Interaction of Tread-hollow Wheel and Worn Switch Point / Stock Rail

by
Brad Kerchof
Division Engineer
Norfolk Southern Railway
1400 Norfolk Southern Drive
Birmingham, AL 35213
205-951-4724
205-951-4706 fax
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Abstract

The increase in both the frequency and magnitude of tread-hollow wheels has caused NS to re-evaluate its switch point / stock rail maintenance practices. After presenting a brief lesson on switch point and stock rail design, the paper describes a derailment of a loaded coal train at the switch point-to-stock rail transition, trailing point move. The derailment investigators examined the height difference between the switch point and stock rail as well as the wheel profiles of the derailed cars before determining the cause to be a tread-hollow wheel that contacted the gage side of the stock rail. This derailment helped influence the AAR’s mechanical division to finally establish a tread-hollow wear limit, one that paradoxically is greater than the wheel blamed on the derailment. Thus, the responsibility for preventing this type of derailment now falls to maintenance of way, which must tighten its switch point / stock rail maintenance standards on territories that carry tread-hollow wheels.

Key words: Tread-hollow wheel, hollow-worn wheel, switch point, stock rail, switch point–stock rail height difference, switch point-stock rail transition
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1.0 Introduction
What is the design height difference between a switch point and a stock rail? According to most standard plans, it is one quarter-inch. But what should the maintenance limit be for this height difference? Chances are MW people do not pay a great deal of attention to this dimension.

Last year a derailment taught us an expensive lesson that switch point / stock rail height differential is something that we need to pay attention to, particularly when the rail car population includes tread-hollow wheels.

1.1 General discussion of switch points and stock rails
One of the fundamental rules of track maintenance is to never install a worn switch point against a new stock rail. The reason, of course, is the risk that the outside edge of a wheel might contact the gage face of the stock rail, thereby forcing the stock rail out and rupturing gage.

Figure 1 shows a new switch point and stock rail. The maximum difference in height of the switch point over stock rail is ¼" (red arrow). Because the top of the point rail is milled gradually down toward the front of the point, this quarter-inch height advantage gradually lessens, until the point and the stock rail are the same height (yellow arrow). Moving even closer to the front of the switch point, the differential becomes negative – the point drops below the top of the stock rail.

The switch point–to-stock rail transition zone can be defined in terms of a section of stock rail. At the heel block end, the transition begins where the edge of the wheel tread moves over the stock rail. Figure 2 shows a wheel roughly one foot into the transition zone; note the quarter-inch of clearance between the wheel and the stock rail. A new switch point will support a wheel until it covers the width of the stock rail. The milling of the switch point will then drop the wheel down gradually until it has bearing on the stock rail. Over time, a switch point on the heavy-tonnage side will see its height advantage over the stock rail decrease, from the design ¼" to something less.

Near the front of the point, the transition ends where the wheel is supported entirely by the stock rail. Figure 3 shows the end of transition; note the clearance between the wheel and the switch point.
The length and location of a transition zone is affected by three factors: switch point length, switch point and stock rail wear and wheel tread profile. As a switch point wears, the wheel contact point moves further back on the stock rail, toward the heel block. A slightly worn point will allow wheel-to-stock rail contact while the edge of the wheel is still over the middle of the stock rail. As the switch point wears further, the tread contact point moves closer to the stock rail's gage corner.

If the rail cars are heavy enough, the outside edge of the wheel tread will deform the running surface of the stock rail. Figure 4 shows a 16'-6" point section; the transition zone is between the two pieces of ballast, where the stock rail running surface has been deformed by wheel-tread contact. This type of wear pattern is typical of heavy axle loads making a trailing point move.

As a matter of field practice, the gradual decrease in switch point / stock rail height difference is not something we measure or otherwise pay a great deal of attention to. Rather, we look at the wear at the tip of the point, more concerned about how a worn thin, broken or ramped point will impact facing-point traffic. With a stock rail, we look for gage-side wear near the front of the point, and for corrugations or an unusual wear pattern through the transition zone, mostly because a rough running surface can contribute to irregular track surface.

2.0 Derailment description
Our evaluation of the importance of the switch point-over-stock rail height difference changed following a derailment in 2003. In July, a Powder River Basin coal train, received in interchange from the UP at Memphis and destined to a Georgia Power generating plant near Macon, derailed in Sheffield, Alabama.

The derailment occurred in a double track to single track no. 14 equilateral turnout with a 22-ft spring switch (figure 5). Timetable speed through the turnout is 20 mph. While the coal train was making a trailing point move through the left-hand side of the turnout at 14 mph, it derailed the six rear cars and the trailing, remotely controlled helper locomotive (figure 6).
2.1 Track inspection
The initial report suggested an open gage derailment immediately ahead of the switch. Both rails were canted or rolled, and both showed multiple wheel flange marks on the web and base. The right-hand stock rail – this would have been the closed point side during train movement – was canted out of the switch plates. But the marks in the middle of the switch point section caused us to consider another cause.

The switch point looked good. The stock rail did not – its running surface through the transition zone was deformed, suggesting that the switch point had worn down relative to the stock rail, and that some worn wheels were contacting the running surface of the stock rail near the gage side.

Figures 7 and 8 show what appeared to be a fresh rub mark on the gage corner of the stock rail (yellow arrows). The mark started at the beginning of the transition zone and continued all the way to the front of the point. The number “12” written on the stock rail in figure 7 indicates 12 feet from the front of the point.

Figure 8 shows a second mark, this one on the running surface beginning near the gage corner and angling toward the middle of the rail head. This mark is from tread-hollow wheel – or false flange – contact, and suggests that some wheels are being supported by the stock rail instead of the switch point. Ideally, the wheel should not make contact with the stock rail until its outside edge is most of the way across the stock rail.

Figures 9 and 10 show the stock rail 6 ft and 3 ft behind the front of the point; note the continuation of the tread-hollow wheel contact mark as it works its way across the running surface of the stock rail.
2.2 Wheel inspection
We turned our attention to the derailed equipment, suspecting that we might find some tread-hollow wheels among the derailed cars. On the second derailed car, we found the wheel shown in figure 11.

Compare its hollow-worn tread to the profile of a fairly new wheel that we found in the wreckage (figure 12). It is worth noting that at the time of this derailment, our industry did not have a maintenance limit for tread-hollow wheels, and, in fact, did not have an approved procedure or gage to measure this characteristic. Subsequently, NS’s Research and Test Department utilized a wheel profile measuring instrument called a Mini-prof to describe the worn wheel as 1.5 mm hollow.

3.0 Derailment Simulation
We were curious to see if we could recreate contact between the wheel tread and the gage side of the stock rail. We reassembled the derailed cars with their original trucks and wheels, and operated the consist through the switch, simulating the move that it had made at the time of the derailment. There were two significant differences between the original and simulated conditions: the cars were empty instead of loaded, and the test train operated at walking speed instead of 14 mph. We looked and listened for any indication that a wheel tread face was contacting the gage face of the stock rail. We observed only smooth switch point-to-stock rail transitions.

Our simulation, while it did not result in a wheel canting out the stock rail, did produce some very informative photographs of both a new wheel and the 1.5-mm hollow-worn wheel in the transition zone.

Figure 13 shows a new wheel positioned nine feet behind the front of the point. Recall that the first signs of wheel tread / stock rail contact were observed just beyond station 11. At two feet into the transition zone, the wheel has overlapped the stock rail by half an inch. Note the clearance between the wheel and the stock rail, as well as the tread contact marks on the running surface just ahead of the wheel.
Figures 14 and 15 show the 1.5-mm tread-hollow wheel at the same location. The edge of the wheel tread was bearing on the stock rail. Note that the stock rail’s running surface had begun to flatten out under the repeated loading of the hollow-worn wheels, creating a square gage corner on the stock rail (red arrow in figure 15).

Figure 16 shows the side view of the tread hollow wheel, figure 17 the side view of the new wheel. The difference in clearance is apparent: the hollow-worn wheel is touching the stock rail, while the new wheel has over an eighth of an inch of clearance.

A week later we performed a second simulation, using the same 1.5 mm tread-hollow wheel under a different, loaded car. The original switch point and stock rail remained in track. Figure 18 shows the wheel spotted six feet behind the front of the point, the location where a new switch point and the stock rail are, by design, the same height. The tread-hollow wheel made tread contact with the stock rail but not the switch point.
4.0 Derailment cause analysis

The three departments – transportation, mechanical and engineering - agreed on the description of events: the outside edge of a wheel contacted the gage face of the stock rail eleven feet behind the point, wedging the stock rail outward and allowing the wheels to drop in. We agreed that there were a number of hollow-worn wheels in the derailed equipment. And we agreed that the switch point had some vertical wear, such that the height advantage of the switch point over the stock rail was now less than the ¼" found on brand-new components. What we did not agree on was the relative contribution of these two conditions to the derailment.

The mechanical side argued that had the switch point not been worn, the derailment would not have occurred, and thus the track deserved at least a 50% allocation of the derailment cause.

Engineering argued that the degree of wear exhibited by this switch point was typical of many switch points, and that it was unreasonable for us to maintain a track structure that protected against severely hollow-worn wheels.

This disagreement prompted a closer look at both the track and the wheels.

4.1 Switch point / stock rail differential height

Here is what the AREMA manual says about switch point and stock rail maintenance:

5.11.3 (d) Make appropriate corrections if the normal ¼ inch point rail rise above the stock rail has been compromised by point rail wear which could permit the overhanging part of hollowed-out treads of worn wheels to contact the gage face of the stock rail rather than pass over the stock rail in a trailing point move.

We did measure the height difference between the switch point and the stock rail.

![Switch Point / Stock Rail Height Differential](image)

*1/8*" = 3.1 mm

Figure 19 shows the height difference between the 22-ft switch point and stock rail through the transition zone. Assuming a new switch point and stock rail, and assuming a wheel that is cylindrical in profile, one would expect that where the wheel begins to move over the stock rail – near station 11 - the wheel would clear the stock rail by ¼". This ¼" clearance continues to station 9.

Between stations 9 and 6, the top of a new switch point has been milled down to match the height of the stock rail. Our cylindrical wheel would make its transition from switch point to stock rail where the two components have the same height – at station 6. A new, conical wheel would make its transition to the stock rail even closer to the front of the point.

We did take light (or not under load) measurements. This is not a reliable method - we found ourselves estimating the under-load movement of switch point and stock rail with a very low level of precision.
The under-load measurements revealed that the height difference at the beginning of the transition zone was 1/8”, or 1/8” less than design. This reduced differential was due to top wear of the switch point.

Our conclusion: on order to have a problem with a stock rail that is 1/8-inch below its switch point, we would need a 3.1 mm tread-hollow wheel.

### 4.2 Wheel profiles

![Wheel Profile Distribution](image.png)

We then turned out attention to the wheels on the derailed cars. Using data collected by NS Research and Test's Miniprof instrument, we produced a distribution graph (figure 20) that presents the wheel data from all five derailed cars. Well over half the wheels were tread-hollow, and the worst offender measured 3.5 mm. Recall that the wheel that we had used in our simulations measured only 1.5 mm. We did not take a photograph of the 3.5 mm tread-hollow wheel.

And while our initial suspicion was directed at the 1.5 mm wheel – it was on the lead axle of the second derailed car - we concluded that its tread hollow measurement was insufficient to have overcome the 1/8-inch switch point / stock rail height difference.

We took a closer look at the 3.5 mm tread-hollow wheel – the only one that exceeded our switch point / stock rail height difference. This wheel was located in the position that we deemed most likely to cause a rail rollover derailment – lead wheel of a trailing truck. In the lead axle/ trailing truck position, there are no other wheels close by that could apply a vertical load to resist the overturning of the stock rail; the lead truck is a car-length (42 ft) away, and the trailing wheel on that trailing truck is still on the switch point – it hasn’t yet made the transition to the stock rail.
This wheelset was also the only one to exhibit a pronounced asymmetric wear pattern. The MiniProf profiles of this axle (figure 21) show a dramatic difference in both flange thickness and tread-hollow measurement. The top pair of wheels, R3 and L3, represent the lead axle of the trailing truck. The R3 wheel measured 3.5 mm hollow and had a badly worn flange. The L3 wheel measured only 1.5 mm hollow and had a slightly worn flange. This wear pattern suggests that this truck had a very strong bias to the left, and while traveling through the right-hand curve of the equilateral turnout, might have displayed a sharper angle of attack than other trucks.

5.0 Measuring Hollow-tread wheels

Prior to this derailment, the industry did not have an official tread-hollow wheel standard. Wheels could be condemned for thin flange, high flange, thin rim or flat spots, but not for a worn profile. In the year following this derailment, the mechanical division of AAR finally established a tread-hollow standard. The railroads had sought a not-to-exceed 3 mm standard. The AAR, perhaps influenced by private car fleet owners, announced in April, 2004 that the standard would be not-to-exceed 4 mm. AAR also approved a gage for measuring hollow worn wheels.

The gage shown in figure 22 uses the vertical edge of the wheel rim as a reference and a horizontal slide piece to locate a pointer over the maximum hollow wear. The amount of hollow tread is the distance between the horizontal reference line and the lowest part of the wheel tread. This worn wheel measures 1.5 mm hollow. A cylindrical wheel would measure zero, while a new wheel would have a value of less than zero, reflecting a conical shape.
6.0 Closing arguments and conclusions: the official derailment cause

The final cause wording came from NS’s Research and Test Department:

*Tread hollow profile (3.5 mm) allowed lead wheel trailing truck of RWSX 94772, loaded coal car, to roll the stock rail and rupture gauge during trailing point move through a #14 equilateral turnout.*

The responsible wheel was located on the third derailed car, trailing truck, lead axle.

So engineering had won the battle – the wording of the derailment cause placed full responsibility on the worn profile of a wheel, and exonerated our stock rail and switch point. But it was a hollow victory.

Consider these observations:
1. A serious main line derailment occurred that involved tread-hollow wheels and a 1/8-inch worn switch point.
2. NS’s mechanical department argued that because there was no AAR standard for tread-hollow wheels, the wheel condition could not be the cause of the derailment.
3. Nevertheless, NS, in its official cause, attributed the derailment to a 3.5 mm tread-hollow wheel.
4. The cause of the derailment – the tread-hollow wheel – was used to encourage the AAR’s mechanical division to develop a tread-hollow wear limit, which it subsequently did – 4 mm.

Now imagine if an identical derailment were to occur tomorrow, engineering people would find themselves in the difficult position of trying to blame the derailment on a 3.5 mm tread-hollow wheel, one that now meets AAR interchange standards.

6.1 Switch maintenance in a hollow-worn wheel environment

It is very important to understand that the presence of hollow-tread wheels changes our switch point / stock rail maintenance model.

The old model had stock rail and switch point installed in the same condition – typically new. As the switch point experienced vertical wear the initial wheel contact point moved further back on the stock rail and perhaps closer to the gage corner. At a later stage, the switch point would wear down to the same height as the stock rail. As long as wheels had tapered or conical profiles, having a stock rail and switch point that were the same height at transition was not a problem.

So what will be our new standard? In certain corridors – where there are tread-hollow wheels - we must watch very closely for evidence of tread contact nearing the gage corner of the stock rail running surface. We proved that we can get in trouble by having a switch point that is 1/8” higher than the stock rail. A 3/16” differential is better, given the AAR’s 4 mm tread-hollow limit. But 3/16” allows for only 1/16” of switch point wear.

Trying to take light measurements of the height differential is unreliable. Instead, MW people need to look for the first signs of wheel tread contact on the running surface of the stock rail; this contact indicates that the differential has likely gotten below 3/16”. When the contact marks extend back to the gage corner, it is time to consider changing out the switch point and stock rail.

The industry is beginning to develop methods to inspect wheel profiles, but it will be sometime before this technology has an impact on the wheel population. In the near term, the number and severity of tread-hollow wheels is unlikely to change; certainly one reason is that owners of the large private fleets are unlikely to commit to changing out tread-hollow wheels on a wholesale basis.

So even though we succeeded in assigning the cause to a mechanical condition, the change in procedure that needs to occur to prevent future derailments of this type will have to come from maintenance of way. On certain routes, we will have to change out switch points and stock rails sooner than we have been.
Six weeks after the derailment we renewed the switch point and stock rail. Figure 23 shows these components
ten months and perhaps 30 MGT after renewal; a tread-hollow mark was already visible on the running surface of
the stock rail.

7.2 Helpful hints for maintenance of way
Finally, this derailment investigation suggested four helpful hints for maintenance-of-way people.

First, be familiar with the wheel profiles running on the territory. The population and severity of tread-hollow
wheels is greatly influenced by the geometry over which rail cars operate. Western road equipment, operating on
long tangents, is more likely to develop tread-hollow wheels than an eastern road like NS, whose curved territory
causes more rapid flange wear, which then becomes the governing reason for wheel replacement.

Second, in hollow-wheel territory, pay particularly close attention to wear marks on the running surface of stock
rails. Look for a hollow tread contact mark that runs diagonally across the stock rail running surface – it is the
eyear warning that the switch point is wearing down. When this wear mark has worked its way back to the gage
corner of the stock rail, the chance of contact between wheel tread face and stock rail gage corner increases.

As the stock rail begins to flatten, maintain a radius on the gage corner of the stock rail by grinding. This will help
prevent a square-corner wheel from getting a grip on the gage face of the stock rail. This is a temporary fix – it
does not increase the switch point / stock rail height difference; it merely provides a ramp for a hollow-tread wheel
to ride up on.

Finally, treat all stock rail braces equally. Many MW people have attached a greater importance to the braces
near the point of switch. These braces are important - they serve to keep the stock rail from moving laterally and
allowing a gap to develop behind the closed switch point. But the braces located through the transition zone are
equally important – they resist the overturning forces caused by a tread-hollow wheel.