the steady-state wheel-climb L/V can be significantly affected by small friction variations. However when applying L/V ratios which exceed the steady-state L/V threshold by at least 25 percent, climb distances are unaffected by friction changes.

DISTANCE TO CLIMB RESULTS

Test runs were repeated for each set of conditions in order to examine consistency. This showed that distance to climb was quite variable for the same nominal set of conditions. Changes in rail cross-section, such as at welds and track irregularities, influenced the wheel-climb trajectory. Nevertheless, there were clear trends evident in the results. In this situation, it was decided that the most meaningful method of presenting the data was to plot discrete points for all of the derailment runs compared to a curve of NUCARS-predicted results for each rail cross section.

Exhibit 4 shows the distance to climb for the new rail cross section. TLV test results are shown as data points and NUCARS predictions as lines. The results are presented as a function of maximum flanging-wheel L/V ratio for a range of angles of attack of wheel sets. The test data has been grouped into ranges for angles of attack around the predicted results.

There are some clear trends evident in the results. For a given angle of attack, as the maximum single-wheel L/V value is reduced, the distance to climb rises rapidly to infinity. The L/V at which this occurs is the steady-state L/V derailment value for this angle of attack. For L/V values higher than this, the distance to climb drops rapidly to an asymptotic value which then reduces only gradually with further increasing L/V.

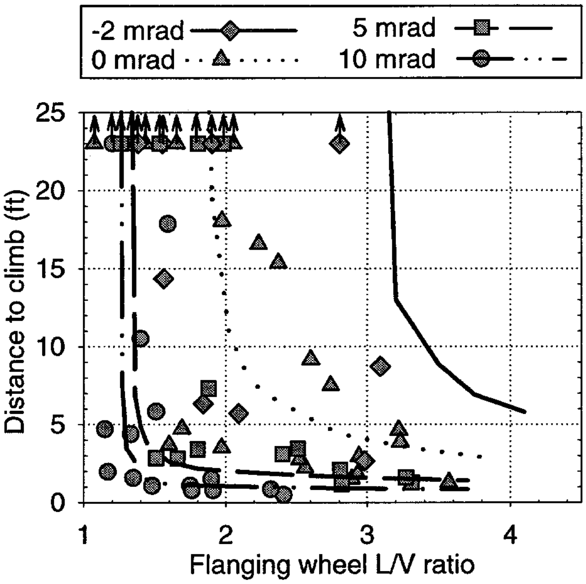

Exhibit 4. Distance to Climb (New Rail)

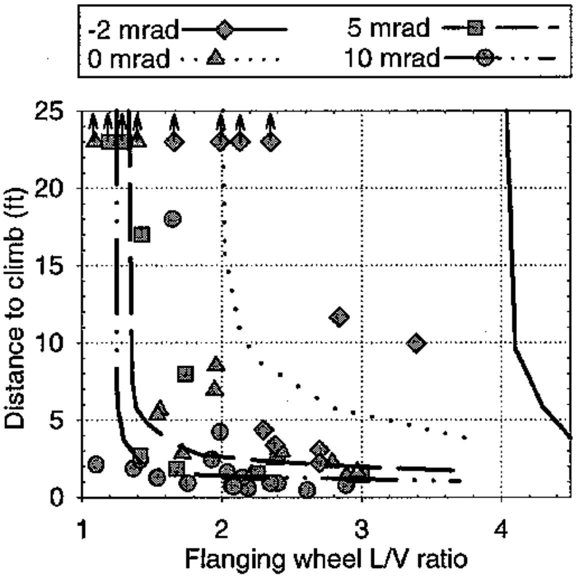

Exhibit 5. Distance to Climb (Worn Rail)

As angle of attack is decreased, the L/V value above which climb can occur increases and the distance to climb also increases.

Exhibit 5 shows the distance-to-climb results for the worn-rail section. These results show the same general trends evident in the results for the new-rail section. For reasons discussed earlier, there is considerable scatter in the experimental data, however the general trends shown in the NUCARS predictions are evident in the test data from both rail profiles.

NUCARS predicts differences for the two rail sections, particularly for small and negative angles of attack. With the worn-rail section, larger L/V values are required to initiate flange climb. This reflects the slightly higher steady-state L/Vs required in previous worn-rail steady-state data, although deemed insignificant at the time. The reason for this result has not been investigated.

CHAPTER XI IMPLICATIONS

The NUCARS predictions, backed up by TLV test data, show that the distance required for flange climb depends largely on the axle angle of attack. It also depends on the maximum L/V value. However, the L/V value has to exceed the steady-state derailment value for climb to occur at all. Once this threshold L/V value is exceeded, the distance to climb is relatively constant for further increases in L/V.

In view of these results, use of a constant time value of 50 milliseconds to evaluate peak forces in Chapter XI might be outdated. The criterion should probably be distance-based and at least account for varying axle angles of attack. Therefore, the use of the current criterion should be carefully re-evaluated.

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A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH THE AAR, PUBLICATION ORDER PROCESSING, 50 F STREET, NW, 5TH FLOOR, COG, WASHINGTON D.C., 20001