LRSSB – LRG - 15.0

Stray Current Management Guidance

LRSSB
16 Summer Lane
Birmingham
West Midlands
B19 3SD

TITLE:	STRAY CURRENT MANAGEMENT GUIDANCE				
REF:	**LRG 15.0**			**STATUS:**	**FINAL**
ISSUE:	**01**	**REVISION:**	**00**	**DATE:**	01/02/2021
DEPT:	LRSSB Safety Assurance			**REVIEW DUE:**	01/02/2022
DOCUMENT OWNER:				**DISTRIBUTION:**	
LRSSB				ALL UK TRAMWAYS	

DESCRIPTION:
THIS DOCUMENT PROVIDES GUIDANCE AND DETAILS FOR STRAY CURRENT MANAGEMENT.

PREPARED BY:	REVIEWED BY:	AUTHORISED BY:
Colin Kerr LRSSB	David Keay LRSSB	Carl Williams Chief Executive Officer LRSSB

SOURCE / RELATED DOCUMENTS:

LRG 1.0 - Tramway Safety Principles and Guidance (TPG) (LRSSB)
LRG 3.0 - Management of Electro Magnetic Compatibility (EMC) Guidance (LRSSB)
BS EN 50122-1 - Protective Provisions Relating to Electrical Safety and Earthing
BS EN 50122-2 - Protective Provisions Against the Effects of Stray Currents Caused by DC Traction Systems
BS EN 50162 - Protection Against Corrosion by Stray Current from Direct Current Systems
BS EN 50163 - Supply Voltages for Traction Systems
IEC 62128-2:2013 - Railway applications - Fixed installations -Electrical safety, earthing and the return circuit - Part 2 : protective provisions against the effects of stray currents caused by d.c. traction systems

RELATED TRAINING COURSES:	RELATED LEGISLATION:
N/A	Health & Safety at Work Act 1974 ROGS 2006

CHANGE NOTES:

Date of Issue	Issue No.	Revision No.	Reviewer	Details of Revision

UNCONTROLLED WHEN PRINTED

LRSSB

DOCUMENT CODE: LRG 15.0

STRAY CURRENT MANAGEMENT GUIDANCE

CONTENTS

TERMS AND ABBREVIATIONS

Table 1 – Terms

Term	Definition
earth	The defined reference point in an electrical circuit from which voltages are measured
Earth	Soil, the substance of land
First generation tramway systems	UK Tramways from the Victorian Era until the middle of the 20th Century
Line of Sight	Operating mode where a tram should be able to stop before a reasonably visible stationary obstruction ahead, from the intended speed of operation using the service brake
Second generation tramway systems	UK Tramways and Light Rail systems from 1990's
Statutory Undertakers	Certain bodies that have been given statutory powers in relation to roles that are of a public character, such as Utility Companies
Stray Current	A flow of electricity from the tramway which does not return via the rail but leaks into local Earth and buried conductors due to voltage imbalances
Voltage Limiting Devices	A device that prevents the existence of unacceptable high voltage

Table 2 – Abbreviations

Abbreviation	Definition
BS EN	**British (BS) adoption of a European (EN) standard**
DC	**Direct Current**
EMC	**Electromagnetic Compatibility**
IEC	**International Electrotechnical Commission**
IRJ	**Insulated Rail Joints**
SCADA	**Supervisory Control and Data Acquisition**
SCWP	**Stray Current Working Party**

1. Introduction

1.1 This document provides high level guidance for Stray Current Management in relation to UK Light Rail systems based on 'line-of-sight' operations only. As with all guidance, this document is not prescriptive and is intended to give advice, not to set a mandatory industry standard, and it is based upon goal setting principles as best practice.

1.2 Much of this guidance is based on the experience gained from existing UK Light Rail systems and from published documents. It does not prescribe particular arrangements adopted by any of these systems and is intended to give guidance and advice to those involved in Stray Current Management.

1.3 This guidance offers good practice that seeks to provide an acceptable level of assurance in the management of Stray Current by those delegated this responsibility. It sets out a strategy to assist a Light Rail system to demonstrate, mitigate and manage the risk of stray current where this is still considered to be potentially significant during electrical design optimisation.

2. Scope

2.1 The power circuit of any direct current supplied tramway or Light Rail system can be considered as consisting of four fundamental elements:

- The substations, from which the direct current at the designated nominal voltage for the line is supplied. (Nominal voltages should be to BS EN 50163[1] unless the system already uses an alternative voltage.);
- The positive conductor (i.e. the overhead line) connecting the supply to the trams
- The load (i.e. the trams);
- The negative conductor (i.e. the rails) through which the current is returned to the substations.

2.2 The flow of electrical current through a conductor will result in a voltage drop along its length, proportional to the Ohmic Resistance of the conductor. The consequence of this is that parts of the rails will be at a different voltage than that of other objects buried in the Earth, such as metallic pipes and cables belonging to Statutory Undertakers such as Utility Companies. Therefore, these buried objects can become 'buried conductors'.

2.3 The rail voltage of the Light Rail system will be dependent on the location and power flow within the electric system and may be positive or negative with respect to local Earth. As there will be some resistance to earth, the voltage distribution along the track at any instant in time will average zero with some parts positive and some parts negative. This distribution will vary depending upon the operating conditions, the location of the vehicle, and whether the vehicles are motoring or braking. (It is to be noted that negative voltages are not caused specifically by regenerative operation.)

2.4 As Earth does not provide perfect insulation, any difference in voltage between the rails and nearby buried conductors would result in some of the traction return current "leaking" from the Light Rail system into the local Earth, with some of this total leakage returning to the substation via buried conductors. The extent to which this leakage could occur would depend upon the

[1] BS EN 50163 - Supply Voltages for Traction Systems

relative total resistance of any of the potential other return paths: i.e. via the Earth or other buried conductors such as pipes.

2.5 The consequence of stray current is seen where it goes via a buried metal object as it can cause electrolytic corrosion if occurring frequently over time, often where it is concentrated at the points where currents exit the buried conductor. The result of this is that it could potentially lead to loss of material from the buried object.

2.6 In the case of metallic pipes carrying gas and water, leakage and / or rupture has obvious safety and / or operational risks to the Light Rail system, utility owner / Statutory Undertaker as well as to the general public. In the case of cables, particularly those that are of the older lead sheathed type, such loss of material can occur even more rapidly as the protection is more quickly ruptured, leading to breakdown of the unprotected inner insulation of the cable.

3. The Legal Position

3.1 In the early days of tramway electrification, damage to underground apparatus was a significant issue to the various Statutory Undertakers who sought to prevent the tramway operators from allowing any current to return via the Earth. This resulted in a court judgment (National Telephone Company versus Graff-Baker, 1893[2]) which ruled that the Earth was not exclusively for the use of the Statutory Undertakers, and that the tramway companies were as entitled to use it as much as they were, providing that they did not exceed reasonable limits.

3.2 These reasonable limits were expressed in terms of maximum voltage drop in the running rails which was promulgated via a series of recommendations published over time by the Board of Trade and the Ministry of Transport. Similar recommendations are now in the form of European Standards which are referenced below in Section 7.

3.3 The ruling of the court judgment established the principle that some leakage of current from tramways is inevitable, and that provided measures are taken to maintain it within reasonable limits, its existence has to be accepted by the Utility Companies and others who elect to bury their apparatus in the ground.

3.4 If stray currents are not managed in line with standards and good practice, this might expose a Light Rail system to claims for civil damages from the owners of buried services. In extreme cases it is possible that failures that to lead to safety incidents could result in criminal enforcement.

4. Overall Stray Current Management Policy

4.1 Stray Current Management should form an integral part of an overall EMC Policy for a Light Rail system. It should be compatible with the design of the Light Rail system for earthing, bonding, and lightning protection.

4.2 The electrical design of Light Rail systems should, as far as practicable and to be consistent with overall safety, be optimised in order that the potential to generate stray currents will be kept to the practical minimum throughout the life of the Light Rail system.

[2] https://uktram.com/wp-content/uploads/2018/07/TGN1-NATIONAL_TELEPHONE_COMPANY_v__BAKER__1892_N_DOC1.pdf

5. Information Exchange and Co-operation

5.1 It is in the interest of the Light Rail system (whether it is the owner, the operator, or the maintainer, etc.) to achieve co-operation and information exchange between all of the parties involved (including Statutory Undertakers) to come to agreement on the aspects of the system where it may potentially have any effect on any parties apparatus or vice versa.

5.2 Information exchange and co-operation with all parties should be conducted at all stages of the life of a tramway, from the planning stage through the design and construction and during the operation of a Light Rail system when significant changes or extensions are proposed or any specific issues reported. In this way, any potential effects or risks and any suitable precautions or remedies can be assessed during its development.

5.3 It is also important that the existence of stray currents from other non-Light Rail system sources, (not restricted to other electric railways), are identified by ensuring a baseline survey of stray current flows in existing buried conductors is undertaken before any Light Rail construction works commence.

6. Stray Current Working Party (SCWP)

6.1 It is recommended that Light Rail systems set up a Stray Current Working Party (SCWP) for each scheme / route. In doing this, there is opportunity for all Statutory Undertakers to contribute, particularly any Utility Companies who may have concerns that their apparatus could be affected by stray current.

6.2 The Light Rail system should determine the membership of the SCWP and propose its terms of reference / constitution. The aim would be that this would then be agreed by the members on a simple majority basis. The outline of issues to be considered should include the following (not exclusively):

- Agree the establishment of a schedule of potential susceptible assets. It should be understood that such assets must be both metallic and close to the rails, and also capable of forming an effective path between different parts of the Light Rail system. Experience from some operators of European Light Rail systems suggests that provided the measures described in the sections below are achieved, then buried metallic apparatus over 1 metre away from the rails in any direction will not be susceptible to stray current;
- Agreement of the pre-construction baseline survey of stray current flows in existing buried conductors is undertaken along the scheme / route before the start of any construction works;
- Cognisance should also be taken of any ongoing programmes where Utility Companies are committed to replacing existing apparatus from metallic to plastic or similar, thus reducing the range and extent of susceptible apparatus;
- Scrutinise the electrical system design of the scheme / route for its stray current management;
- Understand the level of testing of measures to mitigate stray current during the construction phase;
- Review results of testing during construction;
- Agree the level of monitoring in these measures once the scheme / route is in operation;
- Review any issues as they arise during the operation of the scheme / route.

6.3 The frequency of meetings should be by agreement. It would be expected that the frequency will vary throughout the life of the scheme / route. However, once operations are established, it would be expected that meetings would only be required for specific issues to be reported or discussed.

6.4 Where appropriate, other Statutory Undertakers such as Network Rail and London Underground may wish to deal with individual Light Rail schemes / routes in a broader forum along with other interface issues (such as EMC). If this is the case, the Light Rail system should accommodate this approach.

7. Appropriate Standards

7.1 The base standard is BS EN 50122-2[3]. The principles of this Standard may also be applied to existing electrified Light Rail systems where it is necessary to consider the effects of stray current. IEC 62128-2:2013[4] standard also contains applicable guidance.

7.2 Standard BS EN 50122-2 gives comprehensive guidance on the design of Light Rail systems as well as recommended requirements. The design and management of Light Rail electrification should meet the requirements of this Standard along with BS EN 50122-1[5].

7.3 It is important to note that the protective provisions against electric shock in BS EN 50122-1 will take precedence over provisions against the effects of stray currents where safety of staff or protection of the public are concerned.

7.4 BS EN 50162[6] should also be considered during the design process. This Standard assists with the identification and measurement of potential corrosion from stray current if it is still considered a risk. The design and management of the Light Rail system in relation to the management of stray current should take account of this Standard where appropriate, and also any outputs following consultation with the SCWP.

7.5 Other standards could be referred to as appropriate to the Light rail system. Overall, it must be designed, constructed and operated in accordance with respective legislation in force at the time.

8. Electrical Design of the Light Rail System

Fundamental Principle of Stray Current Design and Management

8.1 It is not possible to obtain infinite resistance between the tracks and surrounding Earth for the full length of the scheme / route, and certainly not for the life of the Light Rail system nor under all weather conditions.

8.2 However, it is possible to minimise the risk of stray current even if it is not possible to remove it entirely. Therefore, it is important that the design and ongoing management strategy will ensure that as far as is reasonably practicable, the level of stray current is minimised.

---

[3] BS EN 50122-2 - Protective Provisions Against the Effects of Stray Currents Caused by DC Traction Systems

[4] IEC 62128-2:2013 - Railway applications - Fixed installations -Electrical safety, earthing and the return circuit - Part 2 : protective provisions against the effects of stray currents caused by d.c. traction systems

[5] BS EN 50122-1 - Protective Provisions Relating to Electrical Safety and Earthing

[6] BS EN 50162 - Protection Against Corrosion by Stray Current from Direct Current Systems

8.3 This principle is in accordance with the standards listed above in Section 7.

Designing to Keep Stray Current Low

8.4 Based upon successful experience with first generation tramway electrification, it is the established convention to determine the insulated overhead conductor as the positive pole of the supply, with the running rails functioning as the negative return.

8.5 Therefore, from any point in the system, the return current has the possibility of returning to the negative busbar of the substation by:

- The designated return path (primarily the rails but may include cables as well), or
- Via the Earth (i.e. as stray current).

8.6 The extent to which each path is chosen is governed by:

- Current = Voltage Difference / Electrical Resistance in circuit.

8.7 This means that to keep stray current to a minimum, one of the primary design objectives of the electrical power supply system should be to:

- Keep the Local Rail to Local Earth *voltage* low, and
- Keep the Local Rail to Local Earth *resistance* high.

Designing to ensure that Local Rail to Local Earth Voltage Remains Low

8.8 The Light rail system will be supplied with electricity suitably transformed and rectified from the local electricity network supplier through substations located along its scheme / route. The Local Rail to Local Earth Voltage at any point depends on the overall electrical resistance between that point and the sub-station. Light Rail systems should achieve a low value of resistance by undertaking the following actions.

8.9 Installing frequent feeder points from the traction supply along the scheme / route to reduce the distance that return current has to travel. For each feeder point:

- A robust incoming supply at each feeder point should be provided to the extent that this can be arranged with the local electricity network supplier. Ideally this should be from a ring main rather than a spur connection. This will minimise instances of emergency feeding due to the outage of a feeder point;
- It is usual to specify dual end feeding to each electrical section on the Light Rail system, i.e. each section will be fed from the two adjacent sub-stations. This will reduce the effective distance the return current has to travel. Therefore, care should be taken to ensure that the open circuit voltages of the two feeding transformers are as equal as possible (by use of the secondary tapping adjustment) in order to ensure that the traction load is shared;
- It is also desirable to provide single feeding points at the midpoint of each section, with coupling switches as necessary, to allow for a loss of local supply;
- At the extremities of the line, the final section may be single end fed, but the overall length of the electrical section should be lower to compensate.

8.10 The system should be designed so that the permitted accessible voltage is still achieved in the event that any one feeder point is out of service.

8.11 Welding should be by an approved process along all continuous lengths of rails in order that the electrical resistance of the rail is not increased by more than the level specified in BS EN 50122-2.

8.12 Where welding of adjacent rail lengths is not possible, the rails would be connected by low resistance track bonds. In this scenario, incorporating sufficient redundancy in bonding should be considered.

8.13 A similar arrangement shall apply at special track installations such as points, crossings, and breather switches/expansion joints. It may be desirable for parallel return conductors to be installed across the length of special work to facilitate maintenance of the return path during maintenance operations.

8.14 Frequent cross bonding between rails should be provided. This is to provide several parallel paths for return current, all at equal potential, in order to reduce the resistance of the return path. This also provides a level of redundancy in the event of a failed bond, or rail discontinuity. The bonding should encompass:

- The space between both rails of each individual track. Experience shows that a bond separation of around 200 to 300 metres is appropriate;
- All four rails on double track. Experience shows that a bond separation of around 400 metres is appropriate for these bonds;
- The actual appropriate intervals for each type of bond should be established during the design of the scheme / route.

8.15 The majority of Light Rail systems are operated on the basis of 'line of sight', so it should not be necessary to employ traditional heavy rail signalling track circuits requiring impedance bonds or insulated joints unless there are particular site or alignment conditions which specifically require it.

8.16 Rail sections should be chosen to give the maximum cross sectional area in order to minimise electrical resistance. Cognisance should be taken of the fact that wear to the rail will cause an increase in resistance over time up to the point that the rail is renewed. The calculations that determine the maximum accessible voltage should take into account the renewal limit of wear.

8.17 Consideration should be given to providing parallel negative low resistance return cables where the scheme / route specific power supply studies show them to be required at any point where it is not practical for other reasons to use a larger rail section or, for example, an isolated section of single track within a feeder section.

Designing to ensure Local Rail to Local Earth Resistance Remains High

8.18 Light Rail systems should seek to achieve a high Local Rail to Local Earth Resistance by ensuring a high level of insulation from earth of the running rails and the whole return circuit. The design and method of construction should be such that the overall conductance per unit length throughout the system will not exceed the values recommended in BS EN 50122-2 during routine operations throughout the life of the Light Rail system.

8.19 It would be expected that the scheme / route would be constructed to have conductance values several times better than the values given in the above BS EN 50122-2 standard (as this should be considered the absolute minimum). The inspection and maintenance regime adopted by the Light Rail system should have intervention thresholds such that the track conductance values should never reach the values in this Standard during normal operations at any time in the life of the scheme / route.

8.20 The design of the scheme / route should be such that the conductance values for all trackforms at all points along it should be determined, tabulated and then constructed so they are achieved. The intervention (and eventually renewal) thresholds that should be achieved should also be clearly stated.

8.21 The methods of achieving high levels of track insulation will vary according to the trackform adopted. The basic principles for most trackforms are contained in Appendix 1.

9. Safety Considerations

Permissible Accessible Voltages

9.1 As described above, high levels of insulation between rails and Earth means that in general, whilst the tram is operating, there should be a potential difference between the rails and surrounding Earth. Under fault conditions this potential difference can rise significantly to the extent that there is a risk it could cause a danger.

9.2 There are limits to the permissible accessible voltages due to the traction return current, and touch voltages due to currents under fault conditions as set by BS EN 50122-1. All Light Rail systems should meet these limits throughout the life of the system.

9.3 As the electrical system design is progressed and tram performance and service levels confirmed in the design of each scheme / route, a series of computer based power supply simulations should be conducted for the whole tram network. These will simulate accessible and touch voltages at representative points along the whole network under normal, emergency feeding (i.e. with the designed level of feeder point outage), and fault conditions. This will assist in determining whether additional measures are required to keep within the required voltage limits.

9.4 In addition, a reassessment should always be made. This could be made when, for example, there is any significant increase in the level of service proposed or the introduction of new tram vehicles.

9.5 Any additional measures would relate to further reducing the return circuit resistance, for example, by the provision of additional return conductors. Low accessible voltages under permanent conditions will also assist with the minimising of stray current.

9.6 Under fault conditions it may be necessary to connect the return circuit temporarily to Earth (for example, tripping to interrupt a short circuit current) until other protection measures operate. This would be achieved by the provision of voltage limiting devices. Whilst this gives the risk of a short term increase in the local level of stray current, safety considerations take precedence. Such events should be both rare and of practically no consequence for third party apparatus. Any such changes should be adequately documented.

Voltage Limiting Devices

9.7 All types of Voltage Limiting Devices used should meet the requirements of BS EN 50122-2 in terms of reset after operation. Ideally this should have the facility to be monitored through the SCADA system.

9.8 Experience shows that there is a particular failure mode with some types of Voltage Limiting Devices. If they experience a high fault current or a large number of operational duty cycles due to short-term impermissible accessible voltages, then they may fail in the short circuit mode. This then creates a direct path to Earth for the traction return, which could, if undetected for some time, lead to corrosion on other nearby metallic structures. Testing and maintenance procedures should take account of this failure mode.

9.9 Due to the possibility of a particular failure mode with some types of Voltage Limiting Devices, hybrid switching types composing of a solid state control and separate DC contactor should be considered.

10. Additional or Special Measures

Negative Earthing & Drainage Diodes

10.1 For the UK's first generation tramway systems, it was accepted practice to connect the negative pole of the supply (usually a dynamo) to Earth, and similarly, to connect all external ironwork such as the traction poles to the running rails. It was also accepted practice to connect buried pipes to each other and to the running rails, with the intention that such stray current would leak out of the rails and be returned via a solid electrical connection, obviating the risk of electrolytic corrosion.

10.2 Whilst having some advantages, this method can result in increased current leakage simply by increasing the number of potential current paths from the rail to the surrounding Earth. This method is therefore considered to be flawed in practice because the voltages that drive stray currents go both positive and negative in normal tram operation.

10.3 Initial practice with the UK's second generation tramways was to electrically connect all of the steel reinforcement in the track slab, and to connect this to the negative terminal of the DC rectifier via a diode. Although this was seen to offer a theoretical advantage by ensuring that the reinforcement should act as a collector mat such that any stray current can only return directly to the substation, it is also considered to be flawed in practice. This is because the voltages that drive stray currents go both positive and negative in normal tram operation.

10.4 Therefore, current practice used in more recent systems, is not to provide any permanent connections between the negative bus-bar and Earth, leaving the rails "floating" relative to Earth. The advantage is that because the resistance between the rails and the Earth is not infinite, the rails will adopt an average potential close to that of the Earth. BS EN 50122-2 is written around a "floating" system of track to accommodate this practice.

10.5 Diodes that were used in earlier tramways have since been removed, resulting in a demonstrable improvement in current stray current performance.

10.6 Where steel meshes or similar reinforcements are currently in use as part of the trackform for structural reasons or as a crack control measure, then the Light Rail system should review this and consider whether they should continue to be electrically connected. They should not be connected to the traction return circuit. During the design of new schemes / routes, detailed specifications should be developed during the design of the trackform.

10.7 Provided that proper attention is paid to the return circuit resistance and insulation, the special provision of a stray current mat should not be required.

10.8 It is common practice amongst established tramway and Light Rail systems in mainland Europe to employ an un-reinforced concrete track slab.

10.9 Special requirements may apply to tunnels. These are not considered further in this guidance document but are described in BS EN 50122-2.

Adjacent Structures

10.10 The resistance between conductive structures adjacent to the Light Rail system which are not insulated from Earth and the track return system should be as high as possible. The only exception would be at depots which are considered in the section below.

10.11 Where such structures are located within a zone where it may be possible for a person to be in direct or indirect contact with both the structure and any conductive material connected to the track return, the requirements for accessible and touch voltages of BS EN 50122-1 should be met. This will normally involve the use of voltage limiting devices as described above in Section 9.

Special Arrangements for a Depot

10.12 Within a depot site and in relation to the safety of personnel working in the depot, the traction return should be directly connected to Earth. The depot should be fed from its own separate rectifier or power supply and the running rails within the depot should be separated from the main line by means of insulated rail joints (IRJ). A double set of IRJs between the depot and the operational tracks should be used.

10.13 The layout of the depot should be designed to avoid any necessity for a tram to be stationary such that it will bridge IRJs. Operational procedures should also support this. Arrangements within a depot would need to be in accordance with BS EN 50122-1 and BS EN 50122-2.

10.14 A depot site will normally comprise of an area within which maintenance activities will be undertaken, normally within an enclosed structure, together with stabling areas. The Light Rail system should consider whether the whole site or merely the maintenance area is to be subject to the above feeding arrangements. This decision will depend upon the following (not exclusively):

- The overall maintenance philosophy of the Light Rail system, i.e. the extent to which maintenance is restricted to one particular area;
- The location of the depot. Where for example it is located entirely within an urban area, it is likely the entire site of the depot will require to be considered;
- The effect of the current draw when the fleet is stabled but with much of the auxiliary load enabled. This will determine the maximum voltage drop along the tracks and thus determine whether a direct connection between structural Earth and the return circuit is tolerable.

Other Railway Traction Systems

10.15 Care should be taken to ensure that there will be no direct conductive connection to track sections of other railway traction systems.

10.16 Where conductive structures are adjacent to both systems and in the case of Alternating Current traction systems that are bonded directly to the tracks of the Alternating Current system, special arrangements should be made. These arrangements would be agreed with the owners of each system and take account the particular earthing and bonding arrangements on both systems. They should not compromise stray current levels on the Light Rail system, except for extremely short periods under fault conditions as described above in Section 9.

Cathodic Protection Measures

10.17 The overall design of the Light Rail system should ensure that there will be no adverse consequences for third party apparatus due to stray current.

10.18 Owners of third party apparatus may still wish to install measures including specific cathodic protection measures on particular apparatus, (for example those described in BS EN 12954[7]). Light Rail systems should not be expected to bear the costs of such work or take any responsibility for the performance or monitoring of that apparatus in the future unless there is a proven benefit to them. In any such cases, this would be as a commercial discussion between tramway and the third party and not seen as an obligation on the Light Rail system.

11. Ongoing Monitoring and Control of Stray Currents

Tests and Measurements

11.1 It is not possible to correctly and accurately measure stray currents. The only practical measurement is a local potential difference between the traction return and the surrounding Earth.

11.2 However, in order to be able to demonstrate that rail potentials stay within a consistent range relative to the design values and those measured at first installation, it is advisable to take measurements of this potential difference. This information can then be used to calculate the track conductance along the scheme / route at any future point thus allowing changes or trends to be identified and where necessary, additional inspection and remedial actions instigated.

11.3 These measurements can be taken on a continuous or discontinuous basis. One of the procedures in relation to taking measurements is described in BS EN 50122-1 and its associated annexes and should be adopted by all new Light Rail systems. Existing Light Rail systems should consider changing their present arrangements to those described in this Standard.

11.4 The infrastructure maintainer should make use of this information continuously, particularly that of any adverse trends, and programme early inspection and remedial action accordingly. Intervention thresholds should be clearly defined and acted upon. The methods outlined below are a guide to appropriate actions if intervention is required.

11.5 Using the above information, the Light Rail system should be able to demonstrate that it is maintaining the return circuit insulation at the levels specified in the maintenance instructions. These levels ideally should be higher than those in the standard BS EN 50122-2 which are considered the absolute minimum levels.

11.6 Return circuit insulation levels will always be high compared with soil resistivity changes in the local Earth over time, and as such will have insignificant effect.

[7] BS EN 12954 - General principles of cathodic protection of buried or immersed onshore metallic structures

11.7 Provided the measurements above are taken and the information used, then required levels achieved (and can be demonstrated), then no other testing regime should be required in relation to stray current.

11.8 It is the responsibility of all Utility Companies to carry out any additional monitoring of their own apparatus as a part of their own internal inspection and maintenance procedures.

11.9 Any measurement and criteria for intervention due to measured stray-current interference for apparatus without cathodic protection should be in accordance with the procedures given in BS EN 50162. Acceptable positive potential shifts should be as stated in line with those in Table 1 of this Standard.

11.10 The above guidance in relation to BS EN 50162 would only apply to utility apparatus already installed where the scheme / route is known, being developed and the powers in a Transport and Works Act Order or equivalent legislation have not yet been granted. It is the responsibility of the owner/installer of any new or modified apparatus to take full cognisance of the Light Rail system and therefore to design and install such that the apparatus is not susceptible to corrosion from stray current.

Construction Phase

11.11 The Light Rail system should recognise that the achievement of the agreed Standards for track insulation and bonding (see Section 8 above) will require continuous attention to detail throughout the construction of the scheme / route. There should be procedures put in place and documented that:

- Continuously review the practicality of the design for construction,
- Provide rigorous quality control at all stages, and
- Carry out formal testing and recording at appropriate stages.

11.12 The details of these procedures should be developed along with the design of the scheme / route, during its procurement for construction and also shared with the SCWP. This would then be incorporated into the overall scheme / route quality and test and commissioning documentation.

Maintenance when the Scheme / Route is in Operation

11.13 The Light Rail system should ensure that there is a regime of preventative and corrective maintenance of the system in place throughout the operating period. Maintenance of return circuit insulation levels will form a key part of this. The majority of this maintenance is essentially good house-keeping activities such as (not exclusively):

- Monitoring of return circuit potentials and responding to any changes (see above);
- Keeping ballast clean and free of vegetation;
- removing metallic debris such as discarded cans from track areas;
- Applying regular vegetation management of areas of grass track to keep direct contact between the rail and any growing medium to an absolute minimum;
- Keeping drains clear;
- Cleaning sand deposits away from rails;
- Addressing highway surface failures promptly;

- Checking bonds both for soundness and that they are still correctly in place (for example they have not been stolen);
- Checking cables for insulation damage;
- Checking protection devices for functionality.

Renewal of Equipment

11.14 Over the operating life of the system there is a requirement to renew the equipment of both the Light Rail system and also third party apparatus. This may arise for several reasons including (not exclusively):

- Life expiry;
- Obsolescence;
- Damage.

11.15 For all renewals it will be appropriate to consider the stray current implications of (not exclusively):

- The point at which renewal is judged necessary (for example the remaining cross sectional area of a rail may be considered more important than the physical state of the rail head);
- Service experience;
- Changes in technology or materials.

11.16 For Light Rail system renewals and upgrades, quality should be as a minimum and consistent with the original construction. It would also be expected that renewals and upgrades would take into account any changes in legislation or any appropriate standards that may have been introduced or modified since the original construction of the Light Rail system.

11.17 Third parties should take into account that any renewal of their apparatus should take full cognisance of the presence of the Light Rail system.

12. Heritage and Museum Tramways

12.1 In most cases, existing heritage and museum tramways will have been constructed to meet historic standards as specified by the Ministry of Transport as detailed in see Section 3 above.

12.2 However, all tramway installations whatever their age have a duty to consider stray current implications. In addition, it should be noted that as older tramways have been in situ for some time, they are susceptible to have experienced long periods of stray current flow. However, it should be remembered that for corrosion due to stray current to be an issue, there would have to be a flow that was significant over some time.

12.3 Heritage and museum tramways should particularly consider (not exclusively):

- The length of the return path to their feeding point(s) and its specific resistance;
- The maximum current draw to be expected from the tramcars to be operated on the line taking into account operating speeds and likely loading;
- The operational periods of the line;
- The level of service to be provided during these operating periods;

- The likelihood of significant underground metallic services in close proximity to the alignment of the tramway.

12.4 Careful consideration of the above will allow a judgement to be made by a sufficiently competent person as to whether any additional insulation of the traction return would be advisable, and whether this should be undertaken at the time of renewals. This should also be considered if an extension to the existing system is being developed.

12.5 All future new museum lines will be expected to follow the main sections of this guidance note as they will be classed as a new route.

Appendix 1 - Basic Principles for Basic Trackforms (as referred to in Section 8)

The basic principles for trackforms are listed below (not exclusively):

1) For a traditional railway formation, where this would be an open formation where the running rails are laid above ground level and with the following:
   - Sleepers typically of concrete;
   - Insulated type rail pads between the rail-foot, the fastener and the sleeper which also meet the required rail toe loads and vibration/fretting performance;
   - Ensure the ballast is:
     - not in contact with the rail as far as possible;
     - clean;
     - well drained.
   - If grass or similar aesthetic feature is proposed, it should be clearly demonstrated how contact between the medium proposed and the rails is to be prevented in the design of the tramway and in future maintenance as an ongoing control. This may include, for example, the medium being contained in separate containers located around the rails;
   - In many Light Rail systems, trams will regularly use sand in some locations to assist with adhesion. Build-up of sand deposits providing any direct path between rail and ballast should be dealt with as part of routine maintenance;
   - At points and crossings ensure that there are no direct electrical paths between the rails and any electrical apparatus in the point machine, particularly the neutral and Earth connections;
   - All other rail-mounted conductive equipment would be insulated from Earth. In particular the use of non-metallic connections to drain boxes is recommended;
   - The exposed metal parts of all bonds or other connections to the rail should be kept as short as possible and clear of fasteners, sleepers or ballast or any other conductive structure connected to Earth.

2) For trackform, which would be a slab track with rails proud of grade / surface and with the following:
   - For rail pads, bonds and switches, there are the same issues as experienced with ballasted track;
   - Run-off and drainage should be sufficient to avoid standing water;
   - Prevention of build-up of sand deposits is important;
   - Specific measures may be required in relation to any reinforcement material within the slab.

3) Closed track formation which would be where the top of the running rail is level with the surrounding surface. Typical examples will be the highway and in pedestrian areas.

The points below relate only to electrical considerations of trackform:

1) An insulating layer should be interposed between the rails and the surrounding structure. This can be achieved by any of the following means:
   - Using a rail coated with insulating material;
   - Surrounding the rail with a form of insulated “boot”;
   - Embedding the rail in an insulating medium;
   - The use of insulating filler blocks on either side of the rail web;
   - It may be acceptable to encapsulate the rail directly in concrete.

2) If grass or similar aesthetic feature is proposed it should be clear how contact between the medium proposed and the rails is to be prevented.

3) The choice and design of the insulating system should be consistent with:
   - The Light Rail system’s Noise and Vibration Attenuation Policy, but should not compromise the insulation level. In considering the appropriate solution for a particular area, there should be a clear understanding of the differing requirements for electrical insulation (essentially a thin layer) with any resulting noise and vibration (which would normally require a thicker layer which coincidentally provides electrical insulation).
   - All proposed processes which require access to the rail to attend to defects or make new connections, as well as access for routine welding of rails in order to make good side and head wear.

4) Particular attention should be paid to sealing the joint between the rail and the surface of the immediate surrounding area to minimise water penetration down the side of the rail. The method and materials chosen should take account of the extent to which the alignment at any point is shared or crossed by other forms of road traffic.

5) Particular attention should be given to local insulation of the rail:
   - At all rail welds, particularly if these are carried out after track installation;
   - Where rail bonds or negative return cables are attached to the rails. There should be no exposed metal on either the rail, bonds, or cables both at first installation and after maintenance;
   - Attachment and insulation of tie-bars connecting both running rails if used;
   - At any rail joints not capable of being welded. Continuity bonds should be provided at all such joints;

6) Adequate drainage should be provided such that water runs off quickly and does not remain in the vicinity of the rails. Drainage should be cleaned and cleared regularly so that ponding does not occur except briefly under the most extreme conditions.

7) New drainage slots should be provided in the rail groove at appropriate locations and connections from these to the drainage systems should be with non-conductive materials.

8) Standing water should be avoided.

9) Rail grooves should be kept clean of debris (including sand deposited from the tramcars).

10) At points and crossings ensure that there are no direct electrical paths between the rails and any electrical apparatus in the point machine.

11) Any other rail-mounted equipment should be insulated from Earth. This particularly relates to drain boxes and point machines.

12) Specific measures in relation to any reinforcement material within the slab below and/or around the track.