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# Development of and Evaluation of a Steering Switch for Heavy Axle Loads

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## Summary

The Transportation Technology Center, Inc. (TTCI) has developed a switch alignment design intended to improve the performance of frequently used mainline turnouts. Under a project sponsored by the Association of American Railroads, a No. 20 turnout with a prototype steered switch was built and installed at the Federal Railroad Administration's Facility for Accelerated Service Testing (FAST) High Tonnage Loop (HTL) in Pueblo, CO.

After two years of testing, the initial performance of the prototype switch has been somewhat mixed. The turnout with the prototype steered switch has reduced maximum lateral forces and accelerations by about 10 percent as compared to the same turnout with a typical alignment. This should result in lower wear and track geometry degradation. This result is in line with expectations based on the dynamic simulations of the concept previously reported in *Technology Digest* TD-10-013. However, the diverging stock rail has more wear and deformation than typical. Further testing is needed to determine if this is due to the switch alignment or other factors.

Additional findings from the prototype steered switch tests include:

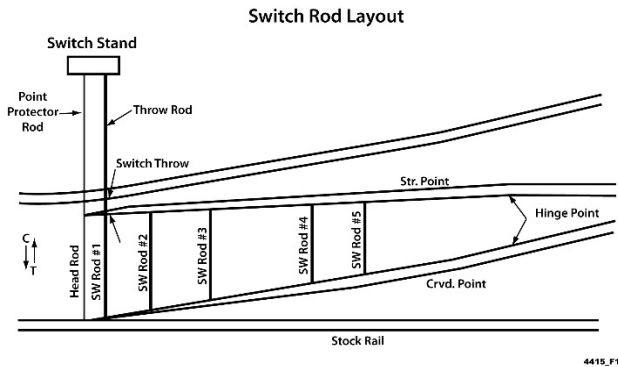
- In facing point diverging moves, the prototype has about 12 percent lower maximum lateral forces than a conventional switch of the same lead length.
- Based on modeling, the potential for an additional 10–20 percent reduction in maximum lateral forces is possible. It would require longer switch points and more gradual transitions.
- In trailing point diverging moves, the prototype has similar lateral forces to the conventional switch of the same lead length. It was expected that some performance benefit would be derived. However, the prototype has very little change from a conventional switch prior to the point of switch.
- The prototype has running surface rolling contact fatigue and plastic deformation on the diverging stock rail. The degradation is more advanced than what is typically experienced on conventional switches after 170 million gross tons (MGT).

Further evaluation is needed to determine the cause(s) of the stock rail degradation and lack of better performance in trailing point moves.



**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. Split Switch Schematic Drawing**

Failure modes of current switch designs were analyzed to determine ways to improve their performance.<sup>1</sup> This analysis was used to guide research and development for the Strategic Research Initiative on Special Trackwork, which reviewed the performance records of the existing split switch designs. Switch related accidents are typically the third leading cause of track-caused derailments.

The review showed four of the top five causes of failure 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 most of the foot of the switch point near the point of switch facilitates twisting under the applied loading. This can result in failure modes such as switch point chipping that are commonly seen. Metal flow from the stock rail can make contact with the switch point problematic, as a narrow band of contact is likely to develop 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 can 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 switch, switches that do not close properly, and worn switch points that increase the likelihood of a wheel climb.

**Potential Solutions**

TTCI researched obsolete switch designs and potential modifications to currently used designs, and two categories of solutions were identified. One category applies only to switches with low traffic volume, low speed (i.e., <1 percent and 10 mph) diverging operations, which is not discussed in this digest. This digest describes possible designs for the second category of solutions, which applies to switches with more diverging traffic or higher speed diverging traffic.

**Presteered Switch Design**

The idea behind the presteered switch is to steer the wheelset away from the most vulnerable part of the switch point, thus lowering the risk of a switch failure. The start of the switch point is separated from the alignment point of switch (i.e., the location where the diverging route begins to deviate from the main route). By manipulating alignment, gage, and running surface profiles ahead of the point of switch, wheelsets may be positioned to minimize the most severe contact with the switch point. Each axle is presteered to a negative angle-of-attack (AOA), so the wheel runs away laterally from either switch point. There are two benefits for this design:

- It reduces the AOA from the start of the switch point—lower AOA means lower lateral force.
- The wheel contacts the switch point rail on the thicker part of the blade and causes less damage on the switch point.

Similar concepts, designed to steer vehicles away from switch points, have been used with success in lower axle load applications. TTCI’s design differs from these concepts and the conventional switch design by extending the switch points beyond the point of switch. This will provide a more robust switch for heavy axle load applications. The new design will accommodate a wider range of wheel profiles.

Figure 2 shows the prototype No. 20 presteered switch installed at FAST. The FAST train consists of 39-ton axle load cars and operates at 40 mph on both mainline and diverging routes through the turnout.



**Figure 2. Prototype Presteered Switch No. 20 Turnout Installed at FAST**

Figure 3 shows one of the features of the prototype switch. In this trailing point view, one can see that the stock rail deviates to the field side of the gage line for a distance near the point of switch. This deviation creates a larger rolling radius difference in the wheelsets that cause them to steer away from the switch point on the opposite rail.



Figure 3. Presteered Switch (showing both mainline switch point and diverging stock rail)

### Presteered Switch Dynamic Simulations

A series of dynamic simulations was conducted using TTCI’s dynamic vehicle modeling program NUCARS® to develop the presteered switch alignment.<sup>2</sup> These simulations used an empty (63,000 pounds gross rail load (GRL)) and a loaded (263,000 pounds GRL) coal hopper car traveling at 40 mph over a No. 20 turnout. Figure 4 shows the wheelset was steered to a negative AOA before it entered the switch point. This negative AOA is seen at distances 28–30 feet in the figure. The point of switch occurs at a distance of 30 feet. This negative AOA means the leading edge of the wheel is pointing toward the center of the track. The flange is likely not making contact with the rail on this leading edge.

Correspondingly, the wheelset moves laterally toward the right rail in a left hand turnout (away from the diverging switch point). This will likely keep loads off the switch point for a greater distance on facing point moves. The expected effect of these changes is extension of service life by reduction of early switch point chipping failures.

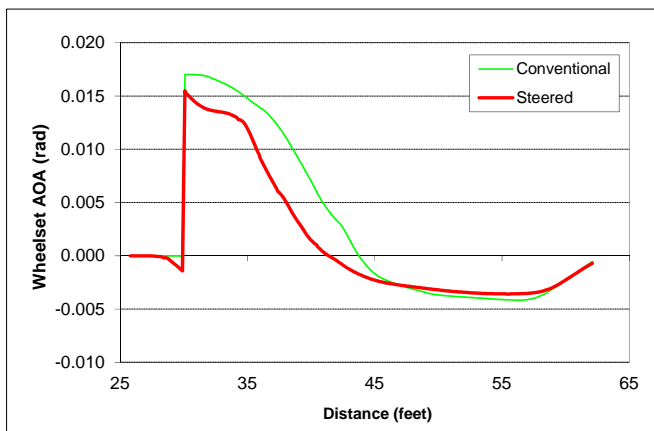


Figure 4. AOA Comparison between a Presteered Switch and a Conventional Switch (empty car)

The simulations also predicted that maximum lateral forces would be reduced by 28 and 18 percent for a loaded and empty car, respectively, compared to the conventional switch in facing point diverging moves. For hollow profile wheels, the reductions in maximum lateral forces would be lower at 5 and 9 percent for a loaded and empty car, respectively. This is due to the lack of uniform wheel tread taper, which makes manipulation of wheel/rail contact position more difficult.

### Field Test Results

In 2013, TTCI installed a prototype switch in the FAST HTL. The prototype switch has most of the features of the presteered switch design described above. However, the extended length of the switch points (in front of the point of switch) was shortened. As a result, the transitions in track gage were made more abrupt. These changes were done for cost and manufacturability reasons. For these reasons, the prototype will be referred to as the steered switch in this digest. Note that the expected performance improvement from the prototype steered switch is expected to be less than the theoretical presteered switch.

The prototype steered switch has been in track for 174 MGT of traffic of which 42 MGT (24 percent) has been diverging traffic. In general, the turnout has performed well. There is a maximum lateral force reduction in facing point moves of about 12 percent at 40 mph.

Figure 5 shows lateral forces versus speed for the original alignment and for the steered switch. Note that there is considerable variability in performance for the same train operating over the turnout in the same day. This is seen in the original alignment turnout at 38 MGT and in the steered switch measurements taken at 57.5 and 57.9 MGT.

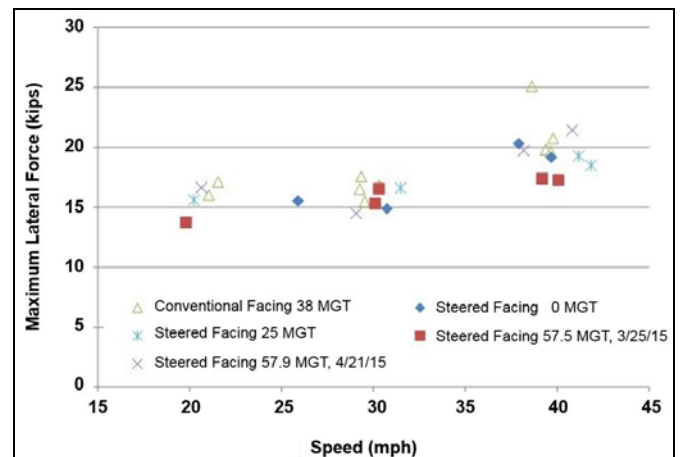
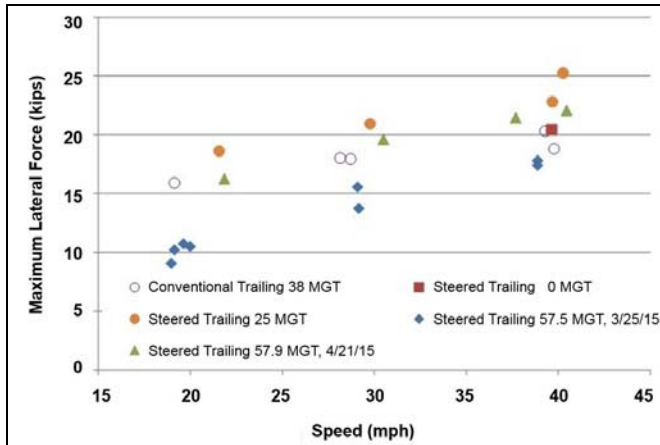


Figure 5. Measured Maximum Lateral Force vs. Speed for Conventional and Steered Switch Turnouts Facing Point, Diverging Moves

In trailing point moves, the steering switch is not lowering the maximum lateral force in comparison to the original alignment. Figure 6 shows a plot of maximum lateral force versus speed for the two switch alignments. Again, variability in performance is seen in the steering switch. The performance measured in March 2015 at 57.5 MGT is much better than that measured at any other tonnage.



**Figure 6. Measured Maximum Lateral Force vs. Speed for Conventional and Steered Switch Turnouts Trailing Point, Diverging Moves**

An investigation as to why the switch has such variability is underway. Seasonal effects, especially temperature and its effects on track gage, are being investigated. The wheel load data will be further analyzed to look at 99<sup>th</sup> and 95<sup>th</sup> percentile values rather than just maximum values. This should produce results that are less subject to random variations associated with train dynamics.

### Prototype Switch Wear

The prototype steered switch had some early degradation issues related to track gage and stock rail wear. Track gage on the diverging route has been tight near the heel of the switch. The crosssties in this area skewed and are likely the cause of the tight gage.

The diverging stock rail has metal flow and rolling contact fatigue in the location where both stock rails are located wider than the theoretical alignment calls for (to allow for a wider switch point and to facilitate wheelset steering). Degradation of this stock rail is more rapid than experienced under conventional switch operations at FAST. Figure 7 shows the stock rail.

Measurements and observations will continue in order to determine the root cause and potential remedies for the stock rail degradation.



**Figure 7. Diverging Stock Rail Wear and Running Surface Fatigue on Prototype Steered Switch**

The turnout was re-gaged near the switch heel by straightening the crosssties and adjusting the stock rail braces on the base plates. The effect of this change was insignificant on maximum lateral forces in the switch for trailing point moves. Lateral forces in the switch heel area, where the track gaged was widened back to track class, were reduced by 20 to 40 percent. However, the lateral forces here are relatively low when compared to those at switch entry.

### CONCLUSIONS

Prototype steered switch testing under heavy axle loads has shown some performance benefits with about 12 percent lower maximum lateral forces in facing point moves. The steered switch point wore less (at 60 MGT so far) than that of the traditional switch, which was changed out at 38 MGT due to test reasons, but with switch point chipping.

### FUTURE WORK

Longer term testing of the prototype steered switch will be conducted to determine life cycle performance and resolve the following issues:

- Lack of performance improvement for trailing point, diverging moves
- Excessive stock rail wear on the diverging route

Continued testing of the prototype will be at FAST done to further refine the design.

### REFERENCES

1. Davis, David D., Vincent R. Terrill, and Daniel B. Mesnick. July 2002. "Railroad Switch Design and Failure Mode Analysis." *Technology Digest* TD-02-015, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO
2. Shu, Xinggao and David D. Davis. May 2010. "Mainline Switch Design to Improve Vehicle Steering." *Technology Digest* TD-10-013, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO

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