Background
Lloyds Register Rail (LRR) carried out this research project for the Rail Safety and Standards Board (RSSB) to investigate the acceptability and implications of the use of a single-sensitivity Automatic Warning System (AWS) receiver for operating over both DC electrified lines and non-DC lines (AC electrified or non-electrified).

DC electrified lines are fitted with extra-strength AWS magnets. This enables trains operating over such lines to have less sensitive AWS receivers, which will therefore be less susceptible to the possibility of false operation from the magnetic fields associated with DC traction supply cables.

Railway Group Standard GE/RT8035 requires trains to be fitted with AWS receivers of the appropriate sensitivity for the type of infrastructure over which they are operating. Therefore trains which operate over both DC electrified lines (fitted with extra-strength AWS magnets) and non-DC lines (fitted with standard-strength AWS magnets) are required to have AWS receivers which can be switched automatically between the two sensitivity levels. For dual-system electric trains, this has been achieved by linking the switching of the AWS receiver sensitivity to the changeover of the electric traction supply.

However, for non-electric trains, no suitable method of switching receivers has been developed. Existing diesel-powered trains have been fitted with a single-sensitivity AWS receiver, although they may travel over both standard-strength and extra-strength AWS magnets. While this was permitted under previous Railway Group Standards, subject to an appropriate risk review, the current standard (GE/RT8035) does not permit this for new trains. New trains introduced after the compliance date of GE/RT8035 have been the subject of a non-compliance pending standards change, authorising the fitting of a single-sensitivity electronic AWS receiver.

Aims
The applications for non-compliance were associated with a proposal to change Railway Group Standard GE/RT8035 to permit the use of a single-sensitivity AWS receiver for trains operating over both DC electrified lines and non-DC lines. This research was primarily commissioned to determine whether such a change to the standard could be justified.

In addition, further investigative work was included in the remit to look at wider issues related to the use of extra-strength AWS magnets and to analyse some of the related fault conditions that had been recorded.

Method
The research project was structured in nine phases:

In phase one LRR carried out a comprehensive investigation of the magnetic fields produced by existing AWS magnets, covering the permanent magnets (south pole) and electromagnets (which produce a north pole when required) for both the standard-strength and extra-strength installations. This investigation was based on a combination of practical measurements of sample magnets in laboratory conditions, manufacturing data from suppliers, and theoretical calculations. This gave a detailed characterisation of the field strength and its distribution in space for the various different types of magnets, indicating the expected range of parameters. A significant factor was the minimum field strength that would be
expected from a magnet at the bottom end of the specified range of field strength.

Findings

The results from phase one of the investigation confirmed that the field strength produced by AWS permanent magnets is generally well above the minimum levels specified in the Group Standard, but the field produced by electromagnets is likely to be much closer to the minimum specified level.

The phase two results indicated that the magnetic fields created by cables carrying a current of 4000 amps DC (which is typical of the ratings of traction feeder cables and by no means a maximum value) are of a similar level to the magnetic field produced by a standard strength AWS electro-magnet. Further analysis in phase three confirmed that it did not appear possible to define a simple threshold level for the AWS receiver that would ensure the receiver would detect all legitimate AWS magnets and would not be activated by the current in traction feeder cables. However, further analysis of other characteristics of the fields (e.g. their shape) did lead to the possibility that a more sophisticated analysis of the detected field might be able to distinguish between the intentional fields from AWS magnets and the unintentional fields from traction cables.
electric trains. This part of the work was included in the remit to address a further question that had been raised; if the outcome of phase three had suggested that diesel-powered trains could satisfactorily operate with a single-sensitivity receiver, was there a specific issue with fields generated by DC traction still requiring the use of less sensitive receivers, and hence confirm the continuing requirement to use higher-strength magnets in DC traction areas? However, the conclusion of phase three suggested that higher-strength magnets may still be necessary in DC traction areas to allow reliable discrimination between AWS magnets and traction cables, for both diesel and electric trains, and therefore the specific case of the DC traction environment investigated in phases four and five does not appear to be the governing factor.

Phases six and seven related to analysis of fault data for AWS faults categorised as ‘Code 2’ (horn instead of bell when clear indication expected) and ‘Code 4’ (bell and horn when warning indication expected). These are faults that could be related to issues of incompatibility between the AWS receiver on the train and the equipment on the track. LRR analysed the data available from fault reports, and identified trends and correlations with certain classes of train and geographical locations. LRR based their conclusions solely on the evidence of the data they had for analysis, and preferred not to introduce conclusions from other investigations that had been conducted into the sources of these faults. The results of their analyses do not show any clear pattern confirming that incompatibility between the train and track equipment is the predominant cause of these types of failure, but the results are not inconsistent with other investigations into these failures.

Phase eight further analysed the findings of the previous phases in order to propose possible solutions. Since phase three had concluded that a simple threshold level could not allow the receiver to distinguish between intentional and unintentional fields, more sophisticated receivers were considered. One possibility suggested was to use an array of receiver elements that could determine the shape of the magnetic field and use this to distinguish between the fields produced by AWS magnets and those generated by traction cables. However, it was anticipated that there would be difficulties in introducing such an arrangement and validating the reliability of the discrimination.

**Comparison of Intentional and Unintentional Fields**

![Comparison of Intentional and Unintentional Fields](image)

An alternative suggestion was to make use of the feature identified in phase one of the project that existing AWS permanent magnets are generally manufactured to produce a magnetic field significantly higher than the minimum levels specified in GE/RT8035. However, electromagnets are often closer to the minimum levels, and thus the sensitivity of the receiver cannot be reduced without introducing the risk that electromagnets will be missed. LRR suggest using a differential threshold dependent on the polarity of the field. The threshold for detection of a south pole (permanent magnet) could be raised, while for a north pole (electromagnet) the sensitivity would remain at its existing level. Since detection of a north pole only has an effect on the train-borne system following detection of a south pole, raising
the detection threshold for a south pole to a level higher than the field strength likely to be generated by cables would reduce the likelihood of false operation.

Phase nine looked briefly at the existing types of AWS receiver in use and determined whether it is possible to modify these designs to provide the polarity-dependent differential threshold required by the solution proposed in phase eight. LRR suggested that generally for modern types of receiver such an adjustment should be possible without a major redesign, although they did not have sufficient access to detailed information on the design of all types of receiver to develop a detailed view of how practicable such a change would be.

**Review of findings**

The results of this research have been reviewed by the AWS Working Group set up by the Vehicle / Train Control System Interface Committee. The working group consider that LRR have made a useful contribution to the available knowledge on this subject. They noted that the work carried out by LRR was mainly theoretical, supported by some laboratory testing; this had clearly shown that there was a possibility of magnetic fields from cross-track cables in DC traction areas of such a strength that they could be difficult to distinguish from the fields produced by standard-strength AWS magnets. However, in the light of the experience of train operators who are obtaining satisfactory performance from trains with single-strength receivers, it is suggested that further research should be carried out to ascertain the levels of traction current and the resultant magnetic fields that are actually encountered on the network.

The working group have noted the solution proposed by Lloyds Register – the introduction of a differential threshold dependent on the polarity (south or north) of the AWS magnetic field – but believe there may be a number of difficulties with the implementation of such a solution. An acknowledged gap in the range of magnets tested was suppressor magnets. These are permanent magnets whose field can be suppressed by an opposing electromagnet when not required to be detected by a passing train, for example on a bi-directional line where an AWS indication is required for trains travelling in one direction only. It has been identified that, due to the design of the suppression arrangement, the field produced by these magnets when not suppressed is generally lower than that of normal permanent magnets, and may (like electromagnets) typically be close to the minimum level specified in the group standard. This could have an impact on the viability of the proposed solution, which might require a complete redesign and re-specification of suppressor magnets.

In addition, the introduction of variable-threshold receivers across the network would not be a simple exercise. Any reduction in the sensitivity of existing AWS receivers for trains operating over “standard-strength” lines could only safely be carried out following a comprehensive check of all existing permanent magnets to confirm that they are producing the necessary higher field strengths which are in excess of the current specification.

The results of this research indicate that a change to GE/RT8035 to permit the use of single-sensitivity receivers cannot currently be justified.

**Next Steps**

The working group have recommended that the theoretical approach taken by LRR in this research project should be supplemented by practical field measurements. A further research project should therefore be undertaken that considers the likelihood and consequences of magnetic fields caused by power cables affecting the performance of the train-borne AWS systems. This should include investigation of how these levels vary with time, so that a realistic measure can be
obtained of the probability of false AWS operation, together with a review of the consequences.

The working group sees this as a necessary consideration as part of the identification and review of possible solutions.

RSSB will agree the scope of this research with the working group before progressing further.

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