

TECHNOLOGY DIGEST

Timely Technology Transfer

"GAGE WIDENING EFFECTS AS A FUNCTION OF RAIL OVERTURNING MOMENT,"

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Summary

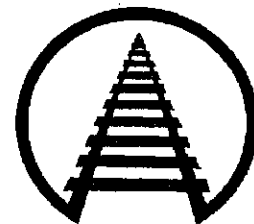
The actual mechanism of gage widening derailments, particularly under 125-ton double stack intermodal cars, has been difficult to identify. Why the inner rail plays a role in this type of derailment was explored through gage widening tests carried out at the Transportation Test Center, Pueblo, Colorado. The tests were specifically intended to relate gage widening to the magnitude and location of lateral and vertical forces applied to the rail in curves and spirals.

Based on marks on the inner web of the rail relative to the point of derailment, many double stack car derailments clearly result from the inner rail in curves and spirals rolling over due to excessive gage widening. At first this may seem inconsistent with the notion that lateral forces at the wheel-rail interface tend to exert greater gage widening effects on the outer rail. These outer rail lateral forces must be balanced however by lateral forces on the inner rail.

Full scale loads were applied to the rail as gage widening was measured during quasi-static tests. A range of lateral and vertical forces typical of both 100- and 125-ton capacity cars were applied at various lateral positions along the railhead. Some tests were also done with a single axle.

On a single rail, vertical forces of 40,000 pounds and lateral forces of 16,000 pounds ($L/V=0.4$) were applied at a spacing equal to the wheelbase of a 125-ton capacity truck. When the field side of the rail was loaded (as is often the case on the inner rail in a curve), the effective gage widening was over 0.5 inch for that rail alone. The gage widening was dominated by the roll of the rail with only minor contribution by lateral translation and bending of the rail cross section.

It is quite clear that overturning is a progressively unstable process in that as the rail rolls over, the overturning forces become greater. Thus, the overturning is terminated only when the input forces are balanced by the torsional forces in the rail.



Association of American Railroads
Research and Test Department

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INTRODUCTION AND CONCLUSIONS

Gage widening derailments where the inner rail in a 4-6 degree entry spiral or curve appears to have rolled over have been the subject of intensive research for the last three years. The mechanics of gage widening and, ultimately, rail rollover had not been previously studied in great detail until the recent rash of double stack car derailments. These have occurred fairly regularly since their introduction in the late 1980's. The tests described here were done with a rig built solely for the purpose of measuring gage widening for a range of lateral to vertical (L/V) ratios where the loading point on the rail is varied. This is to simulate the point of contact between wheel and rail on both inner and outer rail in curves and spirals.

In curves the inner wheel may contact the rail anywhere from the center of the rail to the field side. Hollow wheels in particular may generate a discrete contact point far to the field side which can produce a large overturning moment on the rail. Weak track, in combination with a number of consecutive trucks generating high L/V ratios (typical of articulated equipment), may produce forces sufficiently high to overturn the rail.

A flatcar provided the platform for a gage widening test rig which was installed over a tangent portion of the Precision Test Track (PTT) at the Transportation Test Center. The PTT track is configured with AREA 119 lb/yd rail, timber ties, and compression clip fasteners. Two masses each weighing 50,000 pounds were positioned on both sides of the test location, and the flatcar was then secured to these masses. Additional concrete blocks were then set on the flatcar to provide additional weight to react the wheel/rail loads applied during the test. The underside of the car was modified so that hydraulic actuators and load cells could be suspended vertically to apply loads to the track. Lateral loads were also applied and were reacted by masses directly to either side of the test site.

The following conclusions were drawn as a result of the preliminary tests:

- Gage widening is dominated by rail roll rather than rail translation.
 - Gage widening is composed almost exclusively of rail roll when an overturning moment (about the rail base corner on the field side) is applied to the rail.
 - As the initial overturning moment is increased, rail roll grows linearly.
 - Rail overturning is very sensitive to the lateral position of wheel/rail contact along the railhead.
 - The tests show that as the rail begins to roll, the increase in overturning moment due to changing geometry promotes further overturning of the rail.
 - As the rail rolls, the gage widens until the torsion through the rail (provided by the fastening system and rail) balances the overturning moment.
 - Load application with two axles greatly increases the gage widening compared to a single axle.
 - The fundamental aspects of gage widening have been embodied in a computer model which allows variation in rail weight, wheel/rail load, fastener condition, and the point of loading laterally across the rail and longitudinally along the rail.
- Based on these preliminary tests, further work will be carried out to investigate the gage widening mechanism. Tests are planned for the following conditions:
- Varying rail cross section -- new and worn rail
 - Rail in curves and tangent
 - Rail in varying states of tension and compression
 - Rail constrained under a range of fastening conditions



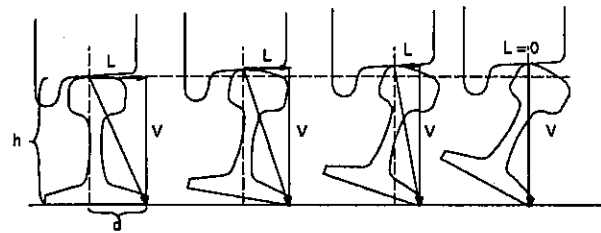
TEST DETAILS

The test location on the far north end of the PTT was selected for its isolation from other tracks and current testing. Also the compression clip arrangement used on the PTT allowed simple changes to the extent of rail fastening during the test. The modified 54-foot flatcar suspended over the test site was equipped with brackets that provided loads at one and two points along the rail. This allowed the simulation of load application for single-axle cars as well as for the wheel spacing of 100- and 125-ton capacity trucks.

Forces were measured with load cells in series with hydraulic actuators. Combined vertical and lateral loads were applied to the rail through a loading "foot" that produced a discrete load point. The foot had a 0.5-inch-transverse radius and a 19.0-inch-longitudinal radius. Several test runs were carried out with vertical and lateral loads on the rail typical of 100- and 125-ton capacity trucks under fully loaded cars. The L/V ratios applied ranged from 0.1 to nearly 0.5.

Hand operated pumps were used to produce lateral and vertical loads independent of each other. The test sequences began with applying the desired vertical load, and then increasing the lateral forces progressively to generate the spectrum of L/V ratios needed. The lateral displacement of the rail was measured with displacement gages at the loading point, and over a 43-foot distance on both sides of the loading location.

Exhibit 1 shows how the initial overturning moment applied to the rail changes with rail roll. This is a fundamental aspect of rail rollover in that it is inherently unstable until the input moment is balanced. In the absence of a counteracting moment, the rail will continue to roll. At this point the gage may be sufficiently wide for the wheel set to drop in.



$$\text{OVERTURNING MOMENT} = L \cdot h - V \cdot d$$

L = lateral force V = vertical force
h = height of the point of contact above
rail base corner
d = lateral distance between point of contact and
rail base corner

Exhibit 1. Rail Rollover Changes

Exhibits 2 through 4 show the gage widening for different conditions. Included are:

- varying point of contact,
- differences between initial and terminal overturning moments as a result of changes in -d- and -h- values, and
- deflection of unrestrained rail along the track as overturning moment changes.

While applying the same combination of lateral vertical wheel/rail forces (40,000 lb vertical, 16,000 lb lateral) at three different locations across the railhead, gage widening was measured. Gage widening was insignificant for the cases where the wheel/rail load was applied toward the gage side and at the center of the railhead. However when the same loads were applied on the field side, the gage widening became very significant. This results from a large overturning moment about the field side rail base corner. In the previous two cases, the overturning moment was negative and the gage widening was apparently the result of lateral translation of the rail and the bending of the cross-section.



Exhibit 3 shows the initial and terminal overturning moment on the rail for the three loading positions: field, center and gage. The initial moment begins the rail rotation. The terminal moment is balanced by the weight of the rail and the fastening system reacting through the torsion of the rail. This exhibit illustrates two aspects of gage widening: (1) the changing geometry of d and h dimension works to increase greatly the overturning moment, and (2) the load location affects the magnitudes and change in the initial and terminal moment.

Exhibit 4 illustrates the decay in gage widening with distance from the load point. Presented are three positive and two negative overturning moments.

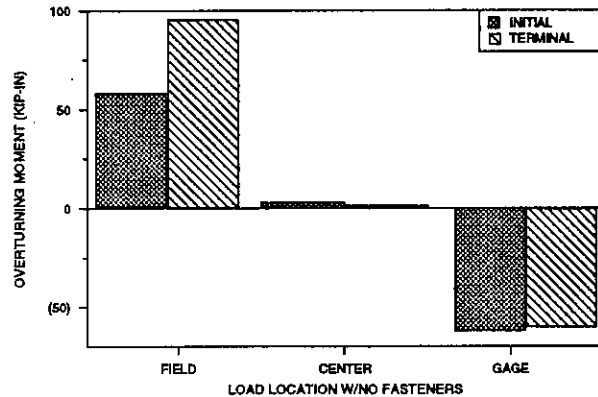


Exhibit 3. Gage Widening as a Result of Changes in $-d$ & $-h$ Values

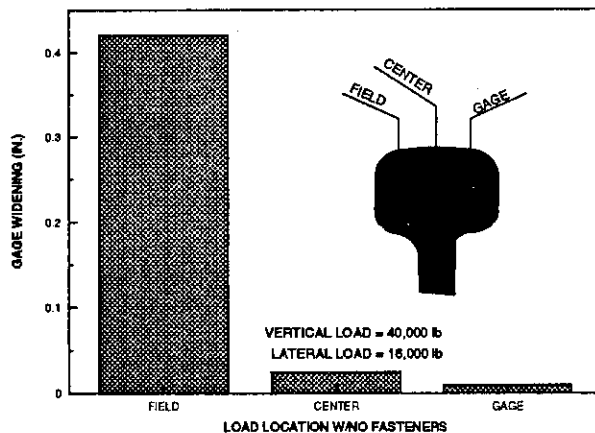


Exhibit 2. Gage Widening with Varying Point of Contact

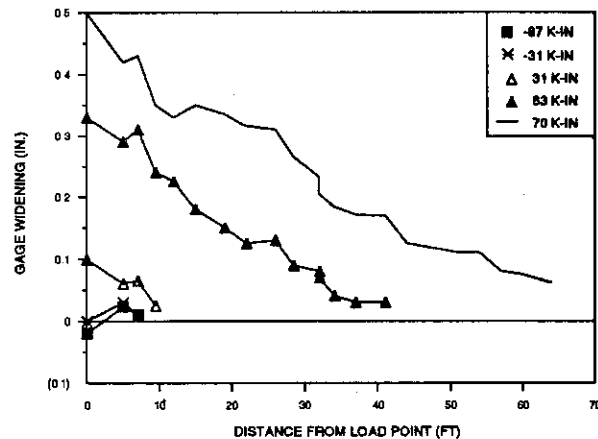


Exhibit 4. Gage Widening as Overturning Moment Changes

Note: Contact John F. Leary at (719) 584-0572 with questions or comments about this document.

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