TECHNOLOGY DIGEST

TD-10-014
Revised
©MAY 2010

TIMELY TECHNOLOGY TRANSFER

The work described in this document was performed by Transportation Technology Center, Inc.,
a wholly owned subsidiary of the Association of American Railroads.

Development of a Vertical Switch Design

David D. Davis and Muhammad N. Akhtar

Summary

Transportation Technology Center,Inc. (TTCI) is developing vertical switch designs for use on selected mainline locations where diverging traffic is low. These designs have a continuous, unbroken surface on the mainline rails to allow premium performance for the mainline route through the switch. TTCI evaluated the technical feasibility of applying one such design to current heavy axle load freight, high speed passenger, and dual use corridors. The design has significant potential for these applications.

One potential vertical switch configuration is described in this *Technology Digest* to illustrate the concept. Alternative designs are being considered for prototype development. The vertical switch concept is intended to be used with the partial flange bearing frogs being adopted by railways for low volume mainline turnouts. In both cases, the new design is intended to greatly improve the performance of the mainline side of the turnout at the expense of the capability of the diverging route. For locations where the majority of the traffic is on the mainline side of the turnout, such as setout tracks or 10 mph industrial sidings accessed from the mainline, the vertical switch turnout provides safety, service life, and maintenance benefits. The key feature of this switch is continuous mainline rail through the switch and frog, which differs from currently used split switches and fixed point frogs.

The reduction in dynamic loads for the mainline route is significant, resulting in decreased wear and improved component fatigue performance. Analysis of dynamic performance on the diverging route suggests:

- Maximum lateral forces will be similar to, or lower than those in a comparable sized current design switch.
  - The proposed switch configuration helps the railroad cars steer to the diverging route curve.
- Maximum vertical wheel forces will be higher than conventional switches. However, the low traffic volume and the relatively low maximum dynamic loads are expected to provide longer vertical switch service life.

A vertical switch requires diverging route wheels to climb over the mainline rail. This is done by lifting the wheels over the stock rail on a field side switch point. The transition from a stock rail to a field side switch point can have a potential change in track gage that exceeds current track safety standards. This design would require a waiver of track safety standards for track gage. Alternate configurations of the field side switch point will be evaluated. These include reduced section stock rails and switch points which are cantilevered over the stock rail or bear on the stock rail.

This study was funded by Association of American Railroads' Strategic Research Initiatives Program to improve the performance of special trackwork.

Please contact **David Davis (719) 584-0754** with questions or concerns regarding this *Technology Digest.* E-mail: david_davis@ttci.aar.com.

INTRODUCTION

Split switches have served the North American freight and passenger railroads well for many years. The standard split switch used today has two moveable switch rails (or points) that are inside the fixed rails (or stock rails) and are connected to each other.

Figure 1 shows a schematic of a split switch.

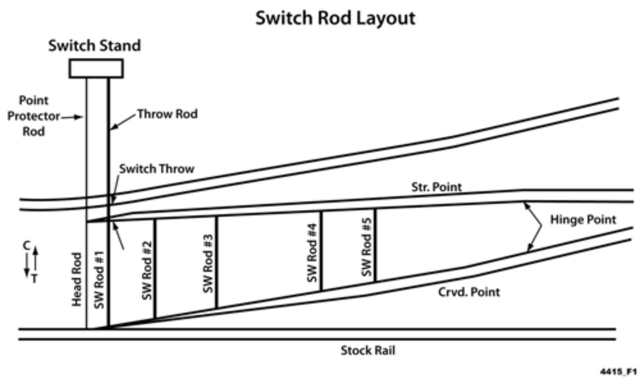


Figure 1. Typical Split Switch

Vertical switches (or continuous mainline rail switches) have been used in freight railroads for many years. These designs are preferred where only a small portion of the traffic is diverging. These switches function by lifting the diverging route wheel over the mainline stock rail. In this design, the mainline rails are unbroken or continuous. Thus, the ride quality and reliability of the switch is greatly improved for mainline traffic. The switch functions with one conventional thin section switch point (in the gage of the track) and one full section switch point on the field side of the other stock rail. Figure 2 shows a vertical switch concept layout.

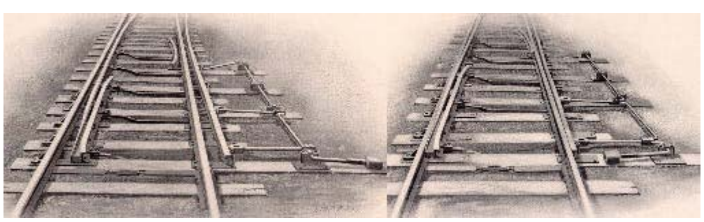


Figure 2. Layout of Vertical Switch

The failure modes of current switch designs were analyzed to determine ways to improve their performance. The analysis was used to guide research and development planning for the Strategic Research Initiatives on special trackwork.

Failure Modes of Conventional Switches

The performance records of the existing split switch designs were reviewed. The top five switch related accident causes are listed below:

- Gapped or chipped switch points
- Dragging equipment derailments
- Track surface and alignment defects
- Worn switch points
- Split switches

Four of the failure modes are related to the specific features of split switches. Dragging equipment derailments are largely independent of switch design. However, the other four failure modes are related to the split switch configuration and the knife-edge switch points it utilizes. The thin section of the switch point is susceptible to breakage from vertical loading and torsion bending. The removal of the foot of the switch point makes it unstable under load. Metal flow from the stock rail can make contact with the switch point problematic, because a narrow band of contact is likely near the top of the switch point. Differential movement of the two components under loading makes the design of the contact surfaces more difficult. These conditions result in overloading of the switch point and stock rail in the same locations, resulting in cracked and broken switch points, track surface defects near the point of the switch, switches that do not close properly, and worn switch points, which raise the likelihood of a wheel climb.

Potential Solutions

Potential solutions were reviewed. This involved reviewing old switch designs and potential modifications to currently used designs. During this process, two categories of solutions emerged. One category is applicable only to switches with low volume, low speed (i.e., <1 percent and 10 mph) diverging operations. Switch designs for this application will be described in this *Technology Digest* (TD). Another category of solutions apply to switches with more diverging traffic or higher speed diverging traffic. Designs for this situation will be described in a subsequent TD.

A review of most previously used low diverging volume, low speed switch designs, revealed their weaknesses. Designs like stub switches and moveable stock rail switches did not have running surface materials capable of carrying heavy axle loads. Other obsolete switch designs were mechanically complex, and thus insufficiently reliable. Also, switches that raise and lower rails, depending on the route selected, were likely incapable of carrying heavy axle loads without significantly more maintenance than the currently used split switches.

One type of vertical switch appears to meet the requirements of eliminating split switch failure modes and having the capacity to carry heavy axle load traffic. This type of switch is described in detail in various patents by Mc Pherson,[1] Wharton,[2] and Gilmore.[3] A significant feature of this design is the elimination of switch point/ stock rail interfaces on the mainline route.

Vertical Switch

Figure 3 shows how a facing point diverging route move is accomplished on one version of a vertical switch. The right hand wheels are raised so their flanges can cross over the continuous right hand stock rail. The left hand wheels will also cross this mainline right hand rail at the turnout's frog.

The left hand switch point is a conventional knife-edge design.

- A switch point with suitable thickness is provided on the left side as soon as the wheel starts touching the right side outer rail. This reduces the wheelset play, increasing the contract area between the wheel tread and the diverging railhead. To further increase the contact area, the head of mainline rail on the field side needs to be cut by 1 inch (B).
- The outer diverging rail lifts the wheel 1.75 inches over a distance of 60 inches. This distance may be longer depending on the location. The track gage abruptly changes from 56.5 to 58.5 inches on diverging rail, where the wheel moves from the mainline to diverging rail (C-D).
- Once the wheel is 1.75 inches higher with respect to mainline rail, the switch point thickness is increased to push the wheelset further toward the diverging rail (E-F).
- While the wheel is ramping down using a spiral configuration, the diverging rail is brought back to a nominal gage of 56.5 inches (G-H).

Vehicle Dynamics

Using NUCARS®* vehicle-track interaction analysis software, a dynamic analysis was conducted on the vertical switch concept to study resulting lateral and vertical loads. Operating speeds were varied from 5 to 20 mph in 5-mph increments. The results were compared with a standard AREMA No. 10 right hand diverging turnout. A loaded coal hopper car with a 263,000-pound gross rail load was used as the test vehicle in the model. This 100-ton capacity car model is well documented and has been used to evaluate many trackwork designs.[4]

The lateral loads applied to the wheels from vertical switch operations were similar to the loads predicted from a standard AREMA No. 10 curved point split switch for all of the operating speeds evaluated. With one wheel approximately 1.6 inches higher than the other (i.e., a cross-level error of 1.6 inches – assuming a conventional switch point riser), the wheelset would have the tendency to move toward the lower conventional switch point and away from the vertical switch point. However, due to the rolling radius difference developed by one wheel contacting in the flange throat on one side and the outer half of the wheel tread on the other side, the wheelset travels down the intended path moving away from the conventional, diverging switch point. Thus, the analysis shows that the maximum lateral loads were slightly lower for the vertical switch as compared to the standard switch.

*NUCARS is a registered trademark of TTCI

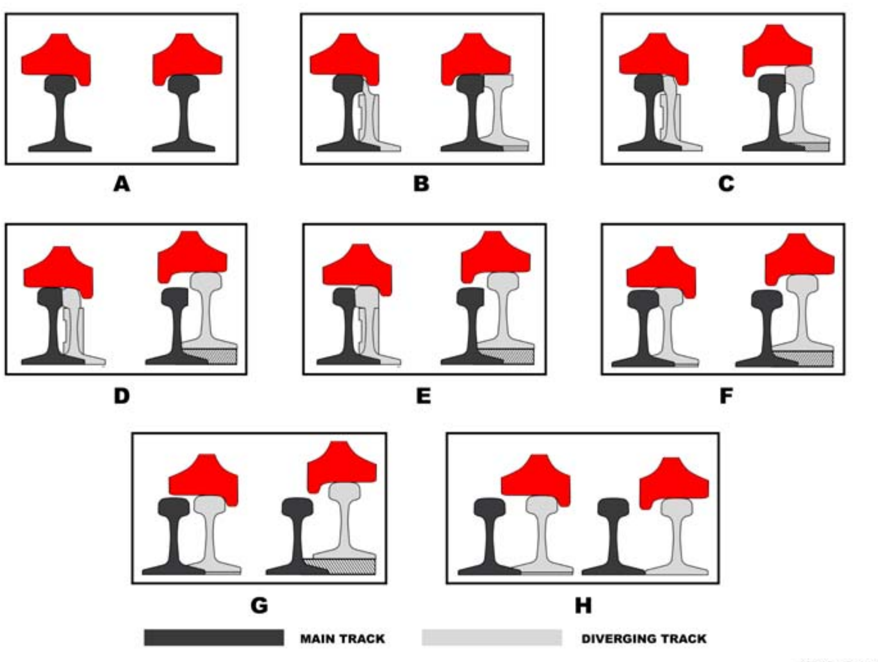
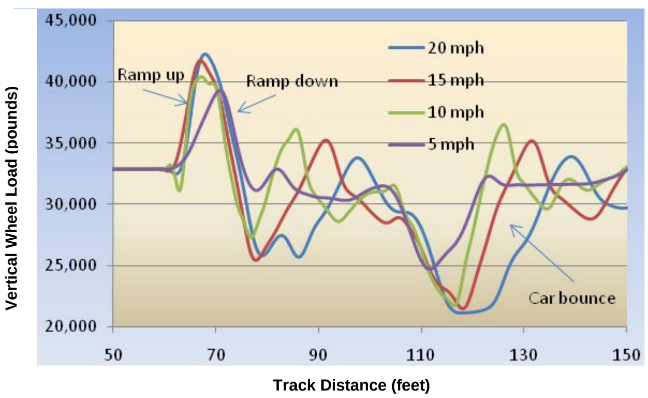


Figure 3. Illustration of a Facing Point Diverging Route Move

As Figure 4 shows, the vertical load of the right wheel of the lead axle increases with the ramp up and reduces with the ramp down, being highest at the maximum height of the vertical switch. In this simulation, the vehicle is moving from left to right. The point of switch is at a track distance of 60 feet in the plots. The right hand switch point is raised 1.75 inches over 5 feet, starting from the nominal top of rail height at the point of switch. The 5-foot ramp is too small for trucks to efficiently distribute load to the other wheels. This is likely the reason the right wheel carries higher loads than the left wheel while lifting up on the ramp. Also, the vertical wheel load increases with speed. Just as the wheel leaves the mainline rail to ride on the outer rail, slight wheel unloading occurs. This wheel unloading reduces with speed. A 10-foot ramp (i.e., a ramp that is half as steep as the 5-foot ramp) shows minimal increase in vertical wheel load. But, the initial cost of the longer ramp switch point will be higher and there are geometric constraints on ramp rate, because the right hand wheel flanges must clear the stock rail when the wheelset diverges from the mainline route.



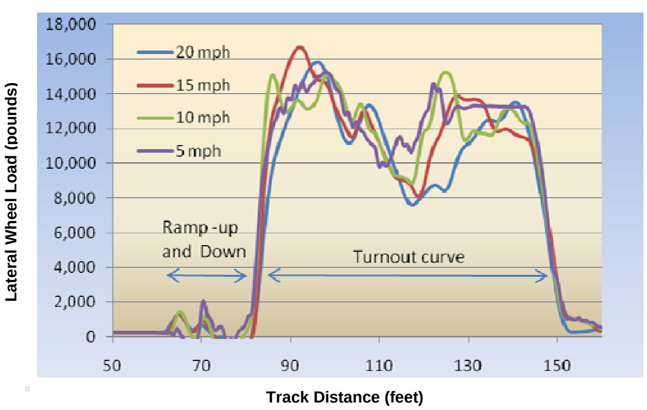


Figure 4. NUCARS® Simulation Results: Vertical Loads (top), Lateral Loads (bottom) for the Right Wheel on Axle 1

Also, as Figure 4 shows, the trailing truck riding up the ramp and then down causes the wheels of the lead truck to bounce. That bounce may cause additional track deterioration about one car length away from the highest point on the ramp of the vertical switch. The track near this location may require a better fastening support system.

The simulation results for an unloaded hopper car were similar to those presented here for the loaded hopper car. The predicted maximum lateral/vertical ratio was similar to that for a conventional AREMA No. 10 turnout.

Issues and Concerns

- Unlike conventional switches where braced stock rails provide most of the lateral stiffness allowing for a minimum number of switch rods, the lateral stiffness of the vertical switch will be mostly due to the switch rods. Switch rods will need to resist lateral loads of 16,000 pounds from one truck.
- The predicted vertical wheel loads over the vertical switch are representative of an average car. A car with degraded truck performance or with a higher truck turning moment may cause higher vertical and/or lateral loads.
- The right hand mainline stock railhead must be cut on the field side by at least 1 inch. This provides sufficient running surface on the switch point to carry wheels and keeps the diverging route track gage within the track safety standards limits. However, reduced head section may cause metal flow hindering the vertical switch fit when closed.
- The track gage will be 58.5 inches, which is above the maximum allowed for FRA Class I track for about 7 feet. At this track gage, wheels will have sufficient, but limited tread contact with the switch point. Wheelsets with narrow wheel back-to-back spacing or narrow treads may split the switch. This configuration would require a waiver of track safety standards for track gage.

Future Work

Different components of the vertical switch will be tested separately. A stock rail with 1 inch of the field side head removed will be tested at the Facility for Accelerated Service Testing (FAST) under 39-ton axle load traffic to assess wear, deformation (metal flow), and fatigue performance. Alternate configurations of the field side switch point that do not exceed allowable track gage will be evaluated. These include reduced section stock rails and switch points which are cantilevered over the stock rail or bear on the stock rail. Later, a full-scale vertical switch will be installed at FAST.

References

1. Mc Pherson, Duncan. August 1894. *Railway Switch*. U.S. Patent No. 524,332. United States Patent Office, Washington, D.C.
2. Wharton, William. April 1901. *Railroad Switch*. U.S. Patent No. 671,254. United States Patent Office, Washington, D.C.
3. Gilmour, Benjamin P. November 1926. *Railway Switch*. U.S. Patent No. 1,605,716. United States Patent Office, Washington, D.C.
4. Handal, Stephen. March 1992. "Partial Validation of a Generalized Turnout Model Based on NUCARS," Research Report R-797, Association of American Railroads, Washington, D.C.