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Review of Loss of Shunt Issues

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Summary

Loss of shunt has been a minor but chronic problem for track circuit-based train presence detection devices, especially longer approach circuits used at grade crossings. Because railroads detect trains by their ability to shunt track circuits, this can create safety and reliability issues for train operations.

Being a relatively rare phenomenon, there is little documentation on track shunt performance. There is even less data on the effectiveness of proposed methods to eliminate loss of shunt. This *Technology Digest* (TD) presents information, from a literature review conducted by the Transportation Technology Center, Inc., about loss of shunt safety and reliability issues and some of the solutions tried to resolve these issues over the years.

Loss of shunt failure modes can be divided into the following categories:

- Rail corrosion related: This case is the rarely used branch-line operation, where the rail has a corrosion layer thick enough to inhibit conductivity for any wheel profile.
- Wheel-rail contact related: This case covers a wide range of operating conditions where some wheel rail contact conditions produce loss of shunt. There may be contaminants on the wheels or rail. Train operations and related vehicle dynamics may also cause partial wheel unloading, which will affect the ability of vehicles to shunt the track circuit.
- Track circuit related: High speed and/or lightweight car operations may test the capabilities of track circuits. Grade crossing approach warning circuits may be very long for high speed operations. The longer circuits may be less reliable.

With a wider range of operations likely on the freight railway network in the future, the problems with loss of shunt are expected to increase. The addition of passenger and other lightweight rolling stock on freight lines will likely increase the potential for loss of shunt problems.

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INTRODUCTION

Loss of shunt has been investigated by railroads, signal equipment suppliers, regulators, and researchers over the years. This *Technology Digest* presents information about loss of shunt safety and reliability issues and some of the solutions tried over the years.

LITERATURE REVIEW

In some applications, especially when higher train operating speeds require extending the distance of approach circuits, sensitivity at the far end of the circuit is reduced, adversely impacting accurate and reliable prediction of train approach times. Such conditions are generally associated with poor shunting or increased rail/wheel resistance, which makes the initial detection of a train (which requires positive shorting of rail to rail) difficult. Past studies addressing grade crossing loss of shunt performance point to issues at the rail/wheel contact patch as a key to improve performance. Railway wheels and rails can be coated with a wide range of conducting and nonconducting films, which if in a certain location, can interfere with the low voltage electrical path.

Problem Description

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

The ability of a vehicle to shunt the track circuit can vary with many factors. These factors relate to the wheel/rail contact conditions and the track circuit configuration. Some general conclusions about which operations will be most likely to have loss of shunt issues can be drawn. High speed, light axle, and infrequent operations are most likely to have loss of shunt issues.

A typical grade crossing loss of shunt event has the approach circuit failing to detect the approaching train, either entirely or within the expected 20-second warning time. In this case, the crossing reverts to a passive warning device crossing. Another loss of shunt failure may occur at the grade crossing island circuit. When a train approaches a grade crossing, two track circuits detect the train to provide warning to crossers. An approach circuit detects the approaching train and activates the crossing warning devices. The flashers and gates activate ahead of the train to provide 20 seconds of warning time to clear the crossing. A second track circuit detects the train within a small zone at the crossing. In this short zone, typically 120 feet, two or three cars of the train shunt the second track circuit. This shunt provides instruction to the crossing warning system to keep the gates down and the lights flashing. After the train has cleared the island circuit, the warning devices are deactivated.

The island circuit is short to allow quick deactivation once the train has passed. This can lead to lower reliability as only a few wheels are providing track circuit shunt. Intermittent shunt can cause the “gate bob” and deactivation failures experienced by motorists at grade crossings. Figure 1 shows a typical island circuit loss of shunt event.¹ When traffic is on the circuit, the relay and circuit voltage change, indicating the train is shunting the circuit. Notice in the right-hand side of the figure, voltage spikes appear indicating intermittent loss of shunt. There is one prominent relay spike, which may have been sufficient to deactivate crossing warning devices if this happened at a road crossing.

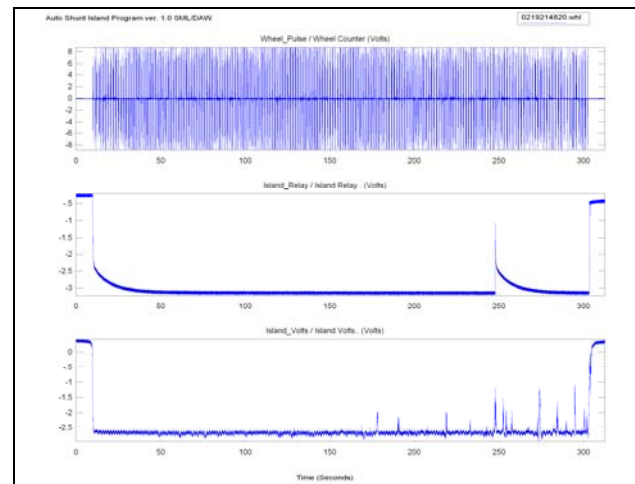


Figure 1. Short Periods of Loss of Shunt Associated with Individual Trucks — Baseline, No Top of Rail Period Showing

Other work on the rail/wheel interface has addressed traction and adhesion problems, most notably on transit and light rail operations. A side effect of such conditions is also poor shunt. However, even though films may be very thick, minor paths remain and overall train detection is often not impacted, although wheels may slip or slide. In almost every case, where such conditions are found on passenger lines, the same area is subjected to blowing or falling leaves, and virtually no freight traffic. The temporary and site specific solution for such conditions includes localized rail grinding, rail cleaning using a variety of high pressure water jets, or mechanical scrubbing mechanisms. In the United Kingdom, the seasonal occurrence of leaf fall has been combated with the addition of a sand-like traction gel applied to the top of rail (TOR).

Traction gels have metal filings added to their mixture to ensure electrical contact is maintained, even during the brief period when the gel and sand combine to develop a very thick coating, which temporarily increases rail/wheel friction. The long-term solution to such problems has been to remove trees that are on railroad right of way property, which has significantly reduced train delays due to braking or traction problems related to leaf fall. As such, traction problems, especially when associated with leaf fall issues, tend to be seasonal, relatively short in duration, and usually occur at known and repeated locations. The solutions are also well established. The problem can often be seen visually on the rail,

while the shunt issues in North America are often year round and not easily visible to the naked eye.

Failure Modes

Loss of shunt failures can be divided into three categories:

- Rail corrosion related: This case is the once a month branch-line operation, where the rail has a corrosion layer thick enough to inhibit conductivity for any wheel profile.
- Wheel-rail contact related: This case covers a wide range of operating conditions where some wheel rail contact conditions produce loss of shunt. There may be contaminants on the wheels or rail. Train operations and related vehicle dynamics may also cause partial wheel unloading, which will affect the ability of vehicles to shunt the track circuit.
- Track circuit related: High speed and/or lightweight car operations may test the capabilities of track circuits. Grade crossing approach warning circuits may be very long for high speed operations. The longer circuits may be less reliable; i.e., a need to address vehicle dynamics related failures.

The following is a brief discussion of potential failure modes found in the literature.

Rail corrosion is climate dependent. Rust will insulate the rail surface, causing a loss of shunt for the first few wheels. In a study by the Federal Railroad Administration (FRA), measurements of the resistance of rust on rails were done.¹ The resistance of rail is increased by orders of magnitude with rust. Figure 2 shows rail resistance versus applied load and rail surface condition. The study noted that heavy rust (described as 2-year exposure to the environment with no traffic) had consistently high electrical resistance.¹ Whereas, the 6-month exposure rail had much lower resistance, but also had higher variability. Thus, track, which may have very infrequent train service, may have intermittent loss of shunt due to rust. When the contact location of such short-term contamination changes, the path used by the electrical circuit may be temporarily blocked. At high speeds (60-80 mph), even a few seconds of delay in reliably detecting a train can reduce grade crossing warning time to less than the mandated 20 seconds. On more frequently used lines, magnetite is formed from iron oxides and wheel/rail contact pressure. This material can form a surface coating that may insulate the wheels from the rail.

Surface films, both intentional and unintentional, may coat the wheels or rails. Other materials come in contact with the wheel and rail. These additional materials may affect the ability of a vehicle to shunt the track circuit. Some of these materials are intentionally put in contact with the wheel and rail. Lubricants and friction modifiers, intended to modify the friction properties of the wheels and rails, do not significantly affect electrical resistance when first applied. However, in some locations and environments they may remain wet for some time and provide a medium for attaching other materials to the wheel/rail surfaces, which may affect resistance. Brake shoe wear debris is also in contact with the wheels. This material,

being largely silicon, with a range of highly proprietary fillers intended to dissipate heat, may also affect resistance.

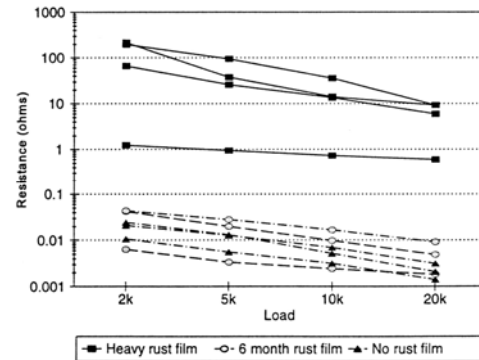


Figure 2. Rail Resistance versus Applied Load

Unintentional sources of materials which may come in contact with the wheel and rail running surfaces include lading, such as grain; track materials, such as mud pumping; wind-blown materials, such as pollen and leaves; and local sources, such as at a grain processor or saw mill.

These unintended wheel/rail contact materials can be formed with lubricants under wheel loading into surprising durable coatings of the wheels and rails. Analysis of wheel and rail surface films collected from revenue service and laboratory testing have been conducted. Figure 3 shows the composition of these films from revenue service components. The wheels have more silicon in these coatings. This is attributed to brake shoe debris. Rails have more iron oxide (rust), carbon (curve grease), and trace materials.²

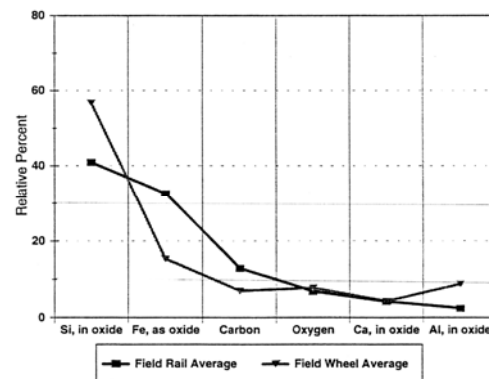


Figure 3. Composition of Rail and Wheel Film

A study of the effects of wheel TOR friction modifiers on shunt was recently conducted.² A short island circuit was installed next to a pair of TOR lubricators to assess the effects of TOR on shunt. The conclusions of this study were that TOR materials did not affect shunt, even when applied at rates well above the intended rates.

The effects of wheel load on shunt were evaluated in laboratory experiments in the 1980s on a variety of rails.¹ In this test, representative of the effects of operating the same car loaded and empty, there is an effect of increasing resistance an order of magnitude when decreasing wheel load from 20,000

pounds to 2,000 pounds. This effect may contribute to loss of shunt, but may not be sufficient to cause failure by itself.

More likely a practical issue is the effects of operating occasional light wheel load cars that have different wheel profiles from the rest of the cars on a given line. In this case, the wheel-rail contact point may occur at a location on the rail outside of the typical wear band. Thus, the combined effects of wheel load and rail contamination may cause loss of shunt issues.

High speed operations may pose some potential technological issues for grade crossing approach circuits. Longer circuits are considered to be less reliable because of variations in weather, ballast resistance, and electromagnetic interference. The sensitivity of the circuit may be lessened by the weaker signal and increased noise produced by a longer circuit.

The short length of island circuits at road crossings also affects the reliability of the grade crossing warning devices. Short island circuits allow the warning devices to be deactivated soon after the train has passed. But, the short length circuit allows only a few wheels to shunt the circuit at any given time. Thus, the reliability of the shunt is dependent on relatively few wheels.

Significant changes in ballast resistance can affect the reliability of track circuits. Low resistivity ballast provides an alternate path for shunting the track. This may result in adjustments to make the circuit less likely to have false train detections. By doing this, the circuit will be less sensitive to detection of actual trains.

Vehicles that do not shunt the track in the conventional way, through solid metal axle wheelsets, must have provision for alternative shunt capability. Many small track maintenance machines, for example, do not shunt the track because of insulating components in the wheelsets or use of stub axle (independent) wheels. All vehicles intended to shunt the track should meet AREMA and AAR recommendations and requirements for maximum allowable resistance between wheels in a wheelset.³

Potential Prevention and Remediation Methods

Several prevention and remediation methods have been tried, including:

- Rail surface cleaning: Rail surface cleaning certainly is effective at lowering rail resistance immediately after cleaning. However, the duration of effectiveness of this approach depends on the cleaning method and the contaminant(s) on the rail. Rail polishers, which remove surface oxidation, are effective for the duration during which it takes rust to return.
- Whetting current: In this system, a whetting current is applied to the track circuit when a train is detected. This whetting current, increasing the circuit potential, should make it easier for light wheelsets to shunt the track circuit. The potential drawback of this approach is that the circuit will lose its ability to discriminate trains from other events.

This could manifest itself in a crossing warning device that remains activated after the train has left the circuit.

- Longer island circuits: Longer island circuits allow more wheels to be in the circuit at any given time. Thus, they increase the chances of having shunting wheelsets in the circuit. This method does not address the root cause(s) of loss of shunt, but can reduce its effects in some cases. The longer circuit will increase motorist waiting time after the train has passed a road crossing, however.
- Shunt averaging: Shunt averaging takes an average voltage value of the train detection circuit using a time window. This approach will reduce the effects of individual wheelsets that fail to shunt. Shunt averaging can be effective for eliminating loss of shunt due to occasional cars. It also does not address the root causes of loss of shunt. It is less likely to provide much benefit for light trains. Shunt averaging will also increase motorist waiting time after the train has passed (by at least the averaging time window used).

Additional evaluations are proposed for the following potential methods:

- Additives to TOR friction modifiers to improve rail conductivity
 - Solvent to clean the rail
 - Anti-corrosion material
 - Conductive coating
- Rail profiles designed to increase shunt reliability by increasing contact stresses, causing a “puncture” in any wheel or rail coating.
- Wheel profiling brake shoes to keep wheels clean.
- Conductive, noncorroding coatings for rail to be used as a coating for lightly used branch-line rails to keep part of the rail surface from rusting. A stainless steel weld deposit has been proposed.
- Alternative train detection methods that would not rely on shunt or would enhance the track circuit to detect and/ or verify a train is in the track circuit.

FUTURE WORK

A field test site with an island track circuit will be established in revenue service to monitor shunt performance. The site will help establish resistance change and shunt failure rates. After a baseline is established, the site will be used to determine the effectiveness of proposed remedies.

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