TECHNOLOGY DIGEST

Timely Technology Transfer

Wheel Drop Derailment Testing Using AAR's Track Loading Vehicle (TLV)

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__*Summary*__

This digest presents the results and conclusions from full-scale derailment tests aimed at the examination of track failure modes associated with track gage widening.

During the tests, it was found that in order to overturn the rail, it was necessary to disconnect both ends of the rails between the trucks of the Track Loading Vehicle (TLV) and push at the center of the disconnected rail section at lateral loads high enough to overcome the rail holddown due to vertical loads. Tests showed that a single lateral load applied to the track is very unlikely to cause a rail to overturn even at L/V ratios in excess of 5. Tests to failure clearly indicated that rail overturning is more probable under the conditions of local weaknesses in track, such as at locations with missing rail joints, broken spikes and missing tie plates on consecutive ties.

These fundamental track gage widening tests were conducted early in 1991 using the AAR's Track Loading Vehicle on mainline-quality track at the Transportation Test Center in Pueblo, Colorado. The purpose of these tests was to investigate the mechanics of rail rollover under a variety of vertical and lateral loads, up to and including critical levels under which track failure can occur. The primary objectives of these tests were to obtain fundamental knowledge about the manner in which wheel drop derailments occur, to establish data about current rail and track quality, to test and validate various derailment criteria, and to provide a means for the continuous measurement of these criteria.

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INTRODUCTION AND CONCLUSIONS

Recent derailment statistics indicate that gage widening caused by inadequate rail restraint is one of the major causes of track related derailments. These types of derailments are typically associated with high lateral wheel/rail forces exerted on relatively weakened cross tie and rail fastener systems resulting in wheel drop or rail rollover.

A joint AAR/FRA Track Train Interaction Derailment Analysis Project was initiated in the late 1980s to begin a series of analytical and experimental studies. The primary objective of this project was to demonstrate the use of the Track Loading Vehicle (TLV) in the area of vehicle/track interaction leading to the development of improved track maintenance methods and the advancement of vehicle design standards to reduce derailments.

The split axle test system utilized in the TLV has the force and displacement capabilities necessary for simulation of full-scale wheel drop derailments. Tests were conducted to quantify the forces and rail displacements that will lead to potential wheel drop derailment.

The following conclusions resulted from these tests:

- *The basic mechanism of track gage widening involves a complex interaction of various modes of deformation, such as rail bending and twist, lateral rail translation, rail roll, spike pullout and bending, tie crushing, etc.*
- *The entire rail section begins to roll outward when the rail overturning moment exceeds the rail hold down moment that results from the vertical load. However, adjacent trucks, fasteners and rail stiffness provide additional resistance to rail overturning.*
- *During tests to failure, although dynamic gage widening large enough to cause a worn wheel to drop between worn rails was experienced, the track structure behaved elastically, returning to its original position after the loads were removed.*
- *Actual track failure under extreme lateral loads may initiate in the form of dynamic gage widening. This may be followed by rail overturning resulting from one or more wheels dropping inside the gage and running on the web of the rail or on the ties.*
- *A single lateral load (in combination with a vertical load) applied at a single point in track, is very unlikely to cause a rail to overturn, unless there is a local weakness near the point of load application. Test results show that "good" track appears to provide adequate rail restraint capability at load levels well above those loads which should be expected in revenue service.*

FUNDAMENTAL TRACK GAGE WIDENING TESTS

The first series of rail rollover tests was conducted on tangent track (136 RE CWR) spiked four spikes per tie on hardwood ties at 19 inch centers. Exhibit 1 shows the TLV load application. The test sequence started by application of vertical loads up to 33,000 lbs per rail. The lateral loads were gradually increased up to 33,000 lbs and the resulting displacements were measured. After completion of the static tests, the vertical wheel load was kept at a constant level of 33,000 lbs while the lateral load was cycled from 2,000 to 33,000 lbs at a frequency of 0.1 Hz.

These tests showed that the initial lateral rail deflection comes in the form of rail translation, twist, and bending. Lateral rail translation resistance comes from the frictional forces between the rail base and the tie plate as well as from the base of the tie plate and the top surface of the tie.

Exhibit 1. TLV Load Application.

When the lateral load applied at the rail head exceeds the frictional force, the rail slides on the tie plate until the rail base contacts the tie plate shoulder. Concurrently, the clearances due to the elongation of the spike holes are taken up, and the primary resistance to rail translation comes from the fastener/tie interface, where the spikes resist lateral tie plate movement. The rail twist and bending is resisted at the rail base by the tie plate/tie structure, and by the torsional rigidity of the rail. Total lateral rail deflection, at a lateral load of 22,000 lbs and a vertical load of 33,000 lbs was 0.26 inches, of which 0.1 inches was due to rail translation and 0.16 inches was due to rail twist and bending.

The primary resistance to rail roll is obtained from the geometry of the rail section and the applied loads. For 136 lb rail with 1 in 40 cant, the L/V ratio required to initiate rail roll about its field corner is about 0.65, which corresponds to about a 22,000 lb lateral load under a 33,000 lb vertical load. Beyond this load level, the rail starts rolling about the field corner on the tie plate. Resistance to this rail roll motion is obtained from the torsional resistance of the rail and the pullout resistance of the gage spikes. The rail continues to experience lateral rail translation although small in relation to the rail roll. At a lateral load of 33,000 lbs, the total rail deflection was 0.71 inches, of which 0.16 inches was due to rail translation, 0.16 inches was due to rail twist and bending, and 0.39 inches was due to rail roll about its field corner. Exhibit 2 shows a break down of the lateral rail deflection contributed by each mode.

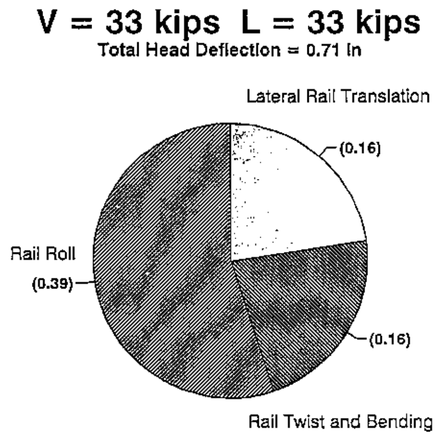

Exhibit 2. Breakdown of Lateral Rail Head Deflection.

Additional tests were conducted to failure in an attempt to quantify the response of the rail/fastener system to continuously increasing lateral loads under a lightly loaded axle. Under the dead weight of the load bogie (7,000 lbs per wheel), the lateral load on each rail was increased up to 35,000 lbs per rail until the loaded gage exceeded 59 inches (a wheel can drop in between the rails when the gage is 59 inches). This produced a total of 2.6 inches of rail deflection at an L/V ratio of 5. The rail did not overturn or fail drastically, but the gage was widened enough to cause a worn wheel to drop between the gage.

As described above, the rail roll was preceded by rail bending and twisting, and further resistance to roll was provided by the fasteners and adjacent wheels. By the end of this test, the spikes on the gage side of the rails had pulled out about 1 inch. When the loads were removed, the rails returned to their original positions implying that any bending or twisting that occurred in the rail was local and elastic.

The test was repeated under a 50,000 lb vertical load, and the same level of lateral deflection was produced when the lateral load reached 44,000 lbs per rail. It is concluded from these tests that a lateral load at a single point, even in the absence of vertical loads on adjacent axles, would not be sufficient to overturn adequately fastened rail.

Another series of tests was conducted to investigate the effect of vertical loads from adjacent trucks on gage widening resistance. The track had originally been constructed for special tests with parallel rail joints on 19.5-foot centers. The TLV was centered over the test track so that both of the parallel joints would fall between the load bogie and the inboard axles of the TLV trucks.

Tests were first run with the joint bars in place in order to quantify the total resistance of the rail to overturning. With the rail joint bars in-place, both the left and the right rails exhibited a strong rail restraint response at L/V ratios up to 1.3.

The rail joint bars were then removed so that the degree of reduction of resistance to rail roll could be quantified. This removed the restraint from the adjoining rails and the weight of the TLV on the trucks.

Under a 20,000 lb vertical load, the low rail rolled over as soon as the lateral load level exceeded the friction at the rail/tie interface, and exceeded the critical L/V ratio(near 0.65).

After these tests, the loads were removed and the track was inspected for damage. It was found that the low rail had come out from most of the tie plates and most spikes were pulled out up to 3 inches (Exhibit 3). The results of these tests clearly indicated that rail overturning is more probable under the conditions of local weaknesses in track, such as at locations with missing rail joints, broken spikes and missing tie plates, etc.

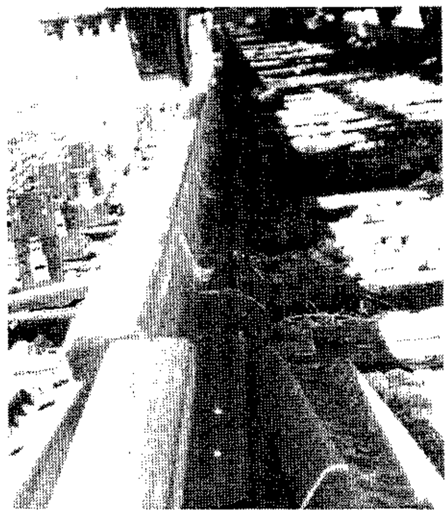

Exhibit 3. Rail Rollover Tests at V=20,000 lbs, L=12,000 lbs.

Note: Contact Semih Kalay at (312) 808-5842 with questions or comments about this document.