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Revenue Service Track Circuit Shunt Performance

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SUMMARY

Track circuits are used to detect trains for train operations control, broken rail detection, and to activate grade crossing warning devices. From April through June 2011, the Transportation Technology Center, Inc. (TTCI) measured the track circuit shunting performance of individual cars and trucks in passenger, empty coal, and freight trains using a 46-foot island track circuit in open track at a site provided by Union Pacific Railroad. The data collection system used with the short track circuit provided a time history of circuit voltage and relay voltage for each train. A database of about 800 trains was collected to serve as a baseline of current performance at the test site. Most of the trains measured at the site exhibited good shunting performance.

The root cause of loss of shunt appears to be development of a resistive film on the running surface of the rail and, presumably, the wheels. Confirming previous studies,¹ rail cars with low wheel loads (i.e., empty coal cars) affected wheel/rail contact pressure adversely, resulting in low efficiency in shunting. Water on the rail (in the form of rain) improved shunting performance for empty coal trains, but this effect was short lived. Larger tare weight empty cars shunted better than low tare weight empty cars, which may be due to the larger wheel load (8,000 pounds versus 6,000 pounds).

Shunting performance varied by train type. Trains were classified into three types: passenger trains, coal trains (all empty westbound) and mixed freight trains. This was done by counting axles and confirmed by analysis of automatic equipment identification tags. Train type affects shunting in the following ways:

- Wheel load – affects wheel/rail contact pressure
- Wheel profile – affects wheel/rail contact pressure and contact location
- Car length – affects number of wheelsets within the track circuit

Note that the track circuit used for this research was much shorter than typically used to control grade crossing warning devices (46 feet versus 120 to 200 feet). This was done to capture the behavior of individual cars and trucks. In practical application, the shunting performance of trains, especially passenger trains, is greatly improved with the use of the typical length track circuits, because three to four times more axles can act to create a shunt across the two rails.

Effective prevention/removal of the rail surface film is one of the keys to preventing loss of shunt. Future research efforts will evaluate the effectiveness of rail cleaning systems and the effects of variations in rail/wheel profiles on shunting performance. The use of the short track circuit will allow evaluation of changes in rail/wheel profile and rail surface conditions on shunting performance.

This research was conducted as part of the Association of American Railroads' Strategic Research Initiatives Program.



INTRODUCTION

Loss of shunt can occur when a train or rail vehicle is unable to shunt (or short circuit) an open electrical circuit in the track. Railroads use track circuits, made up of the two rails as conductors, an energy source and a current detector or relay circuit to detect the presence of trains. By interpreting the current flow through the track circuit, the presence of a train can be detected. Train presence detection (i.e., the signal system) is used to control the movement of trains and also to warn highway vehicles and pedestrians of approaching trains at road crossings. As a by-product, the presence of a discontinuity in the rails (i.e., a broken rail) can sometimes be detected by track circuits.

The ability of a rail vehicle to shunt the track circuit can vary due to many factors. These factors relate to the wheel/rail contact conditions and the track circuit configuration. This *Technology Digest* documents the ability of individual cars in revenue service trains to shunt a short track circuit installed specifically for the purpose of measuring shunting performance. The revenue service site for this testing was selected because of its line characteristics that may allow for the study of the following factors considered likely to affect loss of shunt:

- Rail cars with low wheel loads
 - Passenger trains
 - Empty coal trains
- Top of rail (TOR) contaminants
 - Agriculture nearby
 - TOR lubricators used on coal trains
- Variety of weather conditions
 - Warm, moist summers
 - Cool, dry winters

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Methodology

A short track circuit was installed in tangent track for the sole purpose of monitoring the shunting performance of individual rail cars and trucks. The location selected for this test was on a main line that has had some shunting-related signal issues in the past few years. The line carries 20 or more trains per day, including passenger trains and many empty coal trains. It is operated as part of a paired track between Kansas City and Jefferson City, MO. The line carries westbound traffic almost exclusively. The only regular eastbound trains are two passenger trains per day. A significant portion of the freight trains are empty coal trains. Thus, there are many trains with low average wheel loads.

Figure 1 shows the track circuit layout. This short track circuit allows for the assessment of the shunting performance of individual cars and trucks within the track circuit. However, the short length of the circuit makes it perform its intended

task of detecting trains much less reliably than a typical 120- to 180-foot grade crossing track circuit. The longer length used in practice assures that many more wheelsets are within the track circuit at any given time. This larger population of wheelsets within the track circuit minimizes the effects of individual wheelsets and increases the probability that the circuit is shunted at all times when a train is present.

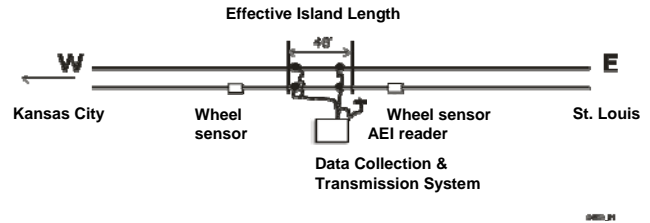


Figure 1. Loss of Shunt Research Track Circuit Layout

The data collection system used with the short track circuit provides a time history of circuit voltage and relay voltage for each train. Train presence, direction and speed were verified using magnetic wheel sensors at each end of the circuit. When trains enter the circuit, the wheel sensors activate the data collection system. The wheelsets shunt the track circuit, causing current to flow and the circuit voltage to drop.

The system is equipped with a typical island circuit relay. The relay is set up to drop when the track circuit voltage drops more than approximately 2.75 volts. In a functioning island circuit, the relay drop activates flashing lights and drops the crossing gate arms.

Figure 2 shows a time history for a train exhibiting poor shunting performance. The increase in track circuit voltage and the releases of the relay in the middle portion of the train indicate loss of shunt problems.

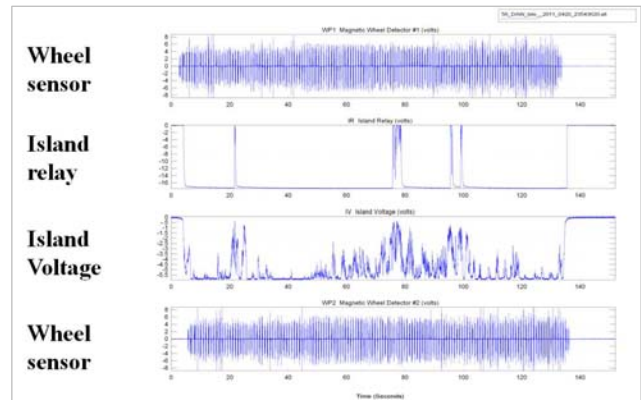


Figure 2. Time History of a Train with Poor Shunting Performance

An automatic equipment identification tag reader installed at the site read the car identification tags from one side of each car. Additionally, data from a local weather station located a few miles west of the site was added to the track circuit database.

Rail Surface Condition Assessments

Electrical resistivity was measured at 12 locations across the head of the rail at the test site. The results showed significant variation across the railhead, as Figure 3 shows. These measurements agree with the visual inspection of the rail,

which showed a film in the center of the railhead. The initial analysis by metal surface coating experts showed the coating contains carbon, plant fibers, and metals used in lubricants, such as titanium. The carbon is present in graphitic- and diamond-crystalline structures.

From Figure 3, one can envision how wheels riding on the center to field side of the railhead would have more difficulty shunting the track circuit.

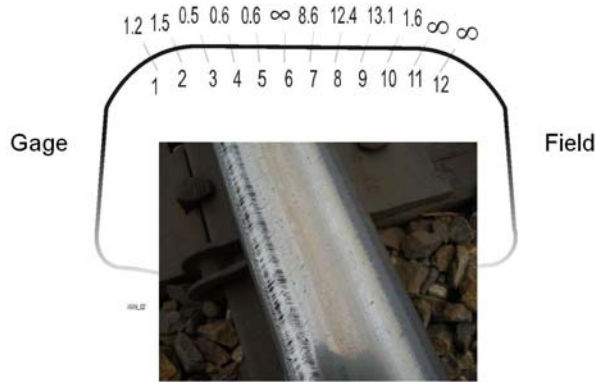


Figure 3. Railhead Resistance Measurements from Test Site

Track Circuit Data Analysis

Shunt performance data from about 800 trains was examined during the period of April through June 2011 at the revenue service test site. The data consisted of 148 passenger trains, 390 empty coal trains, and 267 mixed freight trains. Figure 4 shows a plot of average track circuit voltage versus the standard deviation of track circuit voltage. Note that the track circuit used in this test is configured such that a nominal good shunt measures -6 volts.

In Figure 4, trains exhibiting good shunting performance are in the lower left corner of the graph, with average values near -6 volts and low standard deviation values. The trains exhibiting the worst shunting performing are in the upper left portion of the graph, and exhibit higher average voltage levels and low standard deviation values. The inconsistent trains are on the right side of the graph and have higher standard deviation levels. Most of the trains measured at the site exhibited good shunting performance.

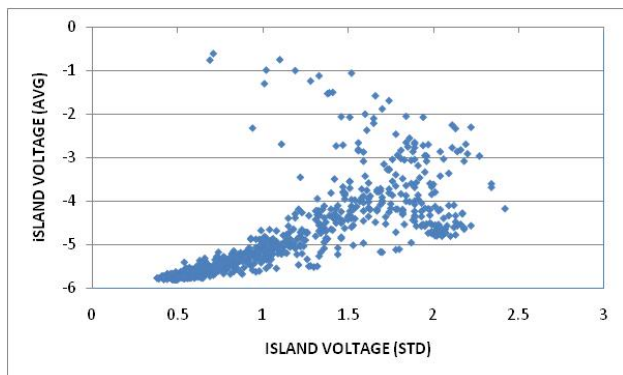


Figure 4. Average versus Standard Deviation of Track Circuit Voltage

Figure 5 shows the average track circuit voltage versus the percentage of time the track circuit relay is dropped. This is an indicator of how consistently the gates and flashers would be operating in an active warning circuit (although this circuit is much shorter than a typical island circuit). In this plot, rail vehicles with good shunting performance are in the lower right corner. There is a correlation between these two measures; low average shunt voltage corresponds with the circuit relay being dropped.

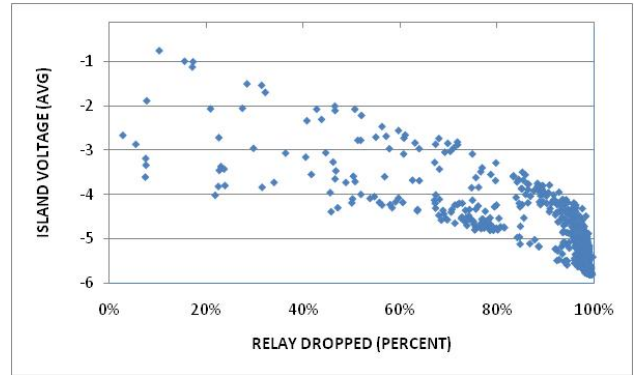


Figure 5. Average Track Circuit Voltage versus Percent of Time Relay is Dropped

There is a better correlation when the data is segregated by train type, as Figure 6 shows. Passenger trains may perform worse than other train types due to the length of the track circuit used for this test. The longer truck-center spacing of the passenger cars allows for periods when no wheels are in the track circuit during train passage. As a result, the passenger trains never achieve more than about 80 percent relay dropped. This can also happen with mixed freight trains, but less frequently.

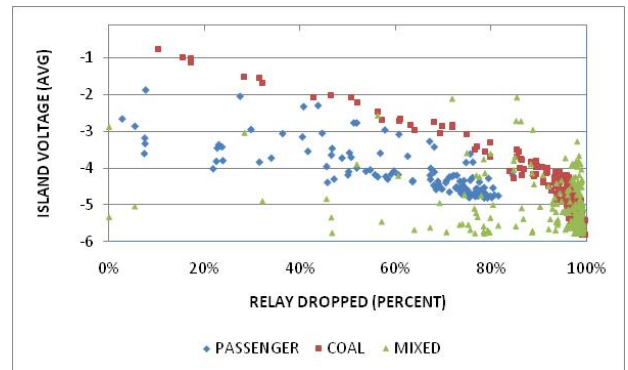


Figure 6. Track Circuit Voltage versus Relay Dropped by Train Type

Note that the coal trains were the least efficient train type at shunting in terms of average circuit voltage. Yet, they were more efficient at dropping the relay at any given average voltage. It is hypothesized that the low efficiency in average voltage is due to the low average wheel load of the empty coal trains. It is hypothesized that the efficiency at dropping the relay is due to the fact that there are more wheelsets in the circuit on average, because of the shorter truck spacing of the coal cars.

Empty Coal Trains Shunting Performance

Several factors appear to affect shunting performance. The more homogeneous empty coal trains (390 in total) were studied for factors that can affect shunting. The most important factors are discussed below.

First, weather affects shunting performance significantly. Using a local weather station to determine the weather conditions at the test site, the presence of rain (measured as any amount of precipitation two or less hours before the train passed the site) showed improved shunt performance of trains.

Figure 7 shows the performance of coal trains with and without rain. The average track circuit voltage is -5.49 with rain and -4.91 without rain. The worst performing empty coal train had an average track circuit voltage of -2.97 with rain and -0.76 without rain. The worst shunting train in the rain dropped the track circuit relay 64 percent of the time the train was in the circuit. All other “rain trains” dropped the relay more than 85 percent of the time (less than 1% below 85%). In dry weather, 11 percent of the trains dropped the relay less than 85 percent of the time.

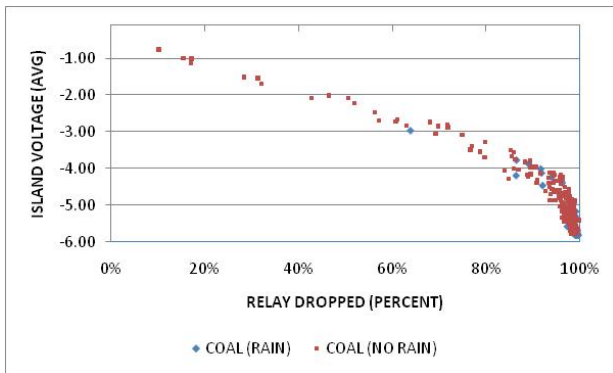


Figure 7. Track Circuit Voltage versus Relay Dropped for Coal Trains by Weather Condition

Humidity was correlated with time of day and temperature, and it showed a small effect on shunting performance. Generally, trains had better shunting performance at night than during the day.

Next, the effect of car capacity was examined for the coal trains. This is a proxy variable for car tare weight and perhaps truck steering ability. The population was split into 286,000- and 263,000- to 268,000-pound gross rail load cars. The 286,000-pound capacity cars likely have lower tare weights (and thus lower wheel loads when the cars are empty). The lower empty car wheel loads may adversely affect the shunting performance of the 286,000-pound capacity cars.

The 286,000-pound capacity cars may also be equipped with better steering trucks. It is unclear if truck steering has any effect on shunting performance. Better steering trucks may affect shunting performance if it affects wheel/rail contact position or rail surface contact stress.

Figure 8 shows the performance of coal trains made up of either 263,000-pound capacity cars or 286,000-pound capacity cars. The average track circuit voltage was -5.14 for the

263,000-pound capacity empty cars and -4.98 for the 286,000-pound capacity empty cars. The worst performing train was made up of 263,000-pound capacity empty cars and had an average voltage of -2.74. The worst performing train was made up of 286,000-pound capacity empty cars and had an average voltage of -0.76. As with the effect of rain, the distribution for the 263,000-pound capacity empty cars had no tail of bad performing cars, as compared to the distribution for the 286,000-pound capacity empty cars.

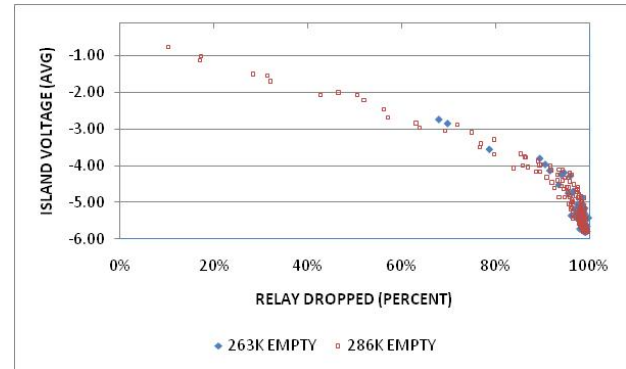


Figure 8. Track Circuit Voltage versus Relay Dropped by Coal Car Capacity

Onboard TOR friction control appears to have a small positive effect on shunting performance for the train with the TOR car and a small negative effect on the first two trains that follow. Train speed does not appear to affect shunting performance for trains in the range of 20 to 60 mph. Train direction showed a small effect on shunting performance for the passenger trains (eastbound), which may be related to track curvature and/or grade.

CONCLUSION

The root cause of loss of shunt appears to be development of a resistive film on the running surface of the rail and, presumably, the wheels. Wheel load and car type (especially related to car length) are important variables. Rain on the rail improved the shunting performance for empty coal trains, but the effect was short lived. Larger tare weight empty cars shunted better than low tare weight empty cars, which may be due to the larger wheel load (8,000 pounds versus 6,000 pounds). But, the effects of truck steering characteristics and resultant wheel/rail contact conditions may also be important.

Future Work

Effective prevention/removal of the rail surface film is one of the keys to preventing loss of shunt. Additional tests will evaluate the effectiveness of rail cleaning systems.

Acknowledgments

The authors thank John Martz, Jim Laur, and Brian Russell from UP who contributed significant labor effort for this test. And special thanks to retired TTCI Senior Principal Engineer Richard Reiff who designed the field test and freely shared his wealth of knowledge on this topic.

Reference

1. Davis, D.D. and R.P. Reiff. Aug. 2011. “Review of Loss of Shunt Issues.” *Technology Digest* TD-11-025. AAR/TTCI, Pueblo, CO

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