Guide

Electrolysis from Stray DC Current

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Preface

The Asset Standards Authority (ASA) develops, controls, maintains and publishes standards and documentation for transport assets for New South Wales, using expertise from the engineering functions of the ASA and industry.

ASA publications comprise of network and asset standards for NSW Rail Assets and include RailCorp engineering standards that were previously managed by RailCorp until July 2013.

This document supersedes RailCorp standard EP 12 30 00 01 SP Electrolysis from Stray DC Current, Version 3.0. The changes to previous content include:

- updates to reflect organisational changes and resulting changes in responsibilities
- minor amendments and clarification to content
- conversion of the standard to ASA numbering, format and style
### Table of contents

1. Purpose ..............................................................................................................................................5

2. Electrolysis ........................................................................................................................................5

2.1 Description.........................................................................................................................................5

2.2 Legislative requirements..................................................................................................................5

3. Stray dc current....................................................................................................................................6

4. Effects and hazards ............................................................................................................................7

4.1 Continuous structures......................................................................................................................8

4.2 Overhead wiring structures .............................................................................................................8

4.3 MEN systems .....................................................................................................................................8

4.4 Concrete bridges...............................................................................................................................9

4.5 Earthed rail locations........................................................................................................................9

5. Minimisation techniques ..................................................................................................................10

5.1 High resistance to earth ..................................................................................................................10

5.2 Voltage drop minimisation .............................................................................................................11

5.3 Isolation............................................................................................................................................11

5.4 Breaking continuity..........................................................................................................................12

5.5 Use of protection systems ..............................................................................................................12
1. **Purpose**

This document provides general information on electrolysis caused by stray dc currents. It explains where stray dc currents are originated from and discusses their potential effects. This document also offers techniques to minimise stray dc currents to mitigate possible electrolysis.

This guide is prepared for and applicable to NSW 1500 V dc electrified railway network.

2. **Electrolysis**

2.1 **Description**

Electrolysis is an electro-chemical reaction involving an electrolyte and metals which are carrying a dc current. It results in the corrosion of the metal which is carrying the current at the point where the current leaves the metal and enters the electrolyte.

In the case of stray dc traction currents, the electrolyte is the moist earth while the metals are the rails and buried metallic services such as pipes and the sheathing on power and communication cables. The buried services in the context of electrolysis are usually referred to as 'structures' but should not be confused with overhead wiring structures. The buried 'structure' does not necessarily have to be underground - it just has to connect to earth at two points. However, note that electrolysis only occurs in the ground.

Whether or not a buried structure is likely to be damaged by stray dc currents is determined by the correlation of the structure to rail and the structure-to-earth potentials. If the potential of structure-to-earth is positive, corrosion is likely; if it is negative, the structure receives protection from corrosion because of the stray dc currents.

As an example, the corrosion rate of steel is 9 kilogram per ampere year.

2.2 **Legislative requirements**

The NSW Department of Trade and Investment, Regional Infrastructure and Services (NSW Trade & Investment) is responsible for administering the *Electricity Supply (Corrosion Protection) Regulation 2008*, made under the *NSW Electricity Supply Act 1995*. This regulation requires the approval and registration of all cathodic protection systems (CPS) including both sacrificial (above 150 mA output) and impressed CPS, drainage bonds (DBs) and transformer assisted drainage bonds (TRADs). The administration is done in conjunction with the NSW Electrolysis Technical Committee (NSWETC).
The NSWETC meets monthly to program testing of both new and existing cathodic protection systems and to recommend approval of CPS. The NSWETC consists of representatives of NSW utilities and includes electricity, gas, water, telecommunications, pipeline, light and heavy rail and other allied/interested parties. Since its inception in 1932, the NSWETC has developed and refined specialised equipment and technical procedures for both CPS testing and investigating problems on members’ assets arising from the operation of CPS and stray traction current.

It should be noted that the NSWETC is not a legal entity and does not have a registered office.

3. **Stray dc current**

The 1500 V dc electrified traction system consists of an overhead wiring system supplied by traction substations spaced every 5 km to 15 km along the tracks.

The current required to operate the train traction motors is received by the train pantograph from the contact wire, and then it returns to the traction substations via the wheels of the train and the unearthed track system. The overhead wiring is positive with respect to the rails.

Ideally, all current should return through the rails, but since the rails are in close contact with the ground through the sleepers and ballast, some current will leak from the rails and return to the substation through the ground. This leaked current is called 'stray current' or 'leakage current'.

Stray dc currents leave the rails far from the substation where there is a relatively low resistance to earth. The currents then use the path of lowest resistance to return to the substation. This usually involves entering a buried structure and then passing from that structure to the ground at some point closer to the substation. It then passes back to the rails at another point of relatively low resistance to earth and completes the circuit to the substation negative.

The return traction current flowing in the rails causes a longitudinal voltage drop along the length of the rails. Although the rails are nominally isolated from earth, there is inevitably a distributed leakage resistance causing a varying potential difference with respect to earth. This potential difference is negative near the traction substations and positive between substations. The resulting potential difference is generally 10 V to 70 V, which is not dangerous.

Regenerative braking fitted to newer trains causes the trains to act as mobile substations causing the rail potentials to be more variable than the simple case described above. In the simple model illustrated in Figure 1, substation earth is always positive to rail; but this is no longer always true.
It is neither practical nor desirable to completely insulate the rails from earth. Some amount of leakage current is acceptable to ensure that the voltage between rail and earth does not become dangerous. Another limiting factor in the rail to earth resistance is the signalling system which requires the rail to earth leakage resistance to be a minimum value of 2 Ω rail-to-rail per kilometre of rail. Thus the minimum allowable value is 1 Ω rail-to-earth per kilometre of rail. A typical track would usually have a value of approximately 8 Ω to earth for one kilometre of rail and a very well ballasted track would have a resistance of over 50 Ω to earth for one kilometre of rail.

![Diagram of traction currents and rail-to-earth voltage](image)

**Figure 1: DC traction currents distribution and rail-to-earth voltage under uniform conditions**

4. **Effects and hazards**

The most common stray dc currents paths in railway environment and the potential hazards and effects are discussed in this section.
4.1 Continuous structures

Continuous structures such as metallic fences and troughs provide conductive paths for stray dc currents because they are close to the tracks for long distances and are connected to earth at many points through which they may pick up and drop off stray dc currents.

Overhead earth wires erected for long distances over high voltage transmission lines to protect them against lightning are earthed at each pole and also connected to the substation earth mat, i.e. a very good connection to earth. These wires may also pick up and drop off stray dc currents along their route.

In addition to transfer of hazard (i.e. dc voltage), the buried parts of these structures are prone to corrosion at the drop off points – fence bases, toughing support columns and earth electrodes at the bottom of poles.

For further information refer to EP 12 10 00 21 SP Low Voltage Installations Earthing.

4.2 Overhead wiring structures

The OHW structure footing has a resistance to earth. A survey of structures has shown that these values of resistance to earth vary from 1.5 Ohms to 280 Ohms. Where an OHW structure is spark-gapped to rail and the spark gap operates (becomes short-circuited) a conductive path for stray dc currents is created.

If the spark gap is not replaced in a timely manner, the OHW structure base will corrode compromising its structural strength.

For further information refer to EP 12 20 00 01 SP Bonding of Overhead Wiring Structures to Rail.

4.3 MEN systems

The local distribution network service provider's (DNSP) low voltage supplies commonly use a multiple earthed neutral (MEN) system for earthing purposes. The neutral conductor – which is connected to earth at multiple points – is reticulated throughout the areas through which the RailCorp network operates. It provides a pick-up and drop-off facility for stray DC currents resulting in corrosion of the earth electrodes at the drop-off points.

A power supply with MEN system is only permissible if the installation and its earthing electrodes are at a reasonable distance from the electrified rail or any metallic element which may be connected to rail. This provision is also to ensure the safety of the consumers connected to the low voltage network by minimising the possibility of stray DC current flowing into the low voltage network.

For further information refer to EP 12 10 00 21 SP Low Voltage Installations Earthing.
4.4 Concrete bridges

The use of reinforced or pre-stressed concrete bridges raises special concerns when used for dc electrified railway networks. If the reinforcing bars or stressing wires are not insulated from rails then these will carry traction current. Even if they are insulated, concrete is not a good insulator and there could be some stray current in the bars/wires. The length of the concrete bridge structures increases the possibility to be affected by stray dc currents.

Since the steelwork is necessary for the strength of concrete bridges, it is vital that corrosion does not occur.

Over the years, numerous methods have been tried to minimise the corrosion of bridge steelwork. A few are listed below:

- insulating membranes have been installed in the concrete between the rails and the reinforcement. But this type of installation is prone to damage during construction and cannot be repaired after the bridge is built
- all steelwork have been bonded together and the current flow has been monitored to ensure there is minimal leakage. If leakage is found to be excessive, then drainage bonds can be installed
- some major pre-stressed concrete bridges such as the ones at Rushcutters Bay and Woolloomooloo viaducts have been successfully insulated by an insulating layer of epoxy grout between the roadbed concrete and the structural concrete

4.5 Earthed rail locations

The RailCorp network traction system is not deliberately connected to earth, although earthing on only one side is allowed; one side only to avoid creation of a complete electric circuit.

When the voltage between rail and earth becomes large, rails are automatically connected to earth via rail-earth contactors (REC) to mitigate the hazard. The connection has to be removed after safe voltage levels have been reinstated.

Earthed rails, obviously, provide direct path for rail currents to enter earth – this is no longer stray dc current but the actual traction return current – and have to be avoided unless necessary.

However, some situations require that the rails be earthed for safety reasons. Examples are in coal and wheat loaders, where sparks caused by a voltage between rails and earth can be catastrophic.

For further information refer to EP 12 10 00 13 SP 1500 V Traction System Earthing.
5. **Minimisation techniques**

The problem of minimising electrolysis is closely related to the problem of earthing and/or bonding of metallic structures to prevent electric shock to people. The solutions to both problems have to be a compromise since the 'best' solution for one situation results in major problems for the other one.

The techniques discussed in this section are as follows:

- maintaining high resistance between rails (and negative connections) and earth
- minimising voltage drop between traction substations
- isolation of services, installations and structures from dc electrified system
- breaking continuity in continuous structures

The above minimisation techniques are recommended for any work within the railway corridor and near 1500 V dc track. All associated mandatory requirements are covered in relevant documents.

5.1 **High resistance to earth**

Ensure the rails and associated negative connections have relatively high resistance to earth. To achieve a high resistance to earth, ensure that:

- the rails are clear of dirt and mud, particularly in sidings, yards, level crossings and through stations
- steel sleepers are not used in the electrified area unless the line is track circuited because track circuitsing detects low resistances to earth
- non-electrified lines and sidings are separated from electrified lines by insulated rail joints and that these joints are installed such that stabled trains do not short them out
- spark gaps have not operated and the insulation of bonding cables is not damaged
- in tunnels, on bridges and under air-space developments, there is no contact between rails and steel reinforcement or any other steelwork
- at substations and sectioning huts, negative connections are insulated from earth and trackside negative rail busbars are not covered in mud or ballast. Also, that rail-earth contactors are not left closed for longer than necessary times
- in car sheds, traction return rails are not connected to building framework and are well insulated from earth by the use of insulating pads under the rails or epoxy coating of the rails
- overhead wiring structures bonded to rail via spark gaps do not contact earthed services such as station awnings, fences, water pipes, etc.
5.2 Voltage drop minimisation

Ensure the voltage drop along the rails is minimised; in other words, the electrical resistance of the traction return circuit is minimised.

To minimise the voltage drop:

- use as many running rails as possible for traction return
- install tie-in bonds to share the current between tracks
- ensure all rail bonds and impedance bonds are correctly installed
- minimise substation spacing
- ensure substation voltages are equalised

Adjacent substations should have balanced output voltages. Equal voltages will keep the traction return current to a minimum resulting in lower voltage drop along the rails. Accordingly the voltage available to drive a stray dc current from the rail to structures and thence to the substation will be minimised.

5.3 Isolation

The following isolation methods can be utilised to mitigate or minimise the effect of electrolysis:

- keep metallic services away from the tracks so that there is a lesser possibility of picking up appreciable dc leakage currents. Select routes away from the route of the dc electrified lines
- use isolating transformers for all low voltage power supplies from the local DNSP, ensuring that no neutral and earthing conductor of that network enters railway corridor
- provide isolating joints, installed at the boundary of rail corridor, for all metallic water and gas pipes servicing buildings in the railway corridor and near 1500 V dc track
- ensure that metallic water and gas pipes crossing or laid along the railway corridor and near 1500 V dc track are insulated from earth. This principle applies also to other services such as power and communication cables with metallic sheaths
- ensure that fences at stations and electrical substations are not connected to metallic fences along the tracks
- ensure all metallic structures such as footbridges and bus shelters are isolated at the boundary of railway corridor. This can be achieved by allowing gaps, minimum 2 m apart, at both ends of the steelwork
- use insulating coating for underground structures
- when lighting is installed, ensure that the local DNSP's earth is not connected to the steelwork of any overhead wiring structure, station or bridge
5.4 Breaking continuity

For continuous structures as described in section 4.1, it is recommended to:

- install insulating panels every 500 m of metallic fences along the tracks
- install insulating sections every 500 m of metallic troughs along the tracks. Care must be taken to ensure that metallic lids of the troughs do not bridge the insulated sections
- ensure that there are no long lengths of metallic water/gas/air pipes within the railway corridor, in particular in car sheds
- ensure that RailCorp network high voltage cable screens are not continuous between substations
- divide underground metallic structures into short lengths using insulating joints
- do not use concrete poles in the railway corridor and near 1500 V dc lines. All local DNSPs have been advised not to use concrete poles near 1500 V dc tracks, especially if overhead earth wire or neutral wire is fitted

5.5 Use of protection systems

Corrosion protection systems methods that can be used to minimise the effect of electrolysis are:

- cathodic protection (CP) systems
- drainage bonds

In CP systems the metal that is to be preserved is made negative to earth and thus avoiding corrosion. However, with relatively large voltages caused by stray currents, CP is not entirely effective and hence railway drainage bonds may be useful.

A drainage bond relies on a deliberate metallic connection of the structure to rails in order that the stray currents return to the rail without entering the earth. See Figure 2 for a typical drainage bond arrangement.

The drained structure – the structure to be protected – becomes negative to earth and therefore attracts current from adjacent structures. Excessive drainage from one structure may cause hazard to other structures in vicinity of the protected structure, particularly when crossing each other. Thus, drainage bonds are fitted with resistance to limit the current returning to rails from the protected underground structure to avoid excessive drainage.

For example, in the case of steel structures, it is preferable to keep the voltage to earth between −2000 mV and −850 mV. At more negative voltages, damages such as hydrogen embrittlement or disbonding of insulation may take place. The common method used to determine the voltage affecting the structure is by using Cu/CuSO₄ half-cell making repeatable contact with earth.
The corrosion effect on the underground structures very largely depends whether the structures are bare or insulated/coated. Although insulation of metallic structures, if perfectly applied and maintained, can provide complete protection against galvanic corrosion, defects in insulation are unavoidable. The consequence of a defective insulation is that stray dc currents may be concentrated in a small defected area and accelerate the rate of corrosion at that point. Hence, insulation of metallic structures from their environment is usually supplemented with the CP systems. However, full protection against stray dc currents cannot be obtained because CP system voltages are generally lower than the traction voltages involved.

For more information refer to:

- AS 2832 *Cathodic protection of metals*
- guide for measurement of interference caused by cathodic protection and railway drainage systems prepared by the NSWETC

![Diagram of electrolysis drainage bond panel]

**Figure 2: Typical electrolysis drainage bond panel**

Below are some typical values for various components forming a drainage bond:

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuse</td>
<td>25 A</td>
</tr>
<tr>
<td>Lamps</td>
<td>32 V, 250 W</td>
</tr>
<tr>
<td>Resistor</td>
<td>0.30 Ω, taps at 0.22, 0.26, 0.30 Ω</td>
</tr>
<tr>
<td></td>
<td>Usually connected at 0.26 Ω</td>
</tr>
<tr>
<td>Diode</td>
<td>40HFR120 (Supplied by RS Components)</td>
</tr>
<tr>
<td>Conductance Bond</td>
<td>1.5 S, 4 V ( I = 6 A )</td>
</tr>
</tbody>
</table>