TECHOLOGY DIGEST

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EFFECTS OF SWITCH-POINT RISERS ON TURNOUT PERFORMANCE

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Summary

A theoretical study of the effects of switch-point risers on turnout performance has yielded findings that will be used to evaluate and develop improved-performance turnouts. Switch-point risers are essential safety features that allow railroads to operate hollow-tread wheels over turnouts. This study compares relative performance benefits of various riser heights on a new Association of American Railroads (AAR) 1B wheel (no hollow tread) and a 3-millimeter hollow-tread wheel representative of severe hollowing of wheels in revenue service. Selection of minimum riser height should be based on the profiles of the wheels in service. The AAR Wheel/Rail Profile Project has determined that 6 percent of wheels in service have 3 mm (1/8-inch) or more hollowing. The studies were conducted under the Association of American Railroads Special Track Work Current Designs research project.

Conclusions of this study include:

- A significant number of wheels in revenue service have a hollow-tread profile exceeding 3 mm.
- Switch-point risers are essential safety features. A riser of 1/4-inch height is needed to accommodate the existing wheel fleet.
- The effect of having 1/4-inch switch-point risers on the dynamic performance of a loaded hopper car is relatively small.
- Vertical dynamic forces increase by about 10 percent at 40 mph.
- Lateral dynamic forces are generally decreased by about 10 to 20 percent at 40 mph.
- The only situation where risers have a large effect is for the lateral forces on hollow-tread wheels moving through the mainline route of the turnout. In this case, lateral forces are doubled from about three to more than six kips at 40 mph.
- The effect of changing riser height by 1/8 inch from the typical 1/4 inch is from 3 to 5 percent for both lateral and vertical loads.

A theoretical study of the effects of switch-point riser heights on loaded-car dynamic performance through an American Railway Engineering and Maintenance of Way Association No. 20 turnout was conducted using NUCARS, a car dynamics model.

Suggested Distribution:
- Maintenance of Way
- Planning & Analysis
- Track Maintenance
- Safety

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INTRODUCTION AND CONCLUSIONS

Research by the Association of American Railroads into the effects of switch-point risers on various turnout designs, and the related costs of maintaining special track work, have yielded findings and analysis tools that should prove useful in the evaluation and development of improved-performance turnouts. Switch points account for 20 to 30 percent of the maintenance and replacement costs of mainline turnouts. These costs amount to $40 to $60 million annually in the United States. The items that may be specifically related to switch-point risers account for at least two-thirds of that cost.

Additionally, switches are consistently among the top-five track-related causes in the derailment data collected by the Federal Railroad Administration. Many switch-related derailments are not design related. However derailments caused by stock rail rollover and split switches are related to design. The incidence of rail-rollover derailments in switches is directly related to wheel-profile maintenance and switch-point risers.

Many features on current turnout designs are there to compensate for undesirable car characteristics. This approach has been favored by railroads because they can control their own track better than they can control vehicles owned by other railroads or private car fleets. The switch-point riser is one such feature that compensates for wheels that are worn to an undesirable profile. The riser is designed to prevent rail-rollover derailments by ensuring that the wheel stays above the stock rail at the point on the switch where the switch point and stock rail converge. The riser "raises" the switch point above the stock rail to ensure that all wheels will ride on the switch point and follow the correct path through the turnout. The riser is needed because running surfaces of wheels can wear into a "false flange" or "hollow-tread" profile. A car with a hollow-tread profile running over a riserless switch point may experience the following problems:

- On facing-point moves, the wheel will bear on the stock rail instead of the switch point until the switch point deviates far enough from the intended route of the vehicle. Then the wheel will impact the switch point as it "jumps" to the correct path.
- On trailing-point moves, the wheel will bear on the switch point with the false flange hanging down below the level of the stock-rail running surface. As the wheel approaches the point where the two railheads converge, it will strike the side of the stock railhead with the false flange (i.e. side of the wheel opposite the flange). This stock rail-wheel false flange interference can cause either a stock rail to roll out, or a wheel to climb in severe cases. Exhibit 1 shows this situation.

VERTICAL FORCES IN TURNOUTS

The effect of switch-point riser height on predicted maximum vertical forces can be seen in Exhibit 2. The effect is relatively small for both wheel types and both routes (straight and diverging) through a standard AREA No. 20 switch. At 40 mph, the maximum NUCARS-simulated vertical forces for riser height from 0 to $^{31}/_{48}$-inch are shown. For straight moves, the maximum forces increase from about 34,000 lbs. to 40,000 lbs. for 1B wheels (about 16 percent) and from about 35,000 lbs. to 39,000 lbs. (about 11 percent) for the hollow-tread wheels. The risers are fairly benign bumps in the track compared to other track-geometry defects. However, the smaller cross-section area of a

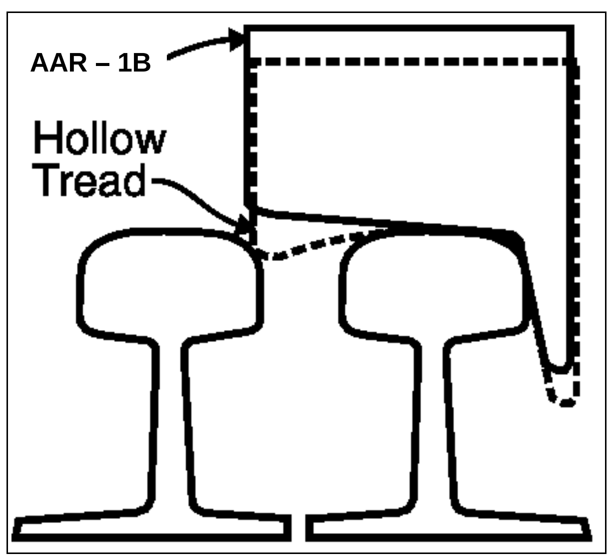

Exhibit 1. Illustration of Hollow-Tread Wheel – Stock Rail Interference on a Riserless Switch Point

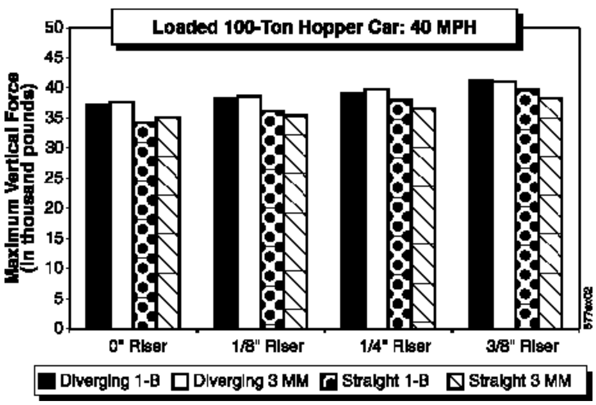

Exhibit 2. The Effect of Riser Height on Predicted Maximum Vertical Forces for a Loaded Hopper Traversing a No. 20 Switch at 40 mph

switch point makes it a weak link in the track structure.

Increases of 11 percent and 9 percent were predicted for the same wheels on diverging runs. The smaller increase in maximum vertical load for the hollow-tread wheels is due to the fact that the hollow-tread wheel is raised less (up to 3 mm) than the 1B wheel. Raising or lowering the riser height by $^{11}/_{48}$-inch from the typically used $^{11}/_{44}$-inch affects maximum vertical forces by 3 to 5 percent. The corresponding differences in maximum vertical forces for straight and diverging route moves are 3,000 to 4,000 lbs. This is equivalent to the steady curving forces expected for a No. 20 switch.

LATERAL FORCES IN TURNOUTS

The effect of switch-point risers on maximum lateral forces can be seen in Exhibit 3. The effect

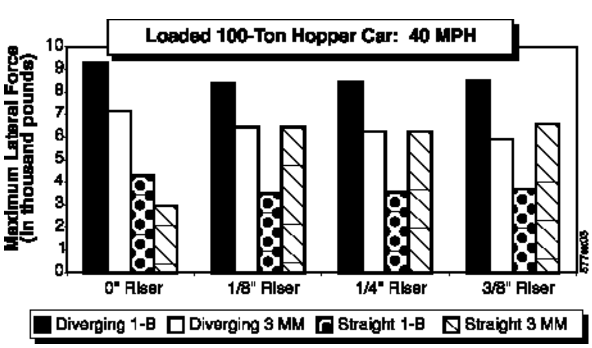

Exhibit 3. The Effect of Riser Height on Predicted Maximum Lateral Forces for a Loaded Hopper Traversing a No. 20 Switch at 40 mph

of a riser on lateral vehicle performance in straight moves is to decrease maximum lateral forces on 1B wheels and to increase them on 3 mm hollow-tread wheels. The effect of going from no riser to a $^{31}/_{48}$-inch riser is a decrease of about 14 percent for 1B wheels (from 4,300 to 3,700 lbs. at 40 mph). However, the maximum lateral forces are more than doubled, from 3,000 lbs. to 6,600 lbs. at 40 mph, for 3 mm hollow-tread wheels. The effect of riser height, however, is small with $^{11}/_{48}$-inch up and down changes from the typically used $^{11}/_{44}$-inch riser resulting in 1- to 5-percent difference in maximum forces for both the 1B and hollow-tread wheels.

Risers also decrease the maximum lateral forces in diverging moves for both wheels, by 9 percent and 17 percent respectively, in going from 0 to $^{31}/_{48}$-inch risers. The maximum lateral forces in diverging moves are larger for 1B wheels than for hollow-tread wheels in all cases. The effect of riser height is negligible for 1B wheels, with a 1-percent change in forces resulting from $^{11}/_{48}$-inch up and down changes from the typical $^{11}/_{44}$-inch riser. The effect of riser height on hollow-tread wheels is 3 to 5 percent for the same $^{11}/_{48}$-inch height changes.

LATERAL FORCES IN OPEN TRACK

A characteristic difference noted in runs with AAR-1B wheel profile and 3 mm hollow-tread wheel profile pertained to the direction and magnitude of wheel/rail contact lateral forces before the vehicle entered the turnout. As expected for the AAR-1B wheel profile, contact was towards the gage side on rail crown, and resulted in small magnitudes of gage-spreading lateral forces. The largest lateral force was about 600 pounds for a 1B wheel. For hollow-tread wheel profile, the contact was between "false flange" and field side of the railhead. This resulted in gage-narrowing lateral forces, the largest magnitude of which was about 3,800 pounds.

WHEEL PATH THROUGH THE TURNOUT

Wheel flanging affects the magnitude of wheel/rail contact lateral forces. Typical mainline speeds, wheel/rail contact geometry, and the degree of turnout curvature determine whether wheel flanging will occur. Riser height or its absence does not have any effect on flanging occurrence. In NUCARS runs a flange contact is assumed whenever the wheel/rail contact angle exceeds 45 degrees. In simulations using AAR-1B wheel profile, the contact angle remained below 26 degrees. Even though the contact moved to the switch-point gage corner, flanging did not occur, while sufficient steering was provided to negotiate the turnout. On the other hand, simulations using 3 mm hollow-tread wheel profile had flange contact at about 45 feet from the beginning of the switch point. The contact angle between wheel flange and switch-point gage face was about 76 degrees.

It was also found that variation in truck center distance had little effect on the magnitude of maximum lateral forces.

STRAIGHT ROUTE FACING-POINT MOVES

A switch-point riser creates a running surface defect (perturbation) in the track somewhat similar to that used in exciting the roll behavior of a freight car. As such, the loading and unloading cycles of vertical force under the left wheel of an axle are opposite to those of vertical force under the right wheel of the axle. On the other hand, riser height or its absence does not create a lateral perturbation. The degree of kink angle and severity of lateral transition in which the wheel stops bearing on the stock rail and starts riding the switch point determine the magnitude of lateral forces.

The risers are graduated, and attain maximum rise at the end of top cut which is 20 feet from the point. Also, cutting back from the theoretical point and the beveling and knife-edging bring the actual point away from the bend (kink) introduced in the stock rail on turnout side. A car upon entering the switch is thus deflected through the kink angle at the point. For the 1B wheel, since contact is near the center of rail crown on the gage side, this transition is not severe. For hollow-tread wheels, since contact is already on the field side, deflection through the kink angle results in the wheel flange impacting the stock rail which in turn results in large lateral thrust before the wheel is raised and borne on the switch point.

The effect of speed on maximum vertical forces due to 1/4-inch risers is quite small compared to other track perturbations. Increasing speed from 40 mph to 60 mph increases maximum vertical forces by about 5 percent for both wheel types. The speed effect does increase with riser height, however. At a 3/8-inch riser height, the effect of increasing speed from 40 to 60 mph is to increase maximum vertical forces by 10 percent for both wheel types.

PROCEDURE

The switch chosen for the study was an American Railway Engineering and Maintenance of Way Association 39-foot curved split switch with graduated risers. Loaded hopper-car simulations were run at 40 mph for the diverging route (left-hand curve) with riser heights of 0, 1/8-, 1/4- and 3/8-inch, respectively. Straight-route simulations were made at 40, 50, and 60 mph, also at the above three riser heights. Results show that the difference in dynamic loading, both vertical and lateral, is not excessive when the riser height is decreased or increased by 1/8-inch from the currently used riser height of 1/4-inch. Both AAR – 1B and 3 mm hollow-tread profiles were used in the simulations.

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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