BENEFICIAL FEATURES OF MODERN AXLE COUNTER APPLICATIONS
Dr. Frank Heibel and Sasanka Chatterjee, Thales Australia

SUMMARY
This paper presents the advantages of axle counters over track circuits for track vacancy detection and highlights some particularly beneficial features of a new axle counter system currently being introduced to the Australian railway market.

The main advantage of axle counters over track circuits is their significantly higher reliability. Further advantages of both technologies are listed, specifically addressing the argument of broken rail detection which is commonly held up against axle counters as justification for continuous use of track circuits.

Specific axle counter features highlighted in this paper comprise methods for highly reliable wheel detection and data transmission, remote diagnostics, inhibit of road-rail vehicle wheel detection, and multi-drop communication between counting heads and axle counter evaluators.

INTRODUCTION
The detection of rail vehicles in block sections of a rail network is the foundation of current signalling systems. The safe permission to a train to enter a section of railway line, given for example by the interlocking, fully depends on the reliable determination that no other rail vehicle is in that same section.

There are two common technological methods to detect vehicles in a section of a railway line, track circuits and axle counters.

- Track circuits use one or both rails to establish an electrical or audio frequency circuit. The axles of a rail vehicle entering a track circuit section form an electrical connection between both rails which changes the characteristics of the track circuit. This change is detected and indicated to the interlocking as the section being occupied.

- Axle counters operate by detecting passing wheels of rail vehicles on both ends of a monitored rail section and counting the number of detected wheels. This wheel detection and counting is performed by detection points which transmit the counting results to an evaluator. The evaluator recognises a difference in the counting results at both ends of the section as indication of the presence of a rail vehicle and reports the section to the interlocking as occupied.

It is interesting to note that both technologies were actually invented by the same person, William Robinson. Axle counters were invented in 1869, mechanical ones at the time, for track occupancy detection in cases where track circuits cannot be used.

NOTATION

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<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
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<tr>
<td>ACE</td>
<td>Axle Counter Evaluator</td>
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<td>AzLM</td>
<td>Thales Multi-Section Axle Counting System</td>
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<td>DP</td>
<td>Detection Point</td>
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<td>SiL</td>
<td>Safety Integrity Level</td>
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<td>UK</td>
<td>United Kingdom</td>
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1. WHY AXLE COUNTERS
Track circuits are the most common method for track vacancy detection. Several rail networks in Australia, for example the suburban networks in Sydney and Melbourne, rely entirely on this technology. Axle counters were introduced to Australia in only small numbers, primarily to solve specific problems which could not be addressed efficiently with track circuits.

The initial main application for axle counters in Australia was for long sections of between 5 km and 20 km length which would have required several track circuits and hence made axle counters a very cost efficient alternative. Another specialised application of axle counters is in tunnels where the risk of regular flooding prohibits the use of track circuits. To date, axle counters have not come to wider use in Australia, mainly because rail operators have specified track circuits as their standard technology for track vacancy detection and hesitate to adapt their operational procedures for the use of axle counters. Another reason against wider use of axle counters was the experience of reliability problems in early applications in Australia, in part due to unsatisfactory installation practices.

While axle counters play only a peripheral role in Australia, they have become the method of choice...
for track vacancy detection in several European countries, including Germany, Switzerland and the UK. The main reason for that preference of axle counters is their significantly higher reliability compared to track circuits by a factor between 3 and 5.

An investigation of the UK rail operator Network Rail (then Railtrack) in 1998 showed a wrong side failure rate for track circuits of $3 \times 10^{-7}$ which is equivalent to a safety integrity level of SIL 2. Axle counters, however, were reported with a failure rate of $1 \times 10^{-9}$ equivalent to the highest safety integrity level of SIL 4. Operational experience, as for example monitored during the introduction of axle counters to the UK main line rail network on the West Coast Main Line, showed an even better failure rate of $7 \times 10^{-11}$.

Further reasons for the trend towards axle counters include the following:

- The higher reliability of axle counters as mentioned above improves the overall reliability of train operation as track circuit failure is usually the main cause of train delays. It also improves the safety of the train operation as degraded modes of operation occur much less often.
- Axle counters can be easily installed on an operational railway. Detection points can be installed, tested and commissioned while the railway remains operational using the existing track sections. This minimises the changeover time from the old sections to the new axle counter sections.
- Axle counters are easier usable on electrified rail networks than track circuits as they do not depend on sensible electrical circuitry to function.
- Axle counters are more compatible with modern rolling stock technologies such as eddy current brakes and regenerative braking.
- Axle counters require no onerous earthing and bonding of the rails.
- Axle counters need no insulated rail joints.
- The length of the block section monitored by an axle counter can be virtually unlimited, while track circuits are limited in length to maximum 1500 m.
- Axle counters do not rely on clean electrical characteristics of the rail ballast and the rails themselves. Rusty rails or contaminated ballast conditions, which cause severe problems with track circuits, are no problem for axle counters.
- Condensed leaf fall can cause seasonal problems for track circuits, but not for axle counters.

Disadvantages of axle counters are:

- The equipment itself is usually more expensive than track circuits, specifically for short sections. Although axle counters usually have advantages in overall life cycle costs due to lower power consumption and less maintenance demand, this is often ignored in favour of lower initial investment.
- Axle counters must be reset after disturbances such as miscounts, which requires specific operational procedures.
- Small wheels of less than 300 mm diameter can be problematic for axle counters to detect while track circuits do not have such limitation.
- Track circuits allow the blockage of a line section with emergency clips, which does not work for axle counters.
- And then there is ...

2. BROKEN RAIL DETECTION

In the case of track circuits versus axle counters, there is an often cited advantage of track circuits which is commonly used to oppose the introduction of axle counters despite their advantages outlined above: Track circuits have the ability to detect broken rails, something that axle counters are principally unable to provide.

What needs questioning, though, is the conclusion that the replacement of track circuits with axle counters would present an intolerable reduction of safety because of the sudden lack to detect broken rails. This needs to be put into perspective to verify if there is a safety risk in the first place, what the effect of such safety risk may be, and how this is weighed against a significant improvement of reliability of track vacancy detection introduced by axle counters.

Some types of track circuits use only one of the rails and hence would not detect a break of the other rail anyway. Also, track circuits can not detect all types of rail breaks. The type of rail break detectable by a track circuit, a full break, is much less likely to cause train derailment than a partly rail break of the rail head, which however would not be detected by a track circuit. Most importantly, many rail operators have confirmed that the increased sophistication in modern track maintenance methods enables detection of broken rails without
the necessity to rely on track circuits, for example by use of ultrasound.

A rail breakage statistic from rail operator MTR in Hong Kong over ten years showed 385 cracked rails and 11 broken rails in total, of which track circuits detected only 4 (about 1%).

In short, the added value of track circuits in detecting rail breaks and preventing train derailments caused by such breaks is negligible. Considering the much higher reliability that axle counters can bring to a rail operation, it is hardly justified to stick to the less reliable option for the rare benefit of occasional rail break detection which is not found by routine track maintenance.

3. A NEW AXLE COUNTER PRODUCT FOR AUSTRALIA

Until recently, the Australian rail signalling market had two suppliers of axle counter products. Now a third one has entered the market with a first pilot application used for the upgrade of the level crossing at Bagshot near Bendigo in rural Victoria. This novel product for Australia, the AzLM axle counter system, has clearly distinguishing characteristics. For example, while the incumbent axle counter products can handle a maximum of five detection points per evaluator, the AzLM system is scalable for up to 32 detection points per evaluator, which has the following benefits:

• Maintained reliability of the overall system due to established and proven high reliability of the axle counter evaluator.
• Reduced cost per track vacancy section in medium to large applications.
• Compact solution requiring less mounting space, wiring, power, maintenance and spare part inventory.
• Allows for cost efficient duplication to achieve redundancy for particular availability demands.

The following chapters describe further selected features of the AzLM axle counter which have proven to be beneficial for rail operators in Australia.

3.1 Reliable Wheel Detection and Data Transmission

The wheel detection within the AzLM axle counter system is performed by the rail contact SK30H which has two physically offset coil sets mounted in parallel to the rail. Outside the rail are two transmitter coils generating an electromagnetic field around the rail. On the inside of the rail are two receiver coils. Those receiver coils supply two time-offset induced voltages with which presence and direction of the passing wheels are determined. The frequencies used, the shape and the material of the receiver housing and the corresponding coil arrangement are designed to keep interference from traction current and track brakes to a minimum. Both voltage and phase of the receiver coil output are evaluated to ensure extremely high wheel detection and accurate counting reliability.

The use of intelligent detection points allows for the counting of detected wheels on site and digital transmission of the counting results to the axle counter evaluator. This has the following significant advantages over the analogue transmission of wheel sensor impulses for counting by the evaluator as featured by other axle counter products:

• The digital transmission allows the use of alternative transmission media to expensive
copper signalling cables, such as cheaper telecommunication cables or radio.

- The repeated transmission of the counting results tolerates intermittent transmission faults. If one or two transmissions of the same counting result are corrupted, the evaluator can still receive the correct input with the next transmission. If however one or two transmissions of counting impulses are corrupted, the counting result will deviate from the actual number of detected wheels, leading to a miscount and hence a disturbance of the adjacent sections.

3.2 Remote Diagnostics
The AzLM axle counter features an optional computer based diagnostic tool which can extract system information of several AzLM systems in real time or as historical data. The diagnostic system can be connected to the AzLM axle counter evaluator either by a serial interface or an Ethernet connection. This flexible connection concept allows for local or remote diagnostics, with the option to implement centralised remote diagnostics architectures for multiple AzLM evaluators.

The remote diagnostics feature has been successfully used for remote monitoring of the AzLM pilot application at Bagshot. The remote diagnostics at Bagshot uses a 3G network as communication medium and a Serial/Ethernet Modem with access through VPN and Com port diverter, which provides the operating and maintaining staff of V/Line with maximum flexibility for data access, whether on site, in the regional maintainer office at Bendigo, or in the Melbourne headquarters.

The same modem and network connection used for the remote diagnostics is also set to generate and send SMS notifications to maintainers’ mobile phones for immediate alert in case of any disturbance in the AzLM system.

3.3 Handling Road-Rail Vehicles
Axle counter systems usually work reliably for wheel diameters in excess of 330 mm. Road-rail vehicles have normally smaller wheels with profiles different from train wheels which may cause misreadings by axle counters leading to operational problems.
3.4 Multi-Drop Communication

While the use of axle counters with remote level crossings such as Bagshot represents a specific application to solve a problem more efficiently than with track circuits, the direct replacement of obsolescent track circuits with axle counters remains the biggest potential for rail operators to generate benefits.

A key issue for replacing track circuits with axle counters is the ability to re-use existing signalling cables to avoid the need for expensive new cabling. The communication features of the AzLM axle counter system provide this possibility. The detection points of the AzLM system combine the information of wheel counts and counting direction with system health status information in fault-tolerant telegrams which are transmitted in common ISDN format to the axle counter evaluator in a central location. While this is conventionally done with copper cables, the ISDN telegrams used can be easily converted to a V.24 protocol which allows transmission via optical fibres or a closed radio backbone.

The ISDN telegrams can also be converted in an Ethernet format, allowing a serial connection chain between detection points and evaluator instead of conventional point-to-point communication links between the evaluator and every detection point. This communication architecture is referred to as ‘multi-drop’ and requires only one pair or wire or optical fibre along the application area of an AzLM axle counter. This communication concept is unique for axle counter products in Australia and has the potential to overcome another major hurdle for replacing track circuits with axle counters for the benefit of the respective rail operation, with significantly higher reliability and lower operating and maintenance costs.

4. CONCLUSION

Axle counters have become a well-proven, established method for track vacancy detection in modern signalling systems. They provide much higher reliability than track circuits which supports more reliable and safer operation of trains. Innovations in modern axle counter products provide additional benefits to rail operators which can be expected to facilitate the wider use of axle counters in the Australian rail networks, as it is already the case in many sophisticated rail networks around the world.

The specific features of the AzLM axle counter outlined in chapter 3 provide the following benefits compared to other axle counter products:

- The AzLM axle counter provides an unique phase reversal wheel detection technology, which enables the actual detection of rail wheels while other products only detect metallic objects of any shape, making them more susceptible to disturbances.
- This unique wheel detection technology further enables to either eliminate or detect non-specific wheels, e.g. of maintenance vehicles.
- Intelligent and flexible diagnostics with both local and remote accessibility, applicable both to single or multiple axle counter evaluators, provide instant alert on disturbances and their causes and support operation with high MTBF and minimum repair times.
- The processor based trackside electronics of the AzLM enables fault tolerant data transmission between detection points and evaluator, which mitigates loss of counting results even in EMC-noisy environments and removes the single biggest cause of axle counter disturbances.
- The digital communication link between detection points and evaluator of the AzLM allows for data transmission over multiplexed digital systems. This enables flexible selection of communication media such as optical fibre or radio. It also allows a safe and highly reliable multi-drop network architecture with re-use of existing signalling or telecommunication cables.

5. FUTURE OUTLOOK

A major criticism of current axle counter products is the need to de-install the wheel sensors for certain track maintenance activities, particularly automatic rail grinding or tamping. Another sensible issue for track engineers, particularly for tracks with very high axle loads, is the need to drill the rail web for mounting of wheel sensors. Current developments...
of the next generation of AzLM detection point promise to address those issues.

- The new SK30K detection point of the AzLM axle counter system can be mounted above the sleepers and hence does not need to be removed during tamping. The improved profile of transmitters and receivers also reduce the risk for damage by rail grinding equipment.
- There are current investigations towards the use of a clamping mechanism as an alternative to drilling the rail web where this is not permitted.

Figure 6 – Mounting of SK30K above the sleeper

6. ACKNOWLEDGEMENTS

The authors would like to thank Thales Australia for their input and support, as well as the organisation and technical evaluation committee of AusRAIL 2010 and the IRSE for acceptance of this paper.

7. REGRETS

In an attempt to present a wider overview of the features of axle counter products available in Australia, the authors placed an enquiry for technical input to other suppliers or distributors of axle counters in Australia, regrettably without any response usable for this paper.
Figure 1 – Phase reversal for wheel detection (zoomed out for better legibility)

Figure 2 – Output offset to identify travel direction (zoomed out for better legibility)