Axle Counters vs. Track Circuits – Safety in Track Vacancy Detection and Broken Rail Detection

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1.0 Introduction

The term "axle counters" refers to subsystems which are utilized for track vacancy detection on fixed-guide way transport systems such as railways. Axle counters function by detecting the presence and traveling direction of wheels at various points along the right of way. The right of way is broken into "blocks" with wheels (axles) being counted into and out of the block. If the same amount of axles is detected departing the block as were previously detected entering it, the block is considered vacant.

Axle counter systems and track circuit systems both provide for track vacancy detection (also referred to as train detection), but function in significantly different ways.

Basic Axle Counter System Components

Axle counters primarily consist of two types of components, the axle counting head, and the axle counting computer (sometimes referred to as an evaluation computer). The axle counting heads are mounted along side the rail profile and actually detect the presence of wheels. They typically use LC oscillators to detect when the flange of a railroad wheel has modified the magnetic field created around the axle counter.

The evaluation computer typically resides in a signal control enclosure alongside the wayside. The evaluation computer generates data based on the axle counting heads and generates either a vacant or occupied declaration of one or more blocks (track sections). The axle counting heads and the computer are physically connected, typically by copper wire to sense the condition of the fields created within the head about the rail. Some recent products also offer alternative transmission media such as fiber optic cable.

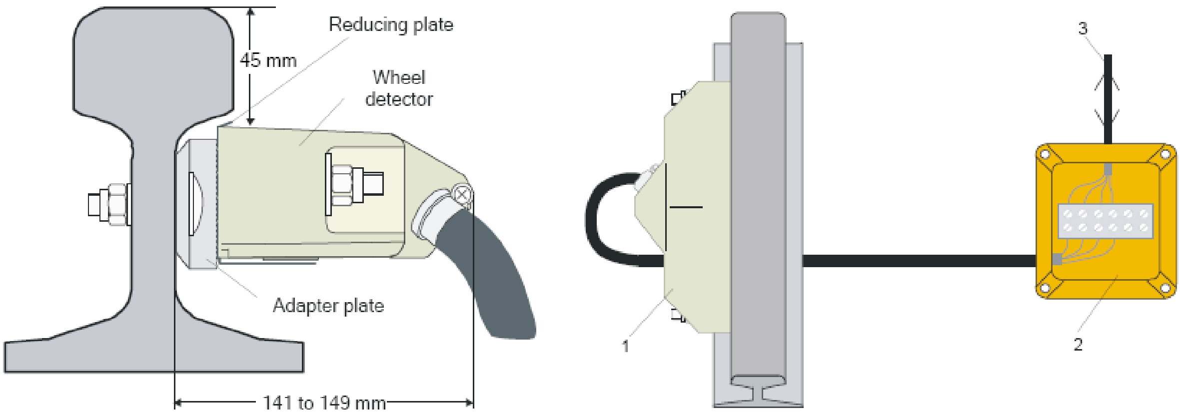

Figure 1, Axle Counter field equipment Layout.

Evaluation computers typically interface to interlocking controllers, grade crossing controllers, etc via a dry contact relay interface. In some systems, these connections can be made through serial communications such as a LAN. In any case, the interface is easily made compatible with conventional signal technology to allow axle counting vacancy detection with virtually any train control system.

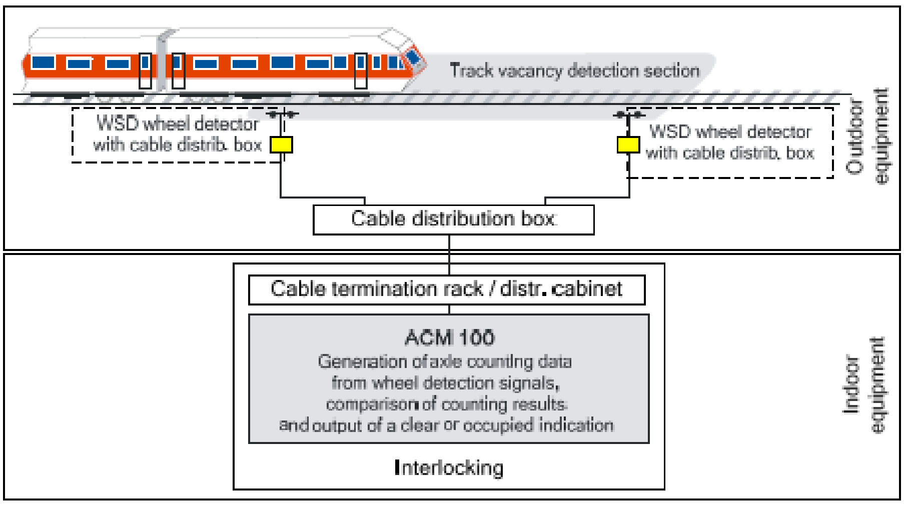

Figure 2, Typical layout interfacing to interlocking control

Manufacturers of Axle Counter Equipment

There are several major manufacturers of axle counter equipment in the marketplace today. These are primarily firms with European heritage such as: Siemens, Thales, Tiefenbach, and Frauscher. Additional suppliers manufacture similar equipment on a smaller scale for specific applications. This technology has been deployed in Europe and Asia on a much larger scale for a number of years, though it has not yet been deployed in great numbers in North America. Axle counters have achieved the highest level of safety certification through Comité Européen de Normalisation Électrotechnique (CENELEC Safety Integrity Level 4), the European rail safety standards; and offer a unique approach and alternative to track circuits.

Geographical Distribution

Axle counters have their origins in Western Europe where they have the largest installation base. Axle counters were first used in Germany in the 1960s and are now extensively used in most parts of Europe, Asia, Africa and Australia.

In recent decades, however, the use of axle counters in both freight rail and passenger rail applications have spread through other parts of Europe, Asia, the Southern Hemisphere, and the Baltic states. Usage is much more sparse in South America and the systems are rarely applied in the United States and Canada.

Countries of Installation

The following list of countries is almost certainly incomplete, but it contains countries with multiple, verified axle counter installations.

- Great Britain
- Germany
- China
- Switzerland
- Australia
- Hungary
- Norway
- Spain
- Greece
- Netherlands
- Estonia
- South Africa
- India
- Poland
- Portugal
- Mexico
- Venezuela
- Philippines
- New Zealand
- Thailand
- Syria
- Finland
- Belgium
- Austria

Operation

These modern contactless versions are much different than the mechanical wheel detectors originally introduced years ago. Axle counter operation depends on several events occurring in sequence, with the evaluation computer making the final determination of vacancy. Trains entering blocks (defined by the axle counter heads attached to the rail) trigger counters in the evaluation computer that track movements into and out of the block. With one counter for each axle counter head, any difference in the count between adjacent axle counter heads indicates the presence of a train. In this way, switching moves into and out of the block that are not complete movements through the block are correctly interpreted.

Adjacent blocks can share the same axle counter to minimize wayside equipment, and should a head become dislodged from the rail or become inoperative the detection scheme defaults to an occupied block since the axle counter head in question no longer "counts".

3.0 Axle Counter Realities and Comparisons

Axle counters offer some unique advantages over traditional track circuit for train detection. Although axle counters are not appropriate for all applications, the following discussions on advantages and disadvantages – as compared to track circuits – illustrate how they can be used effectively in train control and other applications where the expense, maintenance or conditions are a challenge to reliable track circuit operation.

Axle counters and track circuits are both used for monitoring track occupancy automatically. In contrast to track circuits, axle counters have some features that make them particularly well suited to some specific urban and long-distance rail applications. The highlights of these advantages and disadvantages are explained below.

Axle Counting vs. Track Circuits - Advantages

1. Track circuits are sensitive to ballast resistance, power fluctuations, and other track conditions while Axle Counters are not. In wet conditions, when the ballast resistance generally drops, track circuit operation is less reliable. Similarly with rusted rails, rails covered with leaves or flying dust/flakes, or a large amount of salt or conductive minerals impairing its surface conduction properties, track circuit operation is often unreliable. Axle counter applications are independent of track bedding and ballast, which means they can be used with steel structures (bridges), concrete or wood ties, and embedded rails.
2. Track circuits are, by design, reliant on a very specific shunting characteristic of train axles (often 0.06 or 0.25 Ohms). If a train axle actually differs from this resistance (perhaps due to environmental influences such as those mentioned above), track circuits can “overlook” trains and incorrectly determine track vacancy.
3. Track circuits consume a significant amount of electrical power and involve elaborate power supply equipment and cabling which can lead to frequent maintenance. Axle counters consume very low electrical power, simple cabling, and are virtually maintenance free.
4. High traction currents do not influence the detection method used in axle counters, and their installation and maintenance is faster and simpler than the installation of track circuits and related hardware.
5. No insulated joints are required with axle counters.
6. Less traction power bonding is required with axle counters than with track circuits. This has the additional benefit of minimizing the risk of DC stray current leakage into the ground which causes corrosion of nearby utility services.
7. No impedance bonds are required with axle counters.
8. Axle counters are essentially unlimited in block length. Track circuits vary greatly depending on type (AF, AC, DC), but are all very limited in track circuit length.

9. Experience with axle counters in Europe demonstrates an improvement of up to five times the reliability of track circuits carrying out the same function. This has an immediate improvement in service reliability as track circuit failure is often the most significant cause of train delay. It also has safety benefits as it reduces the use of degraded modes of operation outside of the control of the signaling system due to failure.

Axle Counting vs. Track Circuits - Disadvantages:

1. Reset Requirements – If for any reason there is a failure (possibly a loss of power during a train movement), axle counters must be manually reset (the default start up mode is to create an occupied block). This can be done remotely, but requires a pro-active, manual manipulation.

2. No "shunt" – track circuits can be easily physically shunted by maintenance personnel (hard wired shunt applied to the rails), axle counters do not provide this function. A manual occupancy can also be accomplished with axle counters by hand manipulation of a metal object in front of the sensor. However, there is no visualization of the state (as is the case with a physical shunt), and the system must be reset (see above).

3. Axle counters, unlike closed loop track circuits, do not provide broken rail protection. Although there is a great deal of controversy in the industry as to the percentage of broken rails actually detected by track circuits before they are traversed by a train, axle counters will not detect any break whatsoever.

4. By very small wheel profiles (less than 12 inches in diameter), axle counters can suffer from degraded reliability.

4.0 Track Circuits and Broken Rail Protection

One of the disadvantages of axle counting systems is the lack of broken rail detection that is inherently provided with track circuits. In fact, although track circuits are not specifically required in the new PTC rules (CFR 49 "Part I"), they do require broken rail detection for speeds above 59 mph for passenger trains and 49 mph for freight trains. Axle counting systems are applied to High Speed networks in Europe and Asia where the discussions on broken rail detection by track circuits has determined that the detection of these defects is limited and other methods of mitigating the issue outweigh the need for track circuit installation.

In addition, there are several types of breaks that even track circuits will not detect. Some of these situations are detailed in the table below:

Type of Rail Break	Cause	Location	Example
Transverse Cracks in Rail Head	Develops from an original internal defect inside the rail head, an internal horizontal crack, or very occasionally deep shelling of the gauge corner	At the Joint	
		Beyond the Joint	
Transverse cracks in rail head	Develops from an internal defect in the head of the weld	Flash butt Welding Zone	
	Develops along a plane near a normal cross-section of the profile	Thermit Welding Zone	
	Cracks at the periphery of the welding	Electric arc welding position	
Transverse cracks in rail head	Transverse fatigue crack across the resurfaced part of a rail head	Welding or resurfacing position	
	Transverse cracking under	At right angles with an electrical connection for return current	
Horizontal Rail head delaminations	Manufacturing defect	Above the rail web, at rail end	
		Above the rail web, away from rail end	
Vertical rail head end delaminations	Manufacturing defect	In rail head, ±5mm of vertical rail axis, at rail end	
		In rail head, ±5mm of vertical rail axis, away from rail end	
Vertical Rail Web end delaminations	Manufacturing defect	In rail web, ±5mm of vertical rail axis, at rail end	
		In rail web, ±5mm of vertical rail axis, away from rail end	
Horizontal cracking at head-to-web transitions	Manufacturing defect	Head/web interface at rail end	
		Head/web interface away from rail end	
Horizontal cracking at web-to-foot transitions	Manufacturing defect	Web/foot interface at rail end	
		Web/foot interface from rail end	

Figure 3, Rail breaks that can avoid detection by Track Circuits.

Other considerations include where the rail break occurs in the circuit. Breaks contained within angle bars are not likely to be detected as well as clean breaks outside of the joint area. In fact, the use of long bond wires in this instance ensures that the break will not be detected. For transit properties utilizing single rail track circuits, only the signal rail is protected from breaks. Added to this the fact that the rail sits on conductive plates over cross ties, there is in fact only a small percentage of rail that is actually checked for broken rail in transit.

5.0 Track Circuits and wrong side failures

Track circuits have a long history of dependable operation in a variety of environments. They form the basis of train protection in virtually all conventional train control systems, including several forms of Positive Train Control (PTC). Since track circuits are not generally configured in a redundant configuration (Audio Frequency track circuits have this capability), they represent an unexpected single point failure that can cause catastrophic wrong side failures.

Examples of this include the recent WMATA accident at Fort Totten[1], BART[2], Norfolk Southern around New Baden, Ill[3], and the historic shunting problems with RDCs[4]. Train detection issues have also been reported on properties which recently deployed Diesel Multiple Units (DMU) due to the shunting characteristics of these types of vehicles. Other examples exist, however these hazards are not normally considered in the installation of new train control systems.

6.0 Potential applications of Axle Counters in North America

Axle Counters remain a viable alternative to track circuits in several areas where either conditions are not appropriate for track circuit operation or costs over ride the need for issues like broken rail protection. Below is a brief listing of potential applications of axle counters that can provide a unique perspective on their installation:

1. “Signaling” of freight dark territory as a PTC underlay. Since block lengths can be as long as the distance between axle counters, long blocks are no problem for this application.
2. “Redundant overlay” for Train Vacancy Detection in mass transit systems. Axle counters can mimic the installed track circuits to perform a redundant vital check of shunting.
3. Train Vacancy Detection can be accomplished in any place where track circuit shunting is a concern (contaminated rail/ballast, steel structures, light DMUs, etc.)

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[1] Although the final NTSB report is still pending, recent indications point to both maintenance and circuit board issues that prevented an effective shunt from de-energizing the track circuit

[2] The requirement to include a Sequential Occupancy Release System (SORS) was triggered from poor shunting characteristics of the AF track circuits

[3] Investigations found that formations of iron oxides insulated the rails from shunting at certain tonnages, difference in wheel tapper and short Amtrak consists all contributed to loss of train detection here.

[4] RDCs, or Rail Diesel Cars inability to shunt in short consists prompted the Reading Railroad to equip their cars with “exciters” that forced current thru the rail/wheel interface that aided shunting.

4. Axle counters can be temporary or permanent support for staging of cut-ins for any function that a track circuits would be used for. This is particularly true of temporary and low power installations as a work around for special track work and complex alignment issues.
5. Block control of “in street running” for LRTs (train to train collision avoidance), embedded track where track wire maintenance is an issue. LRT operations on the Hiawatha Line in Minneapolis, MN have successfully installed this technology and have already specified installation on the new Central Corridor LRT line.
6. CBTC auxiliary wayside systems can be implemented with significantly reduced complexity and bonding that would be required for conventional track circuits.
7. Defect detectors already utilize simple axle counting systems for train detection and triggering of detector sensors (such as opening the shutter on the bolometer of a Hot Bearing Detector). Single heads designed today give both precise positioning as well as direction of travel.
8. Yards for both freight and passenger operations can benefit from axle counters in yards to determine car velocity, track occupation, and track capacity. The low power requirements make solar power a viable option to reduce cable requirements.
9. Within shops and work areas, blue flag protection and pit occupancy detection can be enhanced for worker protection and compliance with regulations.

7.0 Conclusion

Axle counters have been used in vital train detection schemes on a large scale for a number of years outside of North America. As shown above, there are several applications that fit the North American practice for these devices, and their use should be considered when initial designs are created for both vital and non-vital applications. They can offer a cost effective alternative to track circuits when applied correctly and are available from several manufacturers.