TECHNOLOGY DIGEST

Timely Technology Transfer

"PRELIMINARY FLANGE CLIMB DERAILMENT RESULTS,"

by John A. Elkins, William Shust, Magdy El-Sibaie, and Semih Kalay

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Summary

Full-scale flange climb derailment tests have been successfully completed during a project funded jointly by the Association of American Railroads (AAR) and the Federal Railroad Administration. The test results showed that under dry rail conditions, flange climb derailment occurred at lateral to vertical (L/V) wheel load ratios close to that predicted by theory (Nadal's value). As a result, Chapter XI criteria are good for the dry rail conditions used for Chapter XI tests and very conservative for lubricated rails.

Based on initial results, no changes are proposed to the existing Chapter XI flange climb derailment limits. However, further studies are planned to investigate whether the 50 millisecond duration rule properly accounts for the effect of L/V time duration on the potential for flange climb derailment.

Currently, Track Loading Vehicle test results are being compared to the predictions of an improved version of the NUCARS vehicle dynamics model. This effort will improve upon the interpretation of the experimental work and check the accuracy of NUCARS flange climb derailment prediction.

During these tests using the TLV and its retractable wheel set, repeated and safely controlled flange climb derailments of an instrumented test wheel set were achieved under a range of applied wheel/rail forces, wheel set angles of attack, rail profiles, and lubrication conditions.

The primary objective of this study was to re-examine the current wheel climb criteria used in Chapter XI of Specification M1001 described in AAR's *Manual of Standards and Recommended Practices*. Further theoretical studies are in-process to study the effect of a wide range of wheel and rail profiles and rail irregularities on derailment proneness.

Suggested Distribution:

- ❑ Operating/Engineering
- ❑ Operating/Mechanical
- ❑ R&D/Test Dept.
- ❑ Safety Dept.

Association of American Railroads
Research and Test Department
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INTRODUCTION AND CONCLUSIONS

A recent addition to the continued research by the Association of American Railroads (AAR) into derailment prevention and safety is the use of its Track Loading Vehicle (TLV) for testing the conditions leading to wheel climb derailments.

This digest summarizes the results of wheel climb derailment testing performed with the TLV at the Transportation Technology Center (TTC), Pueblo, Colorado. This was the first time that full-scale testing of wheel climb had been performed in North America.

Test results analyzed so far include:

- Limiting single wheel L/V ratios for new and worn rail sections were essentially the same.
- For dry rail conditions (μ=0.5), derailment occurs at Nadal's value for angles of attack greater than about 5 milliradian.
- In view of the previous conclusion, no changes to the present Chapter XI criteria should be considered at the present time because Chapter XI tests are done on dry rail.
- NUCARS predictions are in good agreement with the measured derailment conditions.

THEORY

Wheel climb derailments occur when the forward motion of the wheel set is combined with an excessive lateral to vertical wheel load ratio. This permits the wheel flange to climb onto the top of the railhead. The maximum single wheel L/V ratio continues to be used by railway engineers as the main criterion indicative of an incipient wheel climb derailment.

In 1908, Nadal established the original formulation for a limiting L/V ratio ("Theorie de la stabilite des Locomotives," 1896). His criterion was based on the simple equilibrium of forces between the wheel and rail at a single point of flange contact. He solved the necessary equations for the case just prior to derailment as illustrated by Exhibit 1.

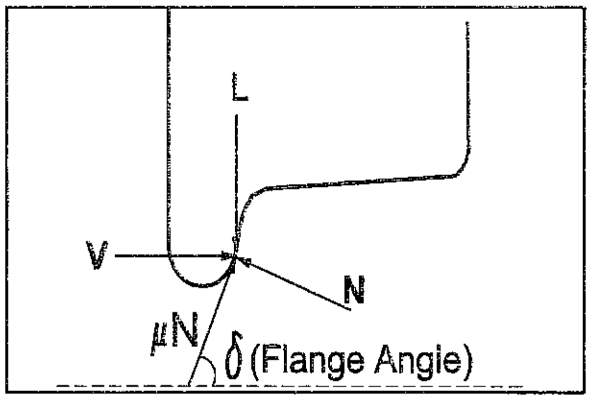

Exhibit 1. Flange Forces at Incipient Derailment

In this equilibrium, L and V, the lateral and vertical forces acting on the rail, are balanced by the forces on the wheel, N and μN, which are normal and tangential to the contact plane. The angle δ represents the contact angle between the wheel's flange and the rail relative to a horizontal reference. Finally, the coefficient of friction between the wheel and rail is represented by μ. Based on this, the equilibrium of forces can be restated to form Nadal's Criterion.

$$\frac{L}{V} = \frac{\tan(\delta) - \mu}{1 + \mu \tan(\delta)}$$

As indicated by this expression, Nadal's Criterion is only dependent on the wheel flange's maximum angle of contact with the rail and the amount of friction present between them.

More recently, Herbert Weinstock ("Wheel Climb Derailment Criteria for Evaluation of Rail Vehicle Safety," ASME 84-WA/RT-1) proposed a criterion which utilizes the absolute sum of the flanging and non-flanging wheel (or Axle Sum) L/V ratio. AAR's safety certification testing of freight cars, commonly known as Chapter XI testing, incorporates a single wheel L/V limit of 1.0 and an axle sum L/V limit of 1.5. This provides the margin for coefficient of friction of 0.5 and a flange angle of approximately 75 degrees, which is the maximum flange angle of the AAR-1B wheel profile.

Since 1987, the Nadal and Weinstock criteria have been included in the Chapter XI specifications without full scale test results to support their use. However, peak L/V values found during some of these tests have exceeded the criteria without any apparent indication of proximity to wheel climb.

A primary goal of this research activity is to further the understanding of wheel climb conditions through full scale testing. Another is to validate, or improve upon, the current wheel climb criteria used in Chapter XI. In order to achieve both goals, the AAR utilized the TLV, with AAR's newly designed and constructed yaw bogie.

TESTING AND ANALYSIS METHODOLOGY

The tests were performed on the tangent north end of the Precision Test Track at TTC. The tests measured wheel/rail forces through many derailments using an instrumented wheel set with an AAR-1B wheel profile running through two test zones, one with a new rail profile and the other with a curve worn profile.

Effects of wheel set angle of attack (AOA) and lubrication on the limiting derailment forces were investigated.

The TLV load bogie shown in Exhibit 2 was used to control wheel set AOA and vertical forces. The lateral actuators were used to apply a gradually increasing lateral force until a derailment occurred.

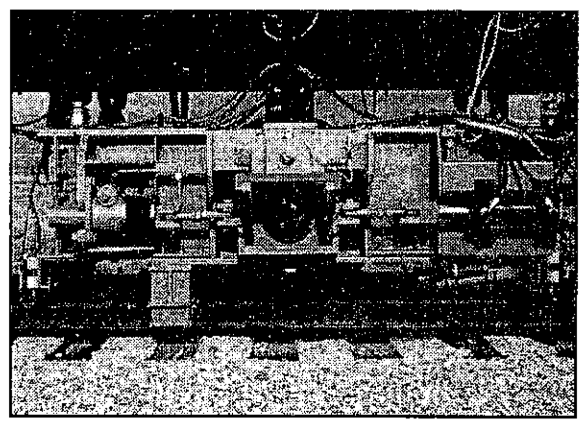

Exhibit 2. TLV Load Bogie

A measurement of bogie lift was used to identify the point of wheel climb. Then over a half second period around this time, the various data channels were time averaged. In this manner, experimental L/V ratios were identified.

Prior to actual testing, wheel and rail profiles were measured and the resulting wheel/rail contact geometry was computed. This data was used in NUCARS simulations, which were performed using a new and improved version of the program.

FLANGE CLIMB DERAILMENT RESULTS

Exhibit 2 shows test results as a function of AOA from two series of runs with the TLV over the new rail section and predictions from the NUCARS model.

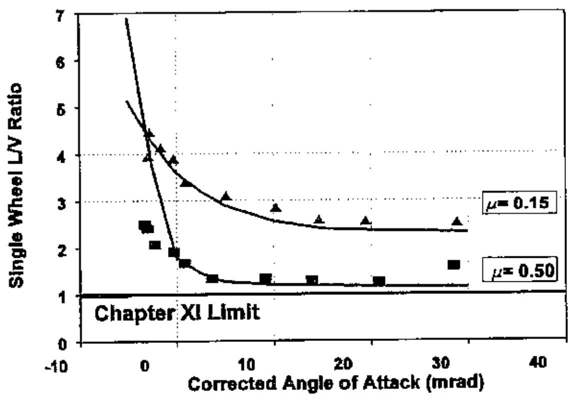

Exhibit 2. Wheel L/V Limit (New Rail)

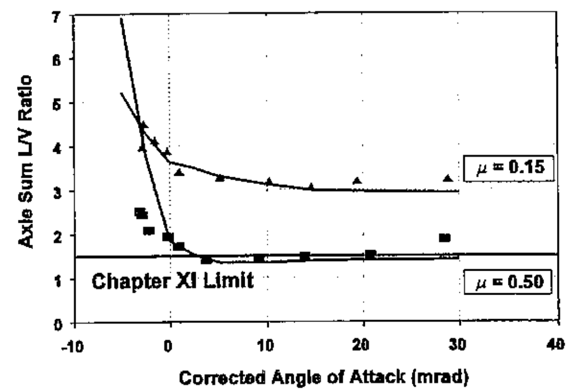

Exhibit 3. Axle Sum L/V Limit (New Rail)

These results are for the limiting single wheel L/V ratio on the flanging wheel, with approximately equal vertical loads on the two wheels. In both cases, no deliberate lubrication had been applied to the rail, which had also been steam cleaned. Analysis of the forces occurring on the flanging wheel at a large AOA indicated that the coefficient of friction (μ) was 0.15 for the 1st series and 0.5 for the 4th series of tests. The test results are indicated by the points and the NUCARS simulation results are the lines. The NUCARS simulations were carried out for the same values of μ as the experimental results.

Exhibit 3 shows limiting axle sum L/V ratio for the same cases shown in Exhibit 2. Data in all these exhibits is plotted versus the net AOA between the bogie axle and the local alignment of the track centerline. This net angle has been corrected for car body yaw.

The data shows that the L/V ratios are highest for negative and small angles of attack, where the lateral creep force on the flange is opposing flange climb. For positive angles of attack, where the lateral creep force is assisting flange climb, the L/V ratios approach the Nadal limit.

CHAPTER XI IMPLICATIONS

The experimental results and NUCARS predictions show that flange climb derailment under quasi-static conditions occurred at the Nadal single wheel L/V limit for angles of attack above about 5 milliradian for clean dry rail. However, previous Chapter XI tests have produced maximum L/V ratios which, when analyzed according to the prescribed 50 millisecond duration rule, exceeded Nadal's value without indication of proximity to wheel climb.

This could be due to the following factors:

- Friction coefficient lower than 0.5
- Small or negative AOA
- 50 millisecond duration rule not properly accounting for effect of L/V time duration on derailment potential

Further studies are planned to investigate the effects of L/V time duration on the potential for flange climb derailment.

Contact John A. Elkins at (719) 584-0582 with questions or comments about this document.

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