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Guide for Measurement of Interference

Caused by Cathodic Protection and

Railway Drainage Systems

NSW Electrolysis Committee

The 1990 version of the Guide was prepared for the New South Wales Electrolysis Committee by the following Members of the Sydney Electrolysis Technical Committee:

AGL Gas Networks (NSW) Ltd
Australian Institute of Petroleum
Telstra Corporation Limited
NSW Department of Energy
EnergyAustralia
Australian Water Technologies

The members of the Sydney Electrolysis Technical Committee contributed to the 1998 revised version of the Guide.

The contributions of these organisations are gratefully acknowledged.

Editing, co-ordination and publishing by the Secretariat of the NSW Electrolysis Committee, c/o: NSW Department of Energy, PO Box 536 St Leonards, 2065.

Note: *The information and recommendations contained in this Guide have been compiled from sources believed to be reliable and to represent current opinion on the subject. No warranty, guarantee, or representation is made by the New South Wales Department of Energy, its Officers, and the New South Wales Electrolysis Committee and its members as to the absolute correctness or sufficiency of any information or statements contained in this and other publications. The New South Wales Department of Energy and the New South Wales Electrolysis Committee assume no responsibility in connection therewith. It cannot be assumed that all acceptable safety measures are contained in this publication. Other and/or additional measures may be required under particular or exceptional conditions or circumstances.*

PUBLISHED	October 1990
REVISED	October 1998

GUIDE FOR MEASUREMENT OF INTERFERENCE CAUSED BY CATHODIC PROTECTION AND RAILWAY DRAINAGE SYSTEMS

OCTOBER 1998

This Guide is approved as the New South Wales Department of Energy's Guidelines for use in electrolysis testing pursuant to Clause 15 of the Electricity Safety (Corrosion protection) Regulation 1998.

(signed)
R S W Neil
Director-General
Department of Energy
21 December 1998

Preface

The NSW Electrolysis Committee was established in 1932 to provide guidance to the Electricity Authority of NSW on the control of stray currents and their effects on buried structures.

Under the Electricity Safety Act 1945, and the Electricity Safety (Corrosion Protection) Regulation 1998, cathodic protection systems and railway drainage bonds installed in the State of NSW must be approved by the relevant authority before they can be operated. At the time of preparation of this Guide that authority is vested in the Director General of the Department of Energy of NSW.

The NSW Electrolysis Committee continues to provide technical advice, co-ordination and liaison and make recommendations for approval to the Department of Energy in respect of examining, reviewing, testing and monitoring the effects of cathodic protection and railway drainage bonds.

The publication of the Guide is an integral part of providing the Department with technical advice in this very specialised field of engineering.

The purpose of the Guide is:

1. To provide for standardisation of interference testing procedures including methods of recording and reporting results.
2. To provide consistency of interpretation of those results thus minimising the possibility of errors and disputes arising therefrom.
3. To provide technical knowledge relevant to interference testing.
4. To provide a field guide for persons involved in interference testing.
5. To promote co-operation between all interested parties through a common understanding of the complex principles and practices associated with the mitigation of interference from stray currents.

This Guide has been prepared to assist all persons involved in the measurement of interference caused by impressed current, sacrificial anode, railway drainage systems and variations of these (hereafter referred to as "systems"). The Guide describes the procedures and techniques used by the Electrolysis Committee in New South Wales and does not address all alternative technology being explored by the Cathodic Protection Industry. Subsequent editions will incorporate new developments in techniques as they become available.

The Guide is not intended as a basic text book on cathodic protection and interference testing. There are a number of publications concerned with the theory and practice of cathodic protection which contain background information useful for understanding interference testing, for example, “Cathodic Protection of Underground Structures” published by the Energy Authority of NSW (1985). A list of references is attached to the end of the Guide.

Administrative arrangements associated with the testing and approval of cathodic protection systems are detailed in Appendix XI and safe-working matters in Appendix XV.

The nature of interference testing is such that the possibilities for error, misunderstanding and dispute are considerable. It follows therefore, that all involved parties should make a genuine effort to follow the Guide as this will provide a uniform approach to testing and assessment of interference.

The Electrolysis Committee works on the basis of co-operation between members to achieve its objectives to the mutual benefit of members and the community.

The Director General of the Department of Energy has prescribed use of this Guide for carrying out interference testing in association with an application for approval of a cathodic protection system or a railway drainage bond.

Contents

Abbreviations and Units

A	Ampere
AGL	AGL Gas Networks Limited
AS	Australian Standard
ATC	Telstra Corporation
AWT	Australian Water Technologies
CAT	Category
CP	Cathodic Protection
DC	Direct Current
DB	Drainage Bond
DoE	Department of Energy (NSW)
EA	EnergyAustralia
FS-E	Foreign Structure to Earth
FS-RR	Foreign Structure to Rail
G	Conductance(in Siemens)
hr	Hour
I	Current
IETC	Illawarra Electrolysis Technical Committee
IR	Product of Current (I) and Resistance (R) which equals Voltage (V)
kPa	Kilopascals
kV	Kilovolts
MoV	Modified Voltage
MoC	Modified Average Current
mV	Millivolts
NETC	Newcastle Electrolysis Technical Committee
NSWEC	New South Wales Electrolysis Committee
PS-E	Primary Structure to Earth
PS-RR	Primary Structure to Rail

R	Resistance
RAC	Rail Access Corporation (of NSW)
RSA	Rail Services Authority (of NSW)
RD	Railway Drainage
s	Seconds
SAA	Standards Australia
S-E	Structure to Earth
SETC	Sydney Electrolysis Technical Committee
SRA	State Rail Authority
S-RR	Structure to Rail
SW	Sydney Water
TDB	Combined TRAD and DB system
TRAD	Transformer Rectifier Assisted Drainage System
UBD	Universal Business Directory (Locality Maps)
V	Volts
WB	Sydney Water

1. Introduction

There are three basic types of corrosion control systems, the impressed current system, sacrificial (Galvanic) anode system and the traction current drainage system (railway drainage bond). In recent years the Transformer Rectifier Assisted Drainage system (TRAD) has been introduced. These systems are illustrated in the following modified diagrams from the Energy Authority publication “Cathodic Protection of Underground Structures” and Australian Standard 2832.1-1985. The TRAD combines the characteristics of cathodic protection and traction current drainage systems.

Figures 1 and 2 illustrate impressed current and sacrificial systems. Both of these systems introduce direct current into the soil, a component of which can flow through nearby foreign structures and cause corrosion. Figure 3 illustrates the way traction current can leave a railway line, enter a structure and exit that structure at some other point causing corrosion at the exit point. A drainage system is a deliberate conducting path (see Figure 4) to return stray current to the railway line in a way that will substantially reduce corrosion. However, the installation of a drainage system on a structure may increase stray current flow by lowering circuit resistance which in turn may increase stray current effect on other nearby structures.

Therefore, the application of the above systems, whilst they may protect the (primary) structures to which they are applied, can cause increased corrosion on other (foreign) structures. This increase in corrosion is indicated by a change of electrical potential on the foreign structure and this change is referred to as interference. When unacceptable interference is found, it is necessary to take actions to minimise it and thereby minimise corrosion.

It must be noted, however, that reference to and/or application of this procedure to any system does not indicate that the system has been proved capable of preventing corrosion of the structure to which it is applied. The determination of satisfactory corrosion mitigation performance is the responsibility of the owner of the protected structure.

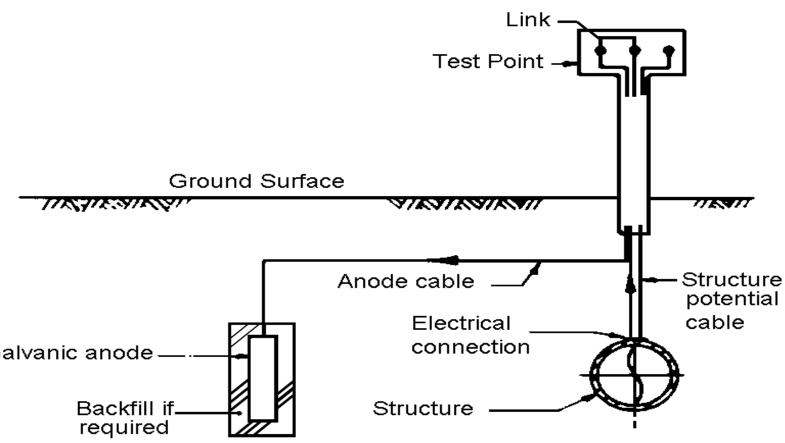


Figure 1 - Cathodic Protection with Galvanic Anodes (Schematic) from AS 2832.1 - 1985

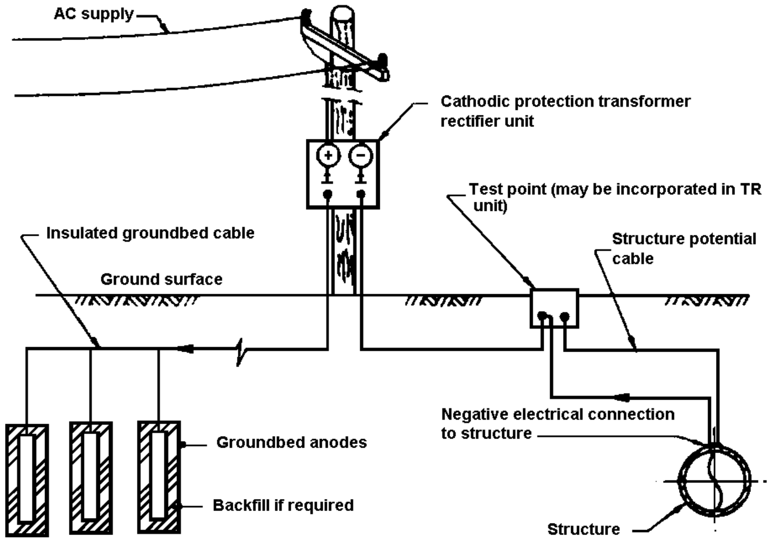


Figure 2 - Cathodic Protection with impressed current system (schematic) from AS2832.1 - 1985

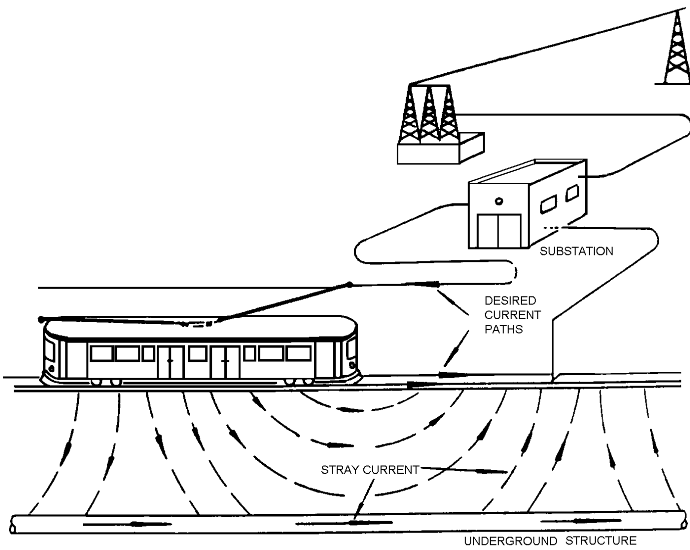


Figure 3 - Stray Current from a Traction System

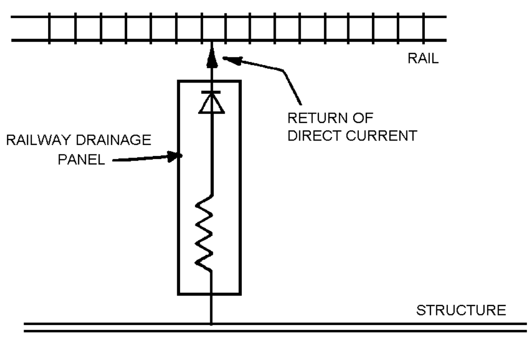


Figure 4 - Schematic diagram of railway drainage system

2. Definitions

Definitions used in this Guide are the same as those contained in Australian Standard AS 2832.1 - 1985, Guide to the Cathodic Protection of Metals except for the definitions marked with an asterisk which are additional to those used in AS2832.1 - 1985.

***Actual potential**	The measured potential of a metallic structure relative to the surrounding electrolyte being the algebraic sum of the natural potential and the potential changes arising from stray current.
Anaerobic	Lacking molecular oxygen.
Anode (in general)	An electrode through which direct current enters an electrolyte causing oxidation reactions to take place thereon.
Corrosion cell anode	The electrode at which metal dissolution (corrosion) takes place.
Galvanic anode	Electrode used to protect a structure by galvanic action.
Impressed current anode	The electrode connected to the positive terminal of an impressed current power supply.
Anode backfill	Material surrounding and in contact with a buried anode to maintain and/or improve its performance.
Anode screen	A safety barrier surrounding a submerged anode for the prevention of electrical shock or shorting.
Anode shield	A protective covering of insulation material applied to a coated structure in the immediate vicinity of an anode to reduce local cathodic current density.
***Anodic interference**	Is the positive change of the surface potential of the foreign structure, measured relative to the surrounding electrolyte. Anodic interference is caused by the operation of a system applied to a primary structure, or by stray D.C. current otherwise generated. Note: the potential change is related to changes in current density flowing from the foreign structure to the surrounding soil or water.
***Authority**	The New South Wales Department of Energy.
Back e.m.f.	Instantaneous open circuit opposing voltage between anode and cathode of an operating cathodic protection system.

Note: Back e.m.f. may have other definitions in other technologies.

Bond (electrical) A metal connection between points on the same or on different structures.

Bond (coating) Adhesion between coating materials and a substrate.

Bond (drainage) See stray current drainage.

Cathode The electrode through which direct current leaves an electrolyte causing reduction reactions to take place thereon.

***Cathodic interference** Is the negative change of the surface potential of the foreign structure relative to the surrounding electrolyte. Cathodic interference is caused by the operation of a system applied to a primary structure, or by stray D.C. current otherwise generated.

Note: the potential change is related to changes in current density flowing onto the foreign structure.

Cathodic protection The prevention or reduction of corrosion of metal by making the metal the cathode in a galvanic or electrolytic cell.

Cell An electrolytic system comprising an electrolyte, an anode and a cathode where current passes from the cathode to the anode by external electronic paths.

***Conductance** The ability of the circuit to pass current. The value is obtained by dividing the current in the circuit (in amps) by the voltage (in volts) and expressed in units of Siemens.

Note: the use of conductance (Siemens) to define a drainage system was abandoned by the NSWEC in late 1996.

Copper/copper sulphate reference electrode ($Cu/CuSO_4$) - a reference electrode consisting of copper in a saturated solution of copper sulphate.

***Correlation** The relationship between the actual potential of a structure to earth (S-E) and the potential of that structure to rail (S-RR).

(a) **Direct Correlation** - the correlation is described as “direct” when S-E potential becomes more positive as the S-RR potential becomes more positive.

(b) **Indirect Correlation** - the correlation is described as "indirect" when the S-E potential becomes more negative as the S-RR potential becomes more positive.

(c) **Zero Correlation** - the correlation is described as "zero" (or flat) when the S-E potential remains constant as the S-RR potential changes.

Corrosion The deterioration of metal caused by electrochemical reaction with its environment.

Corrosion current The current flowing in a corrosion cell, electrochemically equivalent to the anode and cathode reactions.

***Cross bond** A deliberate metallic connection between the primary and foreign structures; may include a diode and/or a resistor.

Differential aeration A condition of differing concentrations of dissolved molecular oxygen over a metal surface.

Driving voltage The difference in electromotive force between the potentials of a structure and the operating anode.

Earth (Noun) The conducting mass of the general body of the earth.

Earth (Verb) The act of connecting any conductor to earth.

Electrode An electronic conductor that allows current to flow either to or from an electrolyte with which it is in contact.

Electrode potential The measured potential of an electrode in an electrolyte relative to the potential of a reference electrode.

Electrolyte Liquid, or the liquid component in a composite material such as soil, in which electric current may flow by the movement of ions.

Foreign (secondary) Structure A buried or submerged structure that may be subject to interference arising from the cathodic protection of a primary structure.

***Fortuitous connection** An unintentional metallic connection between a primary and a foreign structure.

Galvanic Action A spontaneous electrochemical cell reaction in which a metallic anode corrodes.

Groundbed A group of buried anodes.

Half-cell	See “reference electrode”.
Holiday	Any flaw, discontinuity in a coating, or a thinning out of coating.
Impressed current	Direct current supplied by an external power source to cathodically protect a structure.
Insulating joint	A joint which breaks electrical continuity in a structure but does not affect the mechanical integrity.
Interference	A significant change in current density on a foreign structure caused by a cathodic protection system.
Interrupter	A timing device which permits a cyclic on/off interruption to the flow of cathodic protection current.
Loop resistance	Total circuit resistance.
***Modified current**	The 24 hour system current that results from multiplication of the raw 24Hr current by the inverse of the time of operation of the system (where time of operation is expressed as a decimal).
***Modified voltage**	The voltage that results from application of the Modified Current to the system Conductance chart.
Natural potential	The potential attained by a metallic structure in contact with an electrolyte after sufficient time has elapsed to allow the structure to stabilise electrochemically with its environment prior to the application of cathodic protection.
Polarization	A shift in the potential of an electrode from an equilibrium value resulting from current flow through its surface.
Primary structure	The structure subject to intentional cathodic protection.
Protective Potential	The potential to which a metallic structure must be reduced to achieve cathodic protection.
Protection current	The current made to flow into a metallic structure from its electrolytic environment and which cathodically protects the structure.
***Railway drainage bond**	An electrical circuit for the purpose of conducting sstray traction current from a structure to the railway electrical system.
Reference electrode	An electrode which has a stable potential in one or more electrolytes thus enabling it to be used in the

measurement of other electrode potentials at a given temperature.

Remote earth — A location sufficiently distant from the structure and anode where there is no voltage gradient in the electrolyte.

Silver/silver chloride reference electrode — (Ag/AgC1) an electrode consisting of silver, coated with silver chloride in an electrolyte containing chloride ions.

Standard hydrogen electrode (SHE) — An electrode consisting of platinum or other sufficiently noble metal in an electrolyte containing hydrogen ions at unit activity and in equilibrium with hydrogen gas at one standard atmosphere.

Stray current — Current flowing through paths other than the intended circuit.

Stray current drainage — An electrical means whereby stray current is removed from the structure via a conductor.

Structure — A metal surface in contact with an electrolyte.

Structure potential ** — The potential of a structure relative to that of a specified reference electrode situated in the electrolyte immediately adjacent to the structure.

Structure potential shift — A change in measured voltage of a metallic structure caused by the application of current from an external source.

Sulphate-reducing bacteria — A group of bacteria which is capable of reducing sulphate to sulphide in anaerobic near-neutral soils and natural waters.

** **NOTE**: This Guide uses the terms “structure to earth”, “structure to half-cell”, “structure to electrode” and “structure to metal electrode” to describe the potential between a structure and earth. “Earth” is the general term whereas “half-cell” and “electrode” or “metal electrode” identify the means by which the voltmeter is electrically connected to earth, for example, a steel rod may be hammered into the soil/electrolyte adjacent to the structure and the voltmeter connected between this and the structure. Different methods are selected to suit the circumstances, for example there may be already conveniently installed zinc electrodes

System All of the components that are required to change the potential of the surface of a buried or submerged structure, for the purpose of preventing or reducing corrosion. The system shall include the protected structure, transformers/rectifiers, railway drainage circuits, cross bonds, anodes, cables and auxiliary components necessary for correct system operation.

The extent of the protected structure shall be defined by:

(a) the electrical isolation of the structure, or

(b) the limits of detectable change of potential (suggest 10mV) to the primary structure resulting from operation of the system.

Telluric current The current induced by the variations in the earth's magnetic field intersecting the structure.

Test point A nominated point of a structure for electrical contact.

Weight coating The coating applied to a structure to provide negative buoyancy - usually concrete.

3. Preparation for Interference Testing

3.1. Introduction

Preparation for testing is discussed in three parts: preparation for trials consisting of temporary installations; testing of fully installed new systems and retesting of existing approved systems. Trials usually consist of a portable drainage bond or a temporary and often very "makeshift" installation where, for example, the anodes may be steel stakes and the power is provided by automotive batteries.

The NSWEC has developed a written policy covering testing of foreign structures, in particular, the involvement of foreign structure owners, refer to Appendix XII - Interference Testing of Non Members' Assets.

3.2. Trial Systems

A trial system is temporarily installed for assessment of design parameters and sometimes for interference testing and is removed immediately following completion of testing. A trial system should not be operated for more than two days without specific approval of the Authority. Approval for a new installation may be provided on the basis of test results obtained from trial systems - in that case the Authority may require information similar to that described in Section 3.3.

3.3. New Systems

New systems may be installed for the purpose of interference testing and system performance testing, but should only be operated with the prior permission of the Authority and under conditions agreed to by the Authority.

The Corrosion Protection Regulation 1993, requires that proposed systems are approved by the Authority. In particular, Clause 5(1) states that "a person must not operate a cathodic protection system to which this Regulation applies otherwise than in accordance with an approval in force with respect to the system."

3.3.1. Information Required

An applicant seeking approval for a new system or for substantial redesign of an existing system shall present in writing, to the Authority, the following information(Appendix XVI contains the form of application required):

(a) A map and/or drawing showing the precise location of the transformer/rectifier unit, impressed current anode bed, railway drainage system, sacrificial anode bed and the connections to the primary structure. Some systems may not require approval. See Clause 4.2.2.

(b) The map and/or drawing shall show the extent of the system, for example, the position of insulating joints or the end of influence of the system on the primary structure, and including any other structure that may be affected. The extent of the primary structure is the point where the S-E potential movement becomes less than 10mV.

(c) Basic details of facilities for interrupting the system current. These facilities must be provided where interference testing is required.

(d) Details of the primary structure including construction material, coating, type of system (whether impressed current, sacrificial anode or railway drainage system, etc) and design current. Note that the railway authority will, in the case of railway drainage systems, require the design conductance and the 24 hour average positive structure to rail voltage to assist in design of the bond.

3.3.2. Examination of the Proposals

The Authority will normally refer a proposed system to the appropriate Electrolysis Technical Committee to determine if interference testing is required. To facilitate this, copies of system information shall be made available to all Technical Committee Members at the meeting at which test dates will be determined.

The Electrolysis Technical Committee will schedule any testing.

3.3.3. Effects on Foreign Structures

Owners of foreign structures near to the proposed system shall be given adequate notification of the system proposed and of test dates and be provided with locations and other necessary information by the system proponent.

If after examination, the Authority detects that other foreign structures, the owners of which were not represented during field testing, are likely to be affected by interference from a proposed system, then the Authority may require the system proponent to carry out other further tests at a later date.

Note: *In the case of railway drainage systems (including TRAD systems) prior approval of the Rail Services Authority is required, for safety reasons.*

3.4. Retesting Existing Systems

The Authority shall prepare a list from time to time of existing approved systems to be retested. The appropriate Electrolysis Technical Committee shall schedule retesting with the system owner/operator and other interested parties. The system owner/operator will make available the information detailed in Section 3.3.1 including any cross bonds. Systems approved operating conditions shall be included in lieu of design conditions.

3.5. Country Systems

Systems in country areas not serviced by any of the existing Electrolysis Technical Committees shall be tested in accordance with the specific requirements of the Authority. The Authority's Electrolysis Engineer will provide specific advice on request.

4. Field Procedures and Interference Testing Methods

4.1. Impressed Current Systems

4.1.1. Pre-test Condition

For a new system, the owner/operator shall, with prior approval, have it operating at the test current (required to produce the appropriate 24 hr average) just prior to the time of testing.

For an existing approved system that is to be retested, the system owner/operator shall ensure that the system is operating at the approved current for the test. For an existing approved system that is to be adjusted, such as to require reapproval, the current shall be set at the new adjusted level for the retest.

Non-automatic systems operate at a set output voltage which produces a more-or-less steady output current. For testing of non-automatic systems the current is set to the steady output current that is required to achieve acceptable protection.

4.1.2. Automatic CP Systems

Automatic systems will be switched to non-automatic mode for the test and the test current set to equal or exceed the known or anticipated 24 hour average current.

4.1.3. Time Switch

A time switch shall be provided by the system owner/operator and be placed in series with the impressed current circuit to allow switching of the system during testing. Testing will normally be carried out in the following switching sequence (see also paragraph 4.1.8 and 6.2.12 (b)):

5 SECONDS **ON** & **15** SECONDS **OFF**

4.1.4. Primary Structure Check

The "ON/OFF" primary structure potential and the system current shall be recorded on the same chart, with at least 5 "ON" and 5 "OFF" cycles.

Note: The Authority currently keeps and maintains a suitable XY/YT recorder, 2-pen chart recorder, remote-site data telemetry system, suitable voltmeter, half-cell and shunts. All system owners/operators carrying out testing shall provide their own meters, references electrodes and test cables.

4.1.5. Recording of Interference

Measurement for interference is initially made using a voltmeter and, if levels of measured interference are significant, then the interference shall be recorded using the method utilised in this Guide. Objections to interference can only be made on the basis of recorded interference data. The Electrolysis Testing Officer will carry out the recordings.

4.1.6. Testing of Foreign Structures

Foreign structures should be tested for interference by their owners/operators. In determining the test location, consideration should be given to the intersection of the primary and foreign structures, proximity of approved primary and foreign structures, anode bed location and the position of likely coating defects as well as electrical continuity of foreign structures.

The ON/OFF foreign structure potential shall be simultaneously recorded on the same chart as the system current, with at least 5 ON and 5 OFF cycles.

Notes: (1) *Half-cells or metal reference electrodes (refer to 6.2.8) are to be placed immediately adjacent to the foreign structure to reduce voltage gradient error (IR drop). The exact position of the half-cell shall be recorded on the interference chart. Where metal reference electrodes are used, data must be standardised to copper/copper sulphate half-cell (see Appendix VII).*

(2) *Metal reference electrodes are permissible only when it is not possible to use half-cells.*

(3) *Due regard must be given to voltage gradient error (IR drop), when assessing the indicated interference.*

4.1.7. Remote Recording/Telemetry

The Electrolysis Testing Officer/NSWEC are equipped with radio/telemetry equipment to enable transmission of data from remote or difficult-to-access sites to the test vehicle.

As a backup, portable radios are also available to communicate the system "ON" and "OFF" conditions to the Testing Officer who will mark these on the foreign structure potential charts.

4.1.8. Testing For Systems With Overlapping Interference

In some cases a system, or a number of systems may be installed in fairly close proximity and may produce overlapping interference with systems, or with each other, on nearby foreign structures. In these cases the following test procedures are recommended:

(a) Single System

When interference from a single system under test overlaps with interference from other system(s), then the other system(s) should normally remain "ON" whilst the system is tested. However, the Authority may request special switching of all overlapping systems.

(b) Multiple Systems

For the case of several systems being tested which are installed in fairly close proximity such that interference overlaps, it is necessary to install precision real-time switching to enable sequential switching of these units. The Authority should be contacted where there is doubt as to the need for sequential switching or the type of switching devices required.

4.1.9. Interim Approvals

Interim approvals may be desirable in cases where polarization of the protected structure will cause a substantial reduction in system current over time. After initial interference testing the Authority in consultation with owners/operators of foreign structures and the system owner/operator, may give interim approval for operation of a system that may be producing significant interference. Such approval shall be for a defined period to allow for current to be reduced prior to final testing. The system owner/operator should carry out regular monitoring of system current and progress with polarization and shall provide reports to the Authority as requested. Interim approvals may be terminated at any time.

Interim approvals may also be issued by the Authority to provide rapid formal, although temporary, registration for important protected structures and systems .

4.1.10. General

Procedures of general applicability are as follows:

(a) If unacceptable cathodic interference is measured then the system owner/operator and foreign structure operators are to endeavour to find the corresponding anodic interference.

(b) It is good practice for the system proposer to assist foreign structure owners to identify likely areas of interference.

(c) Where unacceptable cathodic interference is measured on a foreign structure and it is suspected that a fortuitous connection exists, then the procedures outlined in Appendix III should be followed.

Note: *Measurement of interference near the ground bed of a CP system may produce a high soil gradient component in the interference measurements, producing a misleading measurement. Ground beds should be located away from structures.*

(d) All diagrams in this Guide express the S-E potential relative to copper-copper sulphate.

4.2. Sacrificial Anode Systems

4.2.1. Procedures

The procedures and test methods for sacrificial anode systems shall generally be the same as for impressed current systems.

4.2.2. Low Powered Systems

The Cathodic Protection Regulations waive the obligation for system approval by the Authority for certain low current sacrificial anode systems. Refer to the Regulation for details.

4.3. Cross Bonds

4.3.1. Anodic Interference

If anodic interference on the foreign structure is detected, the owners/operators of the primary and the affected foreign structure may both consider that a cross bond may mitigate this interference.

4.3.2. Cross Bond Testing

The investigation of the cross bond should be carried out at the time of testing while all interested parties are present. If a satisfactory cross bond design is determined then all foreign structures should be re-tested for interference arising from the original system and the cross bond.

Notes: *(1) A cross bond is installed to reduce the interference caused on the foreign structure by the primary structure's CP system. However, the cross bond may cause interference on other foreign structures and thus additional testing should be carried out.*

(2) Cross bonds should not be used if it is demonstrated that the foreign structure is not electrically continuous.

4.3.3. Approval

Cross-bonds will require approval and registration by the Electrolysis Technical Committee/Authority.

4.4. Railway Drainage Systems

4.4.1. Purpose

The purpose of a railway drainage (RD) system is to "drain" or conduct stray railway (traction) current from underground structures back to the rail via a metallic path. The cable connection shall include a resistor and diode to limit the magnitude and direction of the current.

Returning stray current through a metallic path reduces current flow through the ground and thus minimises corrosion.

4.4.2. Trial Drainage Systems

The proposer/owner of a new system shall arrange with the Rail Services Authority (RSA) for installation of a trial drainage system, and have it operating at the design current/conductance at the time of testing. Owners of existing systems should ensure that the system is operating at the approved conductance or in the case of a redesigned system, at the proposed current/conductance.

Notes:

(1) Arrangements for installation/adjustment shall be made at a previous Electrolysis Technical Committee meeting or separately with RSA.

(2) Current carrying connections to the railway line, other than for temporary potential measurements, must be authorised by the RSA. Improper connections can cause malfunction of the signalling system.

(3) Prior permission must be obtained from the RSA for access, for any purpose, within 2 metres of any rail. All person entering onto State Rail property (other than stations) must carry current track access safety accreditation.

4.4.3. Testing of Primary Structures

Primary structure correlation recordings should be made on an X-Y recorder during which the system should be switched "ON" and "OFF" at various PS-RR voltages. Recordings are to be taken over a sufficient range of PS-RR voltages to indicate system characteristics. The "ON/OFF" switching is conveniently controlled from the Test Vehicle using a DC relay in series with the drainage circuit.

4.4.4. Reference Electrodes

Reference electrode shall be copper/copper sulphate ($Cu/CuS0_4$) half-cells unless this is impractical. Data must be standardised to copper/copper sulphate in those cases where alternative reference electrodes are used (refer to 6.2.8 and Appendix VII for details of electrode calibration). Silver/silver chloride cells (Ag/Ag C1) should be used in salt or brackish water.

4.4.5. Conductance

The system conductance is recorded on the X-Y recorder and calculated from the diagram (refer to Sections 5.3.1.b and 5.3.4.3).

4.4.6. Testing of Foreign Structures

Two alternative testing procedures have been developed by the Sydney Electrolysis Technical Committee. The techniques selected depend on the "phasing" between the foreign structure to rail (FS-RR) and primary structure to rail (PS-RR) potentials, and on the distance between the foreign structure (FS) and primary structure (PS).

These alternatives are:

(a) The correlation chart procedure. This procedure is limited to foreign structures situated such that leads can be run between the rail and the structure under test or where radio telemetry can be used, and where FS-RR or PS-RR voltages are in phase.

(b) The 48 hour FS-RR potential chart. This procedure is used when the above correlation chart procedure can not be used (e.g. FS is remote to RR and telemetry will not work, or potentials are out of phase).

A foreign structure owner may elect to use any combination of these techniques.

Further details of the test procedures are contained in Section 5.3. and Appendix X.

4.4.7. The Correlation Chart Procedure (Assessment of Interference)

The correlation chart consists of a graph of foreign structure to earth potential plotted against foreign structure to railway potential. The change in the relationship that occurs on switching the drainage system "ON" and "OFF" is a measure of interference. If there is no change in the relationship, then there is no interference.

4.4.8. Foreign Structure Owner Responsibilities

Foreign structure owners/operators shall select a suitable location where interference may be anticipated and decide the best point of attachment of the leads. Potential leads from these sites are run back to the Test Vehicle by the structure owner. The correlation chart is recorded, whilst the drainage system is switched "ON" and "OFF" during the period for which the primary structure potential to rail is positive and the system is conducting. Recording should continue for as long as possible so as to obtain a definitive tracing for both system "ON" and system "OFF" conditions.

Note: The recordings will quite often include changes in the underlying correlation which will tend to mask the correlation change caused by switching of the bond. These underlying correlation changes are caused by unpredictable changes in stray current flow patterns. The testing officer must observe the recording process very closely in order to distinguish the switching correlation, otherwise the resulting interference data will be incorrect.

4.4.9. Location of Half-Cells

Half-Cells are to be placed immediately adjacent to the foreign structure so as to reduce voltage gradient error (IR Drop - refer to note in 6.1.2).

4.4.10. Multiple Interference

Where interference from more than one RD system is present at the test site (overlapping interference), then only the system under test shall be switched whilst the other systems remain "ON".

4.4.11. Temporary Boosting Of PS-RR Voltage

Where the primary structure-to-rail voltage is negative at the time of interference testing and the system is therefore not passing current, a temporary DC boost may be used to cause the bond to conduct. The boost shall consist of a power supply, e.g. an automotive battery, inserted in the system circuit with positive terminal connected to the rail. The boost voltage shall be recorded on the test data sheets. As far as is practical the boost voltage should provide the approximate average operating current of the system. Temporary boosting should only be used when absolutely necessary.

Note: The use of temporary boosting may introduce abnormal conditions of testing due to artificially raising the PS-RR voltage at one location. Therefore testing time should be arranged as far as practical at times where boosting is not required. When temporary boosting is used, other drainage systems applied to the primary structure in the near vicinity, that are likely to cause overlapping interference on the foreign structure, should be boosted to the same voltage to allow an accurate measure of the combined interference effects on the foreign structure.

4.4.12. Data Recording

Where appropriate the Testing Officer is to record the data as listed Section 5.

4.4.13. Switching For Correlation Charts

The foreign structure correlation charts should contain at least three "OFF" readings and three "ON" readings and, as far as is practical, the plot should extend between zero structure-to-rail potential and the maximum available positive structure-to-rail potential.

4.4.14. Fortuitous Connection

Where unacceptable cathodic interference is measured on a foreign structure the tests for a fortuitous connection as outlined in Appendix III should be followed.

4.4.15. Remote Short Term Testing

Where the distance between the site of the interference test and the drainage system is excessive for running of rail potential and any other leads, the foreign structure potentials may be recorded on a voltage-time recorder and switching points recorded by hand onto the chart. Switching of the system should be carried out at the system site and the time of switching communicated to the interference test site by two-way radios. The current flowing in the system at the time of switching should be recorded on the chart, using radio communications. A minimum of 5 "ON" and 5 "OFF" data points should be recorded.

Note: *It can be difficult to interpret these recordings where substantial stray traction effects are present.*

Alternatively, radio telemetry can be used to transmit data that would normally travel by hard wire from close-by locations.

4.5. TRADS and Combinations of Systems

4.5.1. Purpose

The purpose of a Transformer Rectifier Assisted Drainage (TRAD) system is to drain or conduct stray railway (traction) current from underground structures back to the rail via a metallic path. The TRAD uses a mains-powered rectifier to assist in the drainage process. TRADs are usually fully automatic systems whose output is controlled in response to the conditions on the protected structure. They have proved to be highly effective in protecting underground structures. In extremely adverse conditions, where large currents are being drained, it is sometimes an advantage to connect both a TRAD and a drainage bond in parallel.

4.5.2. Field Procedures and Field Testing Methods

The field procedures and test methods are generally identical to those applying to railway drainage bonds - refer to Section 4.4. For TRADS the rectifyer voltage is adjusted so as to to produce the 24 hr average current required to provide acceptable protection.

5. Presentation and Interpretation of Data

5.1. Impressed Current and Sacrificial Systems

5.1.1. Information Required

The information required for consideration by the Authority is as follows:

(a) Primary Structure

Simultaneous recordings of primary structure potential-time and system current-time with the system switching "ON" and "OFF". These charts are prepared by the Testing Officer with the assistance of the structure operator/owner. Figure 5 is an illustration showing the simultaneous plotting of system current and actual potential to earth. Information that should be included on the charts is as follows:

(i) System number, where allocated

(ii) Owner/operator of the system

(iii) System test current

(iv) Address and UBD street directory reference of the CP system

(v) Date of test

(vi) Exact position of reference relative to the primary structure

(vii) Where metal reference electrodes are used, then the foreign structure actual potentials, relative to $Cu/CuSO_4$, with system switched both "ON" and "OFF", are noted on the chart.

(viii) Organisation(s) present at the test

(b) Foreign Structure

Simultaneous recordings of potential-time and primary system current-time with the system switching "ON" and "OFF". These charts are prepared by the Testing Officer with the assistance of the structure owner/operator. Figures 6(a) and 6(b) are illustrations showing the simultaneous plotting of primary system current with foreign structure potential to earth.

Information that should be included on the charts is as follows:

(i) System number where allocated and description of foreign structure

(ii) Owner/operator of foreign structure

(iii) System test current

(iv) Address of the interference test location

(v) Date of test

(vi) Exact position of the reference relative to the foreign structure.

(vii) Interference value (Note: this value to be confirmed at the Electrolysis Technical Committee Meeting).

(x) Where metal reference electrodes are used, then the foreign structure actual potentials, relative to $Cu/CuSO_4$ with system switched both "ON" and "OFF", are noted on the chart.

(xi) Organisation(s) at test.

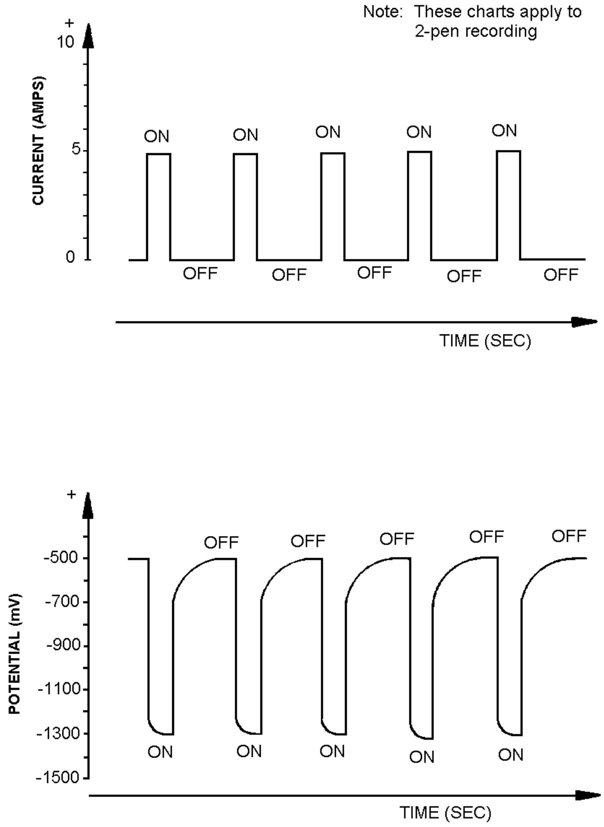


Figure 5 - Primary Structure Current and Potential Charts

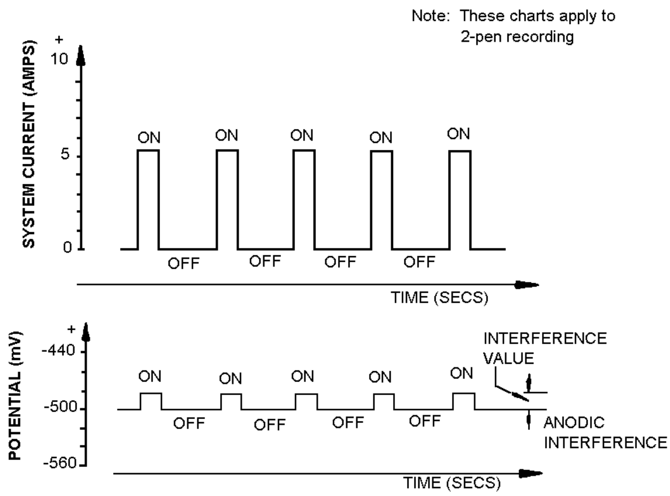


Figure 6a - Foreign Structure - Anodic Interference Measuring Charts

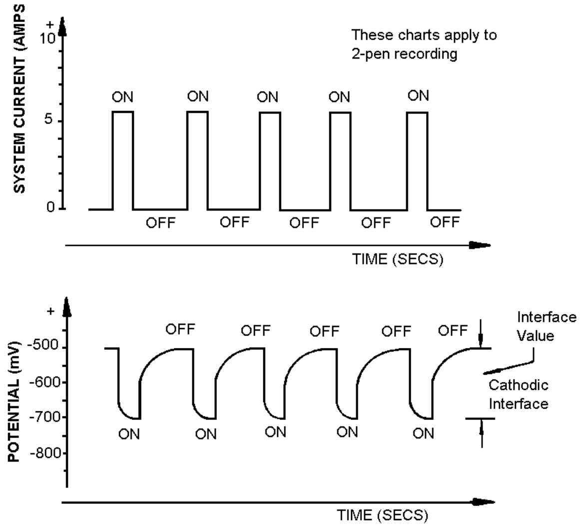


Figure 6b - Foreign Structure - Cathodic Interference Measuring Charts

(c) Traction-Affected Foreign Structures

The 48 hour potential-time chart (24hr "ON", 24hr "OFF"), as illustrated in Figure 7, is used where a foreign structure is simultaneously affected by the system current and strong stray traction current such that the stray traction effects mask the effect produced by switching the system. Validity of this test depends on the stray current influence being equivalent on the two days of test. This should be checked by additional and independent 48 hour recording of railway-to-earth potential. Information which should be on the charts is the same as at paragraph 5.1.1 (b).

Two-pen plots described above (5.1.1.b) are specifically designed to assist with valid interpretation of data and the 48 hour plot is usually only necessary in cases of extreme stray current activity.

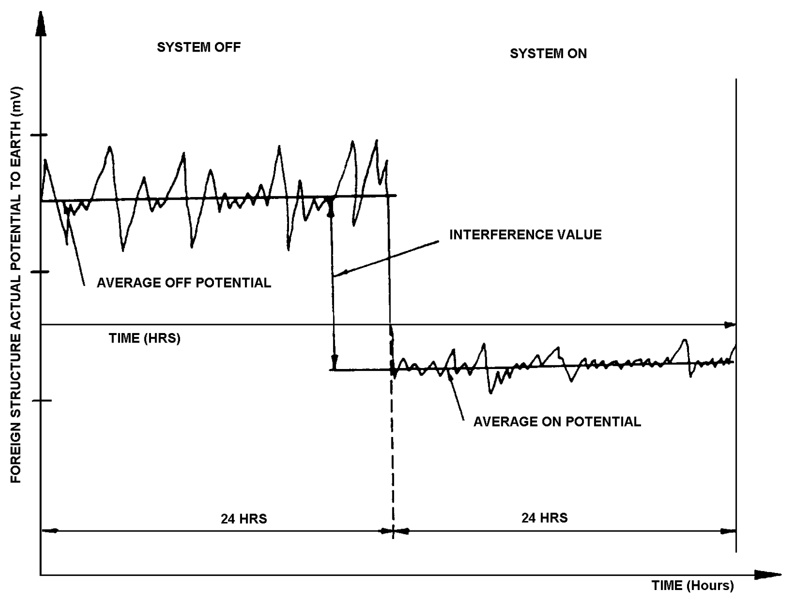


Figure 7 - 48 hour Potential Time Chart Interference

5.1.2. Interpretation Of Data

5.1.2.1. Illustrations

The figures in this Guide are illustrations only and different values will be encountered in practice. The system switching points can sometimes be difficult to determine from a potential time chart alone due to rapid fluctuations caused by stray traction current. Simultaneous recording with a 2-pen recorder of the system current, and structure potential will help to directly illustrate the system switching points and thereby assists in pinpointing the structure potential changes corresponding to system switching.

5.1.2.2. Interference Value

The interference value is the difference in foreign structure potential, expressed in millivolts, between system "ON" and "OFF" conditions. The value is derived as illustrated in Figures 6(a), 6(b) and 7.

5.1.2.3. Interference Criteria

The decision by foreign structure owners to object or not to object to the measured interference should be guided by reference to the interference and taking cognisance of Appendices I and II.

5.1.2.4. Polarization Potential Drift

When a metal reference electrode is used polarization of this electrode can produce a "drift" in the actual potential chart, as illustrated in Figure 8. Use of low impedance measuring devices will increase the rate of drift by allowing a higher polarizing current to pass. Potential drift can also be caused by polarization of the structure being measured: in this latter case, polarization is caused by CP system current flowing through the foreign structure and can occur even when a half-cell is used as the reference. Careful interpretation of the chart may distinguish polarization drift from interference. A half cell should be used wherever possible.

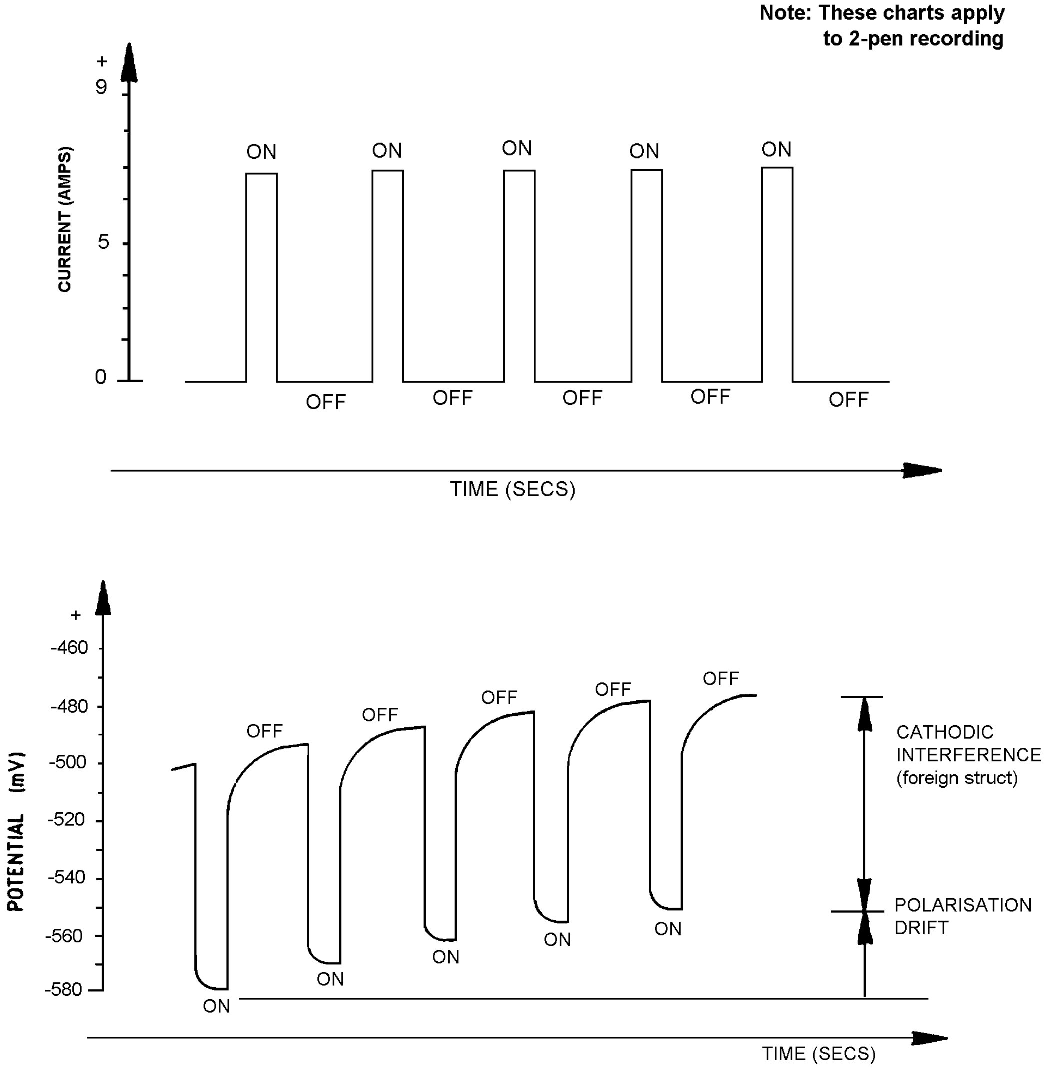


Figure 8 - Foreign Structure Polarization - Potential Drift

5.2. Cross-Bonds

5.2.1. Information Required

The information required for cross-bond interference testing is similar to that required for impressed and sacrificial systems, except that both the primary system and the cross-bond shall be switched and the subsequent interference data recorded on the same chart. Figure 9 is an illustration of the information required for interference testing for a cross-bond and its related primary system. Information that should be included on the chart illustrated in Figure 9, is as follows:

(i) CP system number, where allocated

(ii) Owners/operators of systems

(iii) Primary system current

(iv) Cross-bond current

(v) Address and UBD street directory reference of test location

(vi) Date of test

(vii) Exact position of the reference

(viii) Organisations present at test

(ix) Interference values (Note: this value is to be confirmed at the Technical Committee Meeting).

(x) Point of connection of cross-bond to both primary and foreign structure and whether a diode is included or not.

(xiii) Location of cross bond.

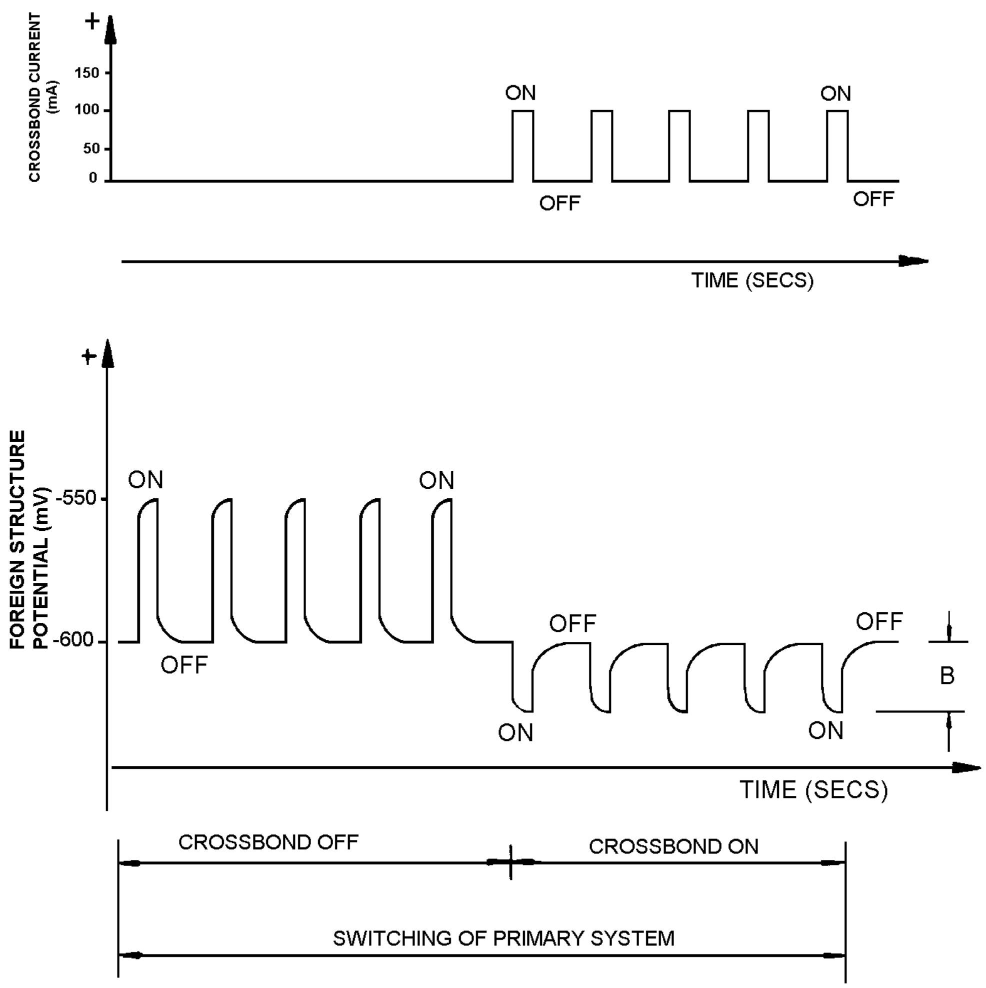


Figure 9 - Cross Bond Interference Testing

5.2.2. Interpretation Of Data

The potential change caused by the primary system, with the cross bond operating, is the value "B" in Figure 9. The first section of the plot illustrates the interference caused by the primary system only, the second section of the plot shows the combined potential change of the primary system and the cross bond. In this illustration, the anodic interference of the primary structure system is offset by the cross bond to produce a cumulative cathodic potential change on the foreign structure. The potential change measured at "B" is evaluated in terms of the criteria in Appendix II, and both the primary system and the cross bond are accepted or rejected on the basis of interference, the value "B".

5.3. Railway Drainage Systems

5.3.1. Information Required - (Primary Structure)

The following information shall be supplied for a primary structure.

(a) Voltage/Time Chart

24 hour structure-to-rail voltage/time chart as illustrated in Figure 10. This chart is prepared by the system owner/operator on a normal day and should be recorded with the system disconnected and this condition noted on the chart. The chart is used by RSA staff to assist in design of the bond and shall include the following information:

(i) System number (if allocated)

(ii) Owner/operator

(iii) Address and UBD street directory reference of the system

(iv) Date of recording

(v) Scale per chart division and full scale range

(vi) Time of start and finish of recording

(vii) Zero clearly marked with positive and negative voltages clearly distinguished.

(b) System Current/Voltage Chart (Conductance Chart)

System current versus structure-to-rail voltage is as illustrated in Fig 11. This chart is used to determine the Modified Voltage and conductance. Use of this chart is described in Appendices IV and X. The chart should include the following information:

(i) System number, where allocated

(ii) Owner/operator of the system

(iii) Address and UBD street directory reference of the RD system

(iv) Date of test

(v) Organisation(s) present at the test

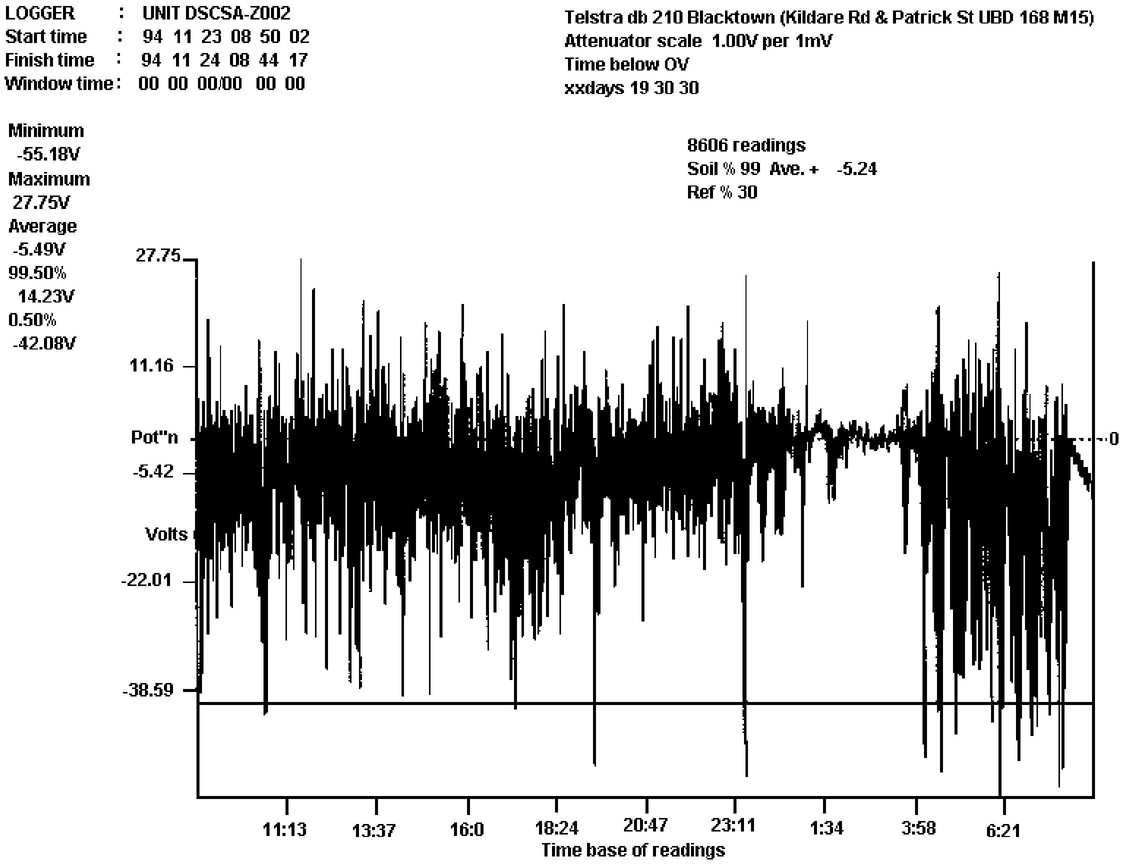
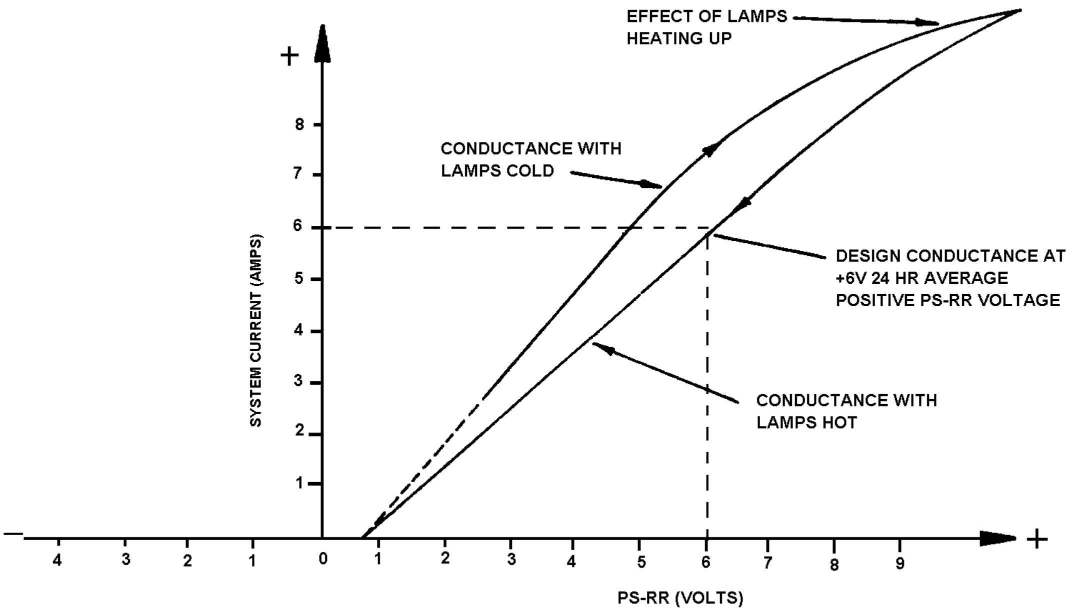


Figure 10 - 24Hr Structure to Rail Voltage Time Chart



Note: If lamps are not included in the system circuit then one conductance line may occur.

Figure 11 - Railway Drainage System Conductance Chart

(c) System Correlation Chart

System correlation chart to demonstrate the change in the structure to earth potentials for a range of PS-RR voltages, that is, the change in the correlation with system both "OFF" and "ON" (see Figure 12). This chart demonstrates the effectiveness of the bond in protecting the primary structure. The chart should include the following information:

(i) System number where allocated

(ii) Owner/operator of system

(iii) Address and UBD street directory reference of the RD system

(iv) Date of test

(v) Exact position of the reference relative to the primary structure

(vi) Organisation(s) present at the test

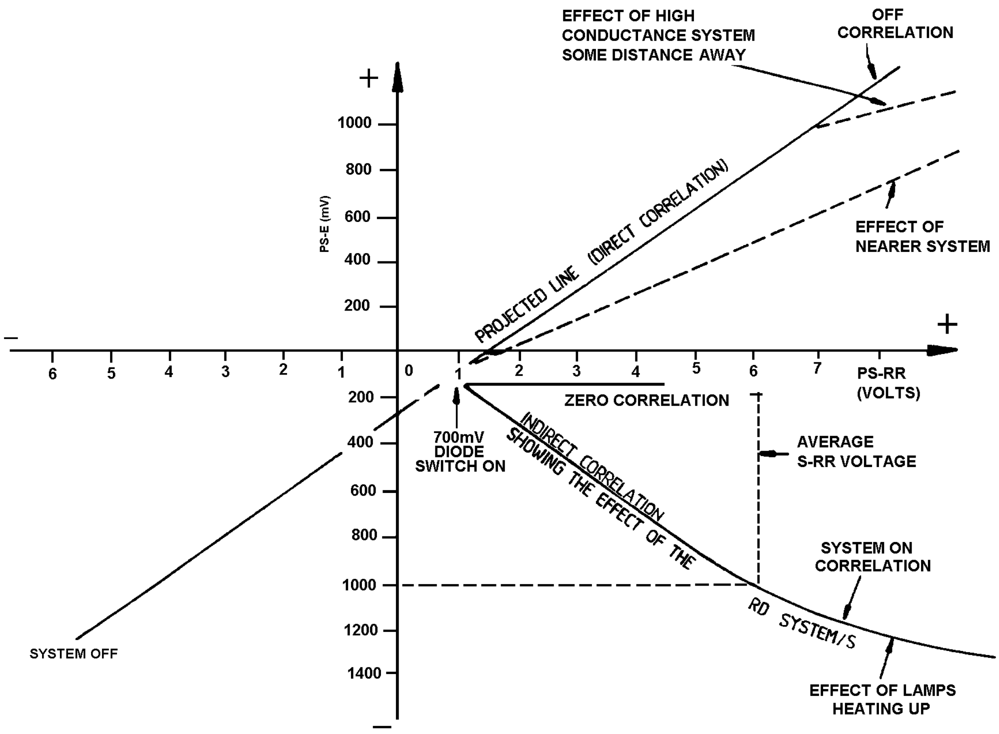


Figure 12 - Railway Drainage System - Correlation Chart - Primary Structure

(d) 24 Hour Current Chart(Data Logger Chart)

System current logged over a 24 hour period, on a normal business day. This data is processed using appropriate and recognised software to produce a 24 hour average and the Time of Operation of the system where the latter is expressed as a decimal fraction. Time of Operation is defined as when the system current is greater than 0.1 amps. Data used for computing the average will include zero current readings. The chart should include the following information:

(i) System number where allocated

(ii) Owner/operator of system

(iii) Address and UBD street directory reference of the RD system

(iv) Date of test

(v) Exact position of the reference relative to the primary structure

(vi) Organisation(s) present at the test

(e) 48 Hour Potential Chart

A 48 hour structure actual potential to earth Y-T, chart 24 hours system "ON" 24 hours system "OFF", when considered necessary by the Authority (see Figure 13). The chart should include the following information.

(i) System number where allocated

(ii) Owner/operator of the system

(iii) Address and UBD street directory reference of the RD system

(iv) Date of test

(v) Exact position of reference relative to structure

(vi) Organisation(s) present at the test

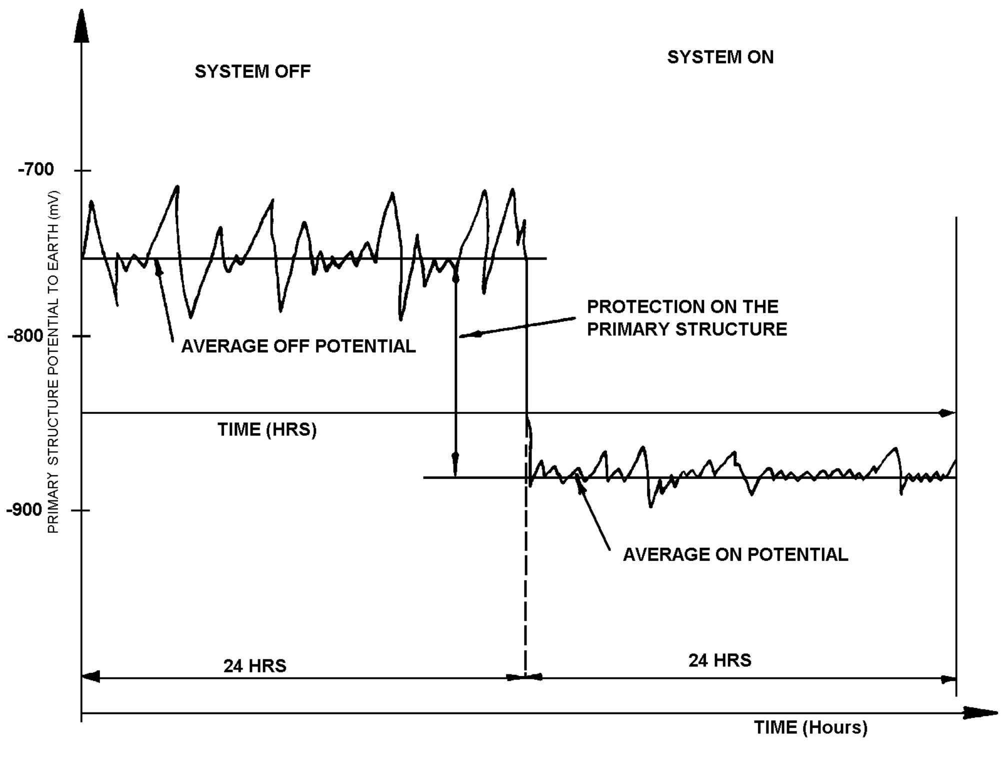


Figure 13 - 48 Hour Potential - Time Chart - Protection

5.3.2. Information Required - (Foreign Structure)

The following information shall be supplied for foreign structures:

(a) System Correlation Chart

Correlation chart similar to Figure 12 but for the foreign structure and information as described above in paragraph 5.3.1(c) with the system switched both "OFF" and "ON".

(b) 48 Hour Potential Chart

48 hour structure actual potential to earth chart similar to Figure 13 but for the foreign structure, to be produced when considered necessary by joint decision of the owners of the primary and affected foreign structures. Include the information as described in 5.3.1(e).

Note: This chart is normally only necessary when the correlation chart cannot be produced or is inadequate.

5.3.3. Interpretation Of Data (Drainage Systems) - General

The following general comments apply to the determination of interference.

(a) Interference may be assessed by use of either correlation charts or the 48 hour potential charts.

(b) Refer to Appendix IV for further details on construction of charts and to Appendix X for further information on determination of interference.

5.3.4. Interpretation Of Data (Drainage Systems) - Primary Structures

5.3.4.1. Voltage/Time Chart

The Railways Staff will interpret this chart (Figure 10).

5.3.4.2. 24 Hour Bond Current Chart (Data Logger Chart)

The 24 hour average current is determined by downloading data to suitable computer/software and determining the 24 Hour Average and the Time of Operation. (Section 5.3.1(d) refers). Specialist advice may be required to set up the necessary programs which will most likely be adaptions of commonly used spread sheet software. The 24 Hour Average is multiplied by the inverse of the Time of Operation to produce the Modified Average Current. Appendix X describes the method in more detail.

5.3.4.3. Conductance Chart (System Current/Voltage Chart)

The conductance chart is used to determine a primary structure to rail voltage that is subsequently transferred to the foreign structure correlation chart to determine interference. The system Modified Average Current, determined by the procedure described in Appendix X (Section 5.3.4.2 also refers) is applied to the conductance chart to produce the Modified Voltage (MoV).

In addition, these charts are used to determine the conductance of a railway drainage system and are used by the railway organisations to design the system.. The value of conductance has little relevance to determining interference, although it was of primary importance in past years. Production of these charts is described in Appendix IV.

To determine conductance:

(a) The majority of systems include incandescent lamps in the circuit and as the lamps heat up, the conductance lowers due to the increased resistance of the hot lamps. The initial current rise on the conductance chart occurs with the circuit lamps cold and this part of the chart is not used for determining conductance but rather the "hot lamp" line is used. In some cases the hot and cold lines will be virtually identical.

(b) The conductance of the railway drainage system is determined from the formula:

$$G = \frac{I}{V}$$

Where: G is the conductance in siemens at V volts.
I is the system current in amperes at V volts.
V is the 24 hour average positive PS-RR voltage in volts.

System current is determined by projecting a horizontal line from the intersection of the "hot" conductance line with the vertical projection from the agreed average positive PS-RR voltage. In the example in Figure 11 a current of 6 amperes is obtained at an average voltage of 6 volts giving a conductance of 1 siemen.

5.3.4.4. Conductance Chart-Temporarily Boosted RD Systems

Figure 14 is an illustration of the method of calculating conductance for a temporarily boosted system where, for example, the 24hr average PS-RR voltage is + 6 volts. In this illustration a 4 volt temporary boost is used to cause the system to conduct at a time when the PS-RR voltage is negative. The conductance of the temporarily boosted RD systems is determined using the formula:

$$G = \frac{I}{V}$$

Where: G is the conductance in siemens. e.g. Conductance = $\frac{4\ \text{Amps}}{6\ \text{Volts}}$

I is the system current in Amperes = 0.66 Siemens at 6 volts.

V is the 24 hour average positive PS-RR voltage measured from the boosted zero.

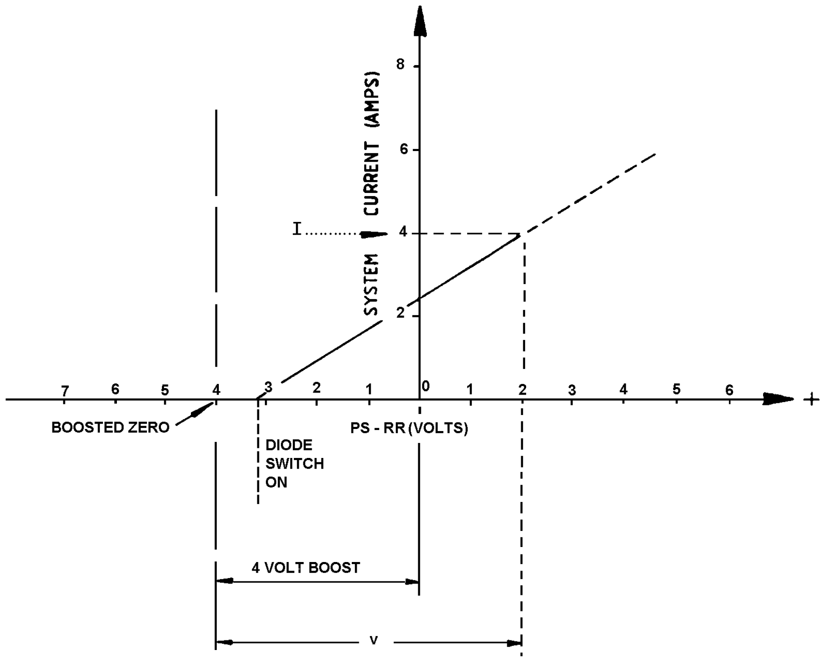


Figure 14 - Temporarily Boosted System Conductance Chart

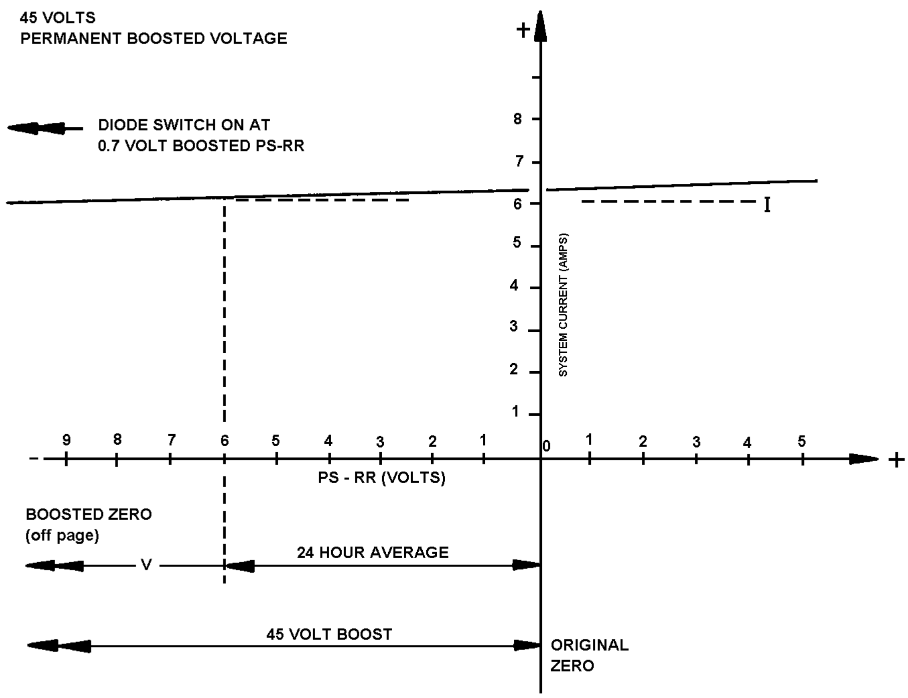


Figure 15 - Permanently Boosted System - Conductance Chart

5.3.4.5. Conductance Chart-Permanently Boosted RD System

Permanently boosted systems are used in cases where stray traction current is adversely affecting structures in circumstances where PS-RR is mostly negative and a conventional system will not conduct. Figure 15 is an illustration of the method of calculating conductance for a permanently boosted railway drainage system where, for example, the 24hr average positive PS-RR voltage is -6 volts. In this example a boost of 45 volts is used to cause the system to conduct in circumstances where the PS-RR voltage is mostly negative. The conductance chart is recorded on the normal PS-RR voltage scale so as to give a reasonable amount of pen movement over the average PS-RR voltage. The conductance of the permanently boosted RD system is determined by using:

$$G = \frac{I}{V}$$

Where: G is the conductance in siemens

I is the system current in amps with boost

V is the sum of the average PS-RR voltage and the boost voltage, in volts, i.e. V is the average system voltage measured from the (off-page) boosted zero.

e.g. Conductance = 6.0 amps = 0.15 siemens at 39 volts

45 + (-6) (-6V, 24hr average PS-RR volts plus 45 volts permanent boosted).

5.3.4.6. Correlation Charts - Primary Structure

The correlation chart expresses the relationship between the actual potential of the primary structure to earth and the potential of the same structure to rail. The purpose of this particular correlation chart is to determine the protection provided by the temporary or permanent system. The procedures for interpreting the chart and determining the level of protection are illustrated in Figure 12. This is an illustration of a correlation for a primary structure showing both the system "OFF" and the system "ON" correlation lines

(a) Neighbouring Systems

If the system is being affected by neighbouring systems then the system "OFF" line will not be straight but will curve over as illustrated in Figure 12. For a high current system that is distant from the point of measurement, the effect on the correlation line may not be seen until the PS-RR voltage is strongly positive.

(b) Interpretation

When the system is switched "ON" it will start to conduct when the PS-RR volts exceeds the diode switch-on point (+700mV) and the correlation will ideally enter the lower right hand quadrant as PS-RR voltage increases in the positive direction. The gradient of the curve depends on the conductance of the system. As conductance increases so does the gradient.

(c) Zero Correlation

In practice, some systems may only achieve correlation lines that are approximately horizontal (zero correlation) at best, and the line may even lie in the upper-right hand quadrant. In these cases only limited reduction in stray current effect has been achieved.

(d) Effect of Lamps

Some systems contain lamps for the purpose of limiting current at high positive PS-RR voltages. As the lamps heat up, the correlation curve will flatten out as illustrated (see Figures 11 and 12).

(e) Average Protection Levels

The system-ON correlation slope is indicative of the protection provided. The average level of protection provided is determined by projecting a vertical line from the agreed 24 hour average positive PS-RR voltage onto the plotted correlation line as illustrated in Figure 12. From the intersection, a horizontal line is projected to determine the corresponding average structure-to-earth potential of the primary structure. The adequacy of projection provided by the system can be evaluated by reference to the acceptable levels of protection listed in APPENDIX II. In Figure 12 the average protection level is 1000 mV.

(f) Correlation Chart - Temporary Boost

Figure 16 is an illustration of a temporarily boosted RD system correlation chart for a structure using a 4 volt boost. The average structure potential to earth of the primary structure is determined at the 24hr average of 6 volts. In this illustration the average PS-E potential is about 1070 mV negative measured from the boosted zero.

(g) Correlation Chart - Permanent Boost

Figure 17 is an illustration of a primary structure correlation chart for a 45 volt permanent boost. The correlation chart is recorded on a suitable PS-RR voltage scale so as to give a reasonable amount of pen movement over the average PS-RR voltage. The average primary structure to earth potential is determined at V, PS-RR Voltage of 39 Volts (45 Volt permanent boost and -6 Volts 24 hour average PS-RR Voltage) measured from the boosted zero.

Note: In this illustration the average PS-E potential is 1000 mV negative.

5.3.4.7. 48 Hour Structure-To-Earth Potential-Time Charts

The 48 hour primary structure potential chart can assist in the correct design of the system. Figure 13 is an example of a 48 hour chart for primary structures. In the case of a primary structure the difference between the "OFF" and "ON" average potentials is the protection being provided to the primary structure.

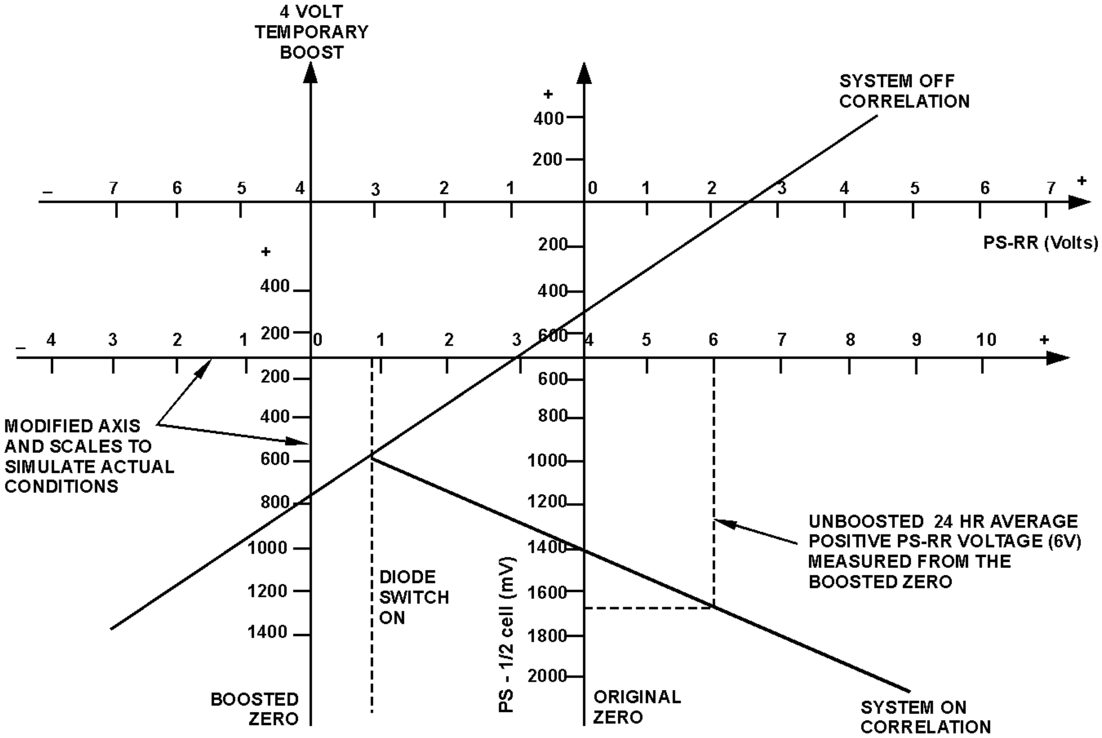


Figure 16 - Temporarily boosted railway drainage system correlation chart - Primary Structure

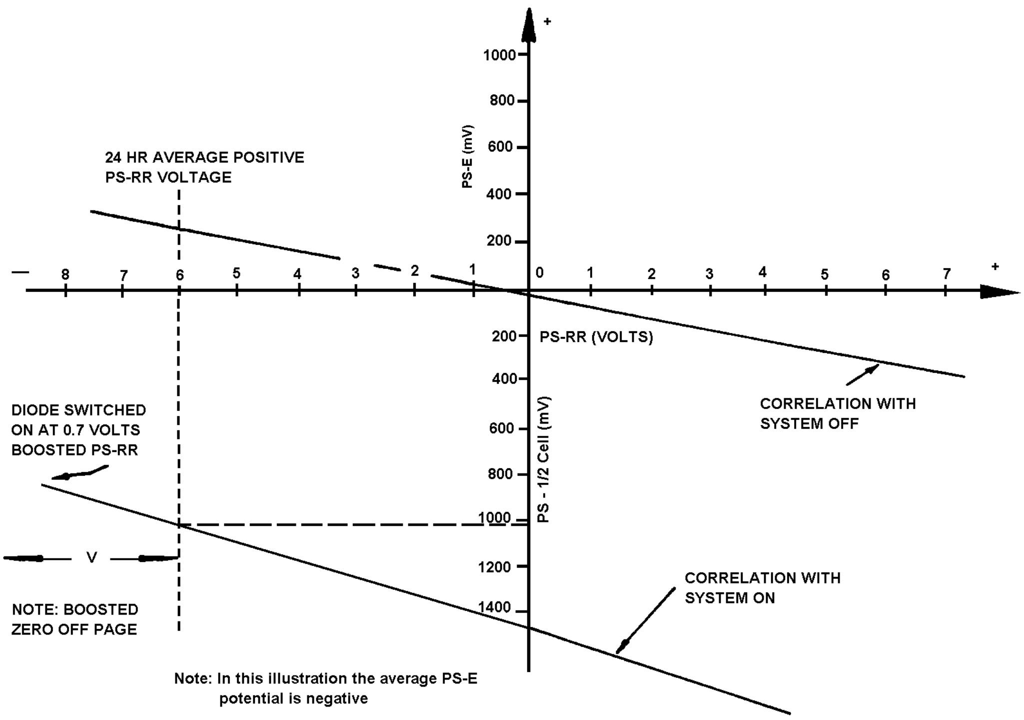


Figure 17 - Permanently boosted railway drainage system correlation chart - Primary Structure

5.3.5. Interpretation Of Data (Drainage Systems)-Foreign Structures

5.3.5.1. Correlation Charts (Determination of Interference) - Introduction

The correlation charts for foreign structures are used to determine the level of interference being caused to the foreign structure by the system applied to the primary structure. Interference is measured from the change in the correlation line when the primary structure railway drainage system is switched "ON" and "OFF". Interference is the change in actual potential to earth of the foreign structure measured at the agreed foreign structure to rail voltage that is in turn derived from the primary structure conductance chart. To determine the interference, a vertical line is drawn from the agreed FS-RR voltage (MoV) to intersect both the system ON correlation line and the system-OFF correlation line. Refer Appendix X for method of determining MoV. Two horizontal lines are drawn through the intersection points to the vertical axis to give the two potential readings, the difference being the measured interference. Figures 18 and 19 are illustrations of correlation charts based on typical data for a steel structure using a copper/copper sulphate half cell to measure potentials to earth. Figure 18 is an illustration of anodic interference (structure becomes more positive) and Figure 19 is an illustration of cathodic interference (structure becomes more negative).

The decision as to whether the measured interference is acceptable or not shall be made after reference to the table of criteria in Appendix II.

Note: *Where unacceptable cathodic interference is measured on a foreign structure the tests for a fortuitous connection, as outlined in Appendix III, should be followed*

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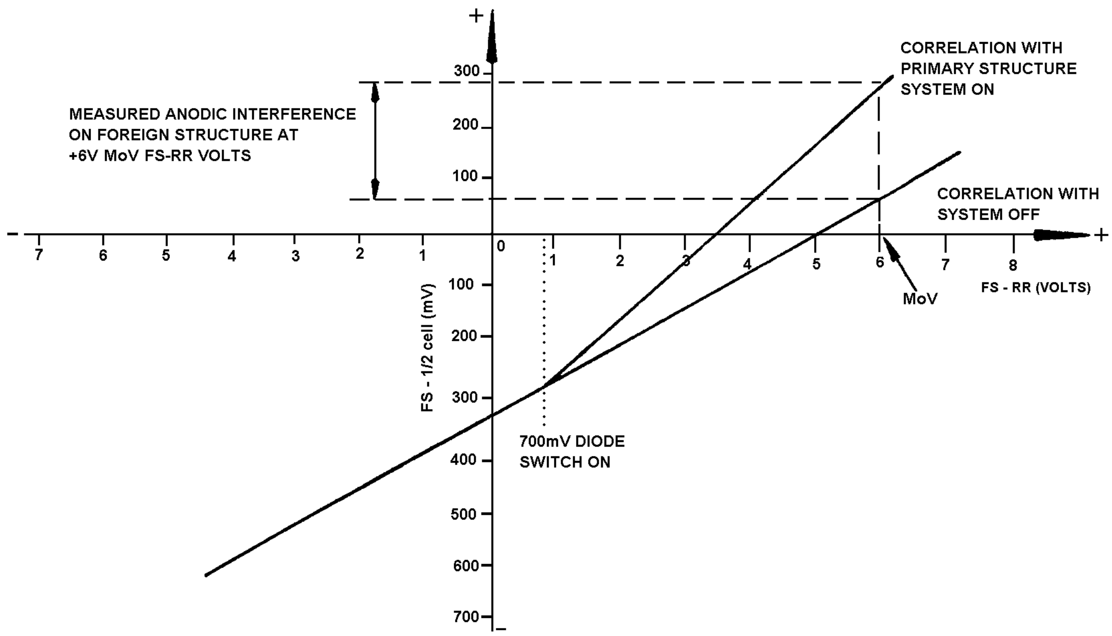


Figure 18 - Anodic Interference - Correlation for Foreign Structure

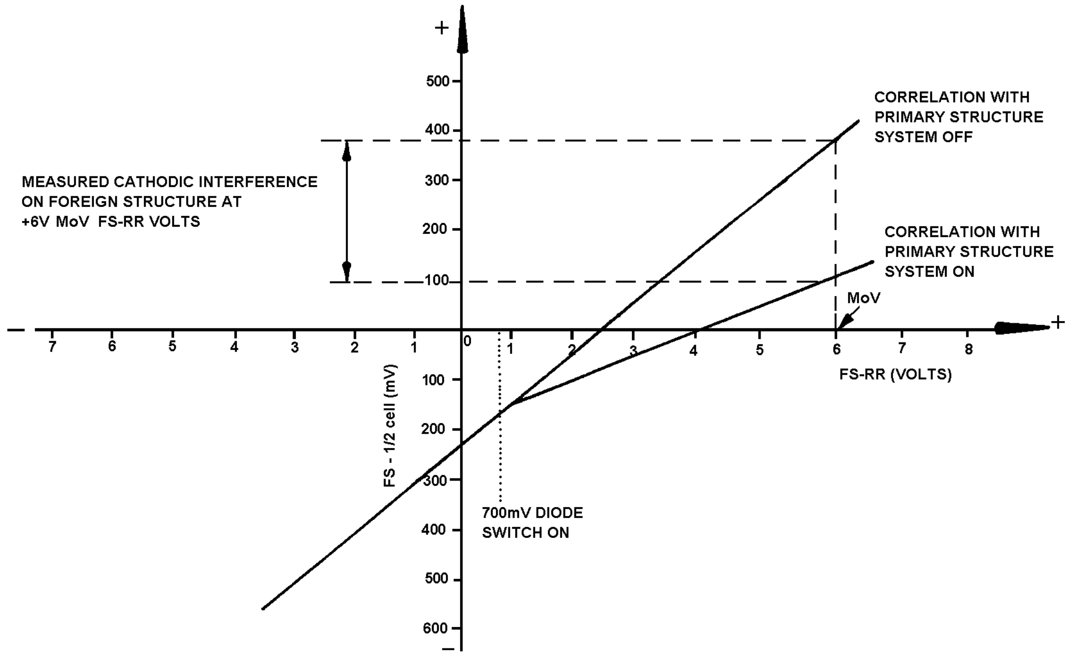


Figure 19 - Cathodic Interference - Correlation for Foreign Structure

5.3.5.2. Correlation with Collapsing Rail Volts

The switching on of an RD system can cause the FS-RR voltage to drop significantly (referred to as "collapsing rail volts"), as illustrated in Figure 20. Where this occurs the X-Y plotter recording pen will be seen to take a diagonal path across the chart as the RD system is switched "ON" and "OFF". In these cases it is not appropriate to measure interference by projecting a vertical line from the modified average rail volts to intersect the "ON" and "OFF" lines. Instead, the two intersection points A and B are determined by projecting a vertical line from the average FS-RR volts to intersect the "OFF" correlation line at A and then projecting another line parallel to the path described by the recording pen, until it intersects the correlation line at B. The two intersection points are then projected horizontally on to the vertical axis, as previously, to obtain the interference.

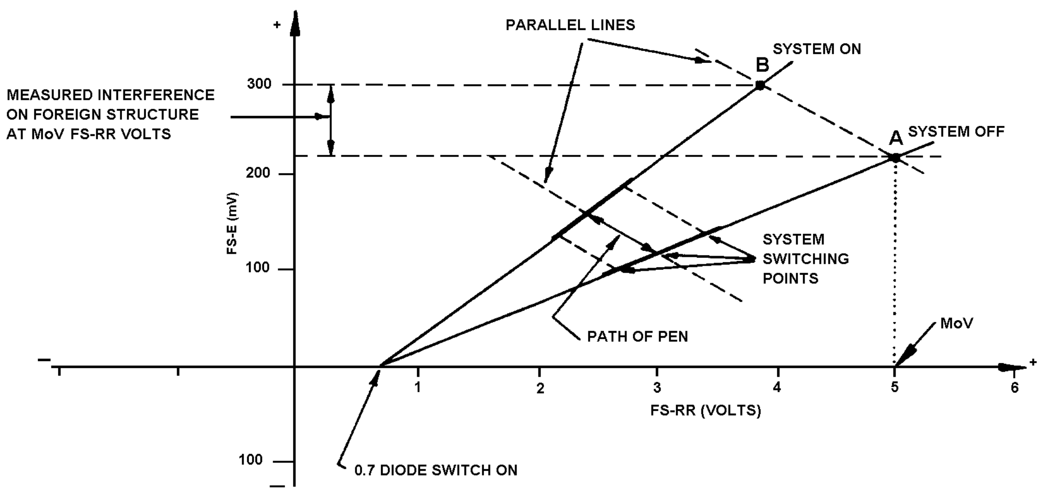


Figure 20 - Correlation with collapsing rail volts and measurement of (anodic) interference

5.3.5.3. Boosted RD System Foreign Structure Correlation Charts

Figures 21 and 22 are illustrations of foreign structure correlation charts for a temporarily boosted RD system on a steel structure and Figures 23 and 24 for a permanently boosted system on a steel structure. Interference is measured at V, the modified 24 hour average positive FS-RR voltage measured from the boosted zero.

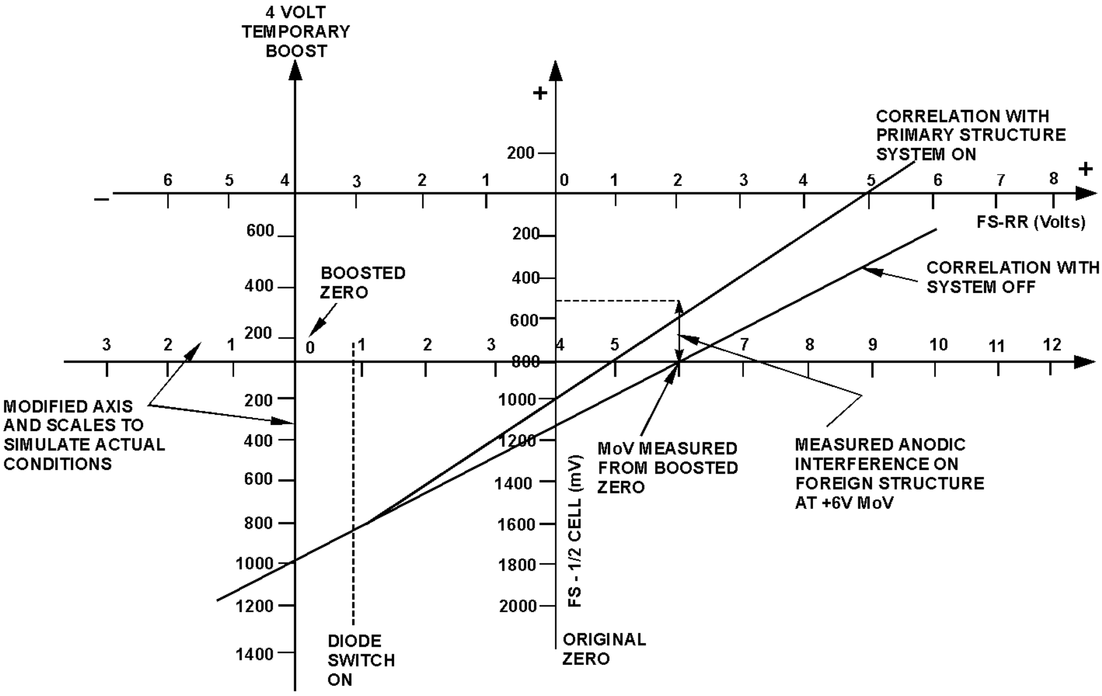


Figure 21 - Anodic Interference - temporary boost

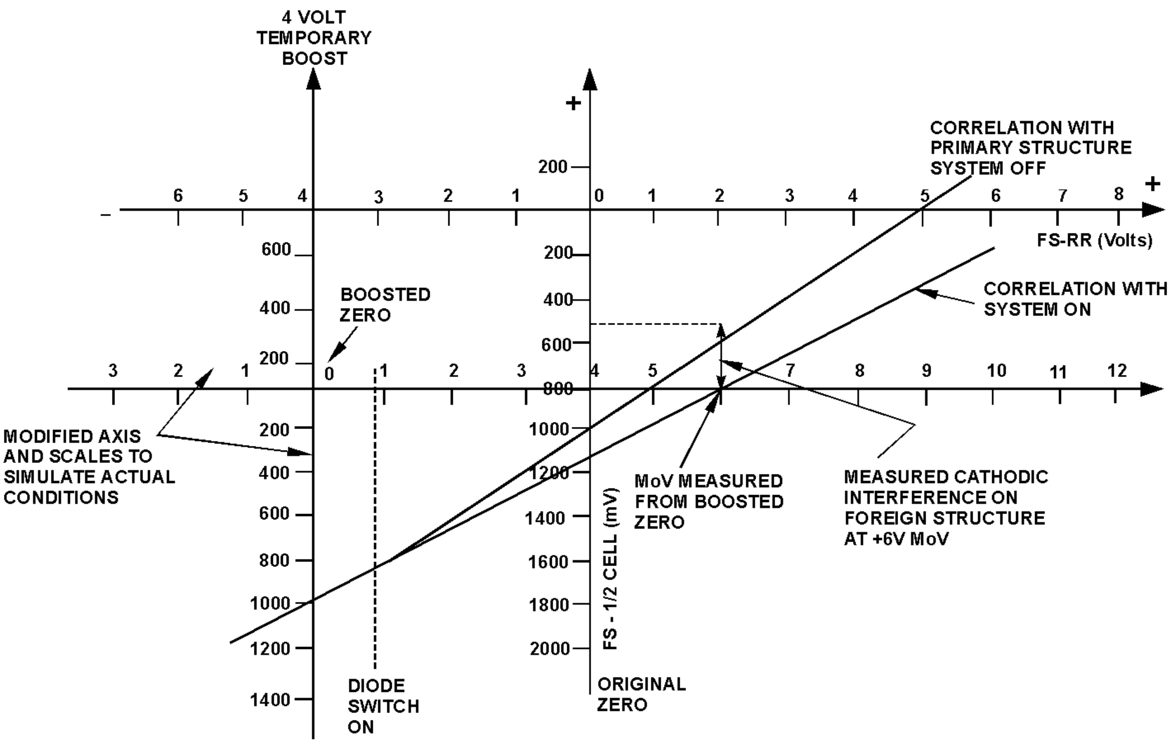


Figure 22 - Cathodic interference - temporary boost

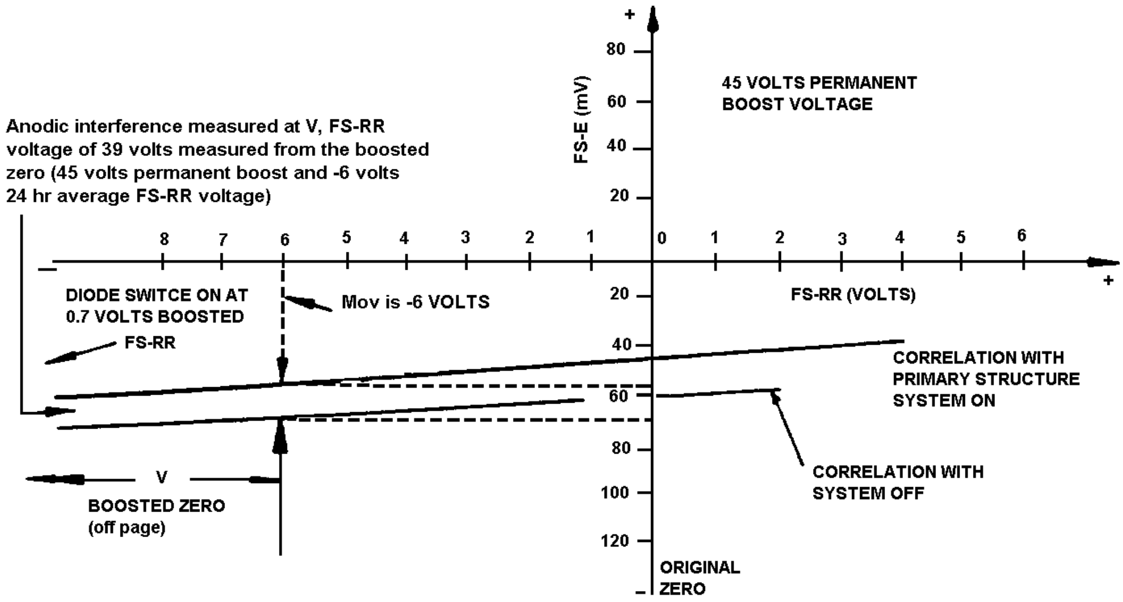


Figure 23 - Anodic interference - permanent boost

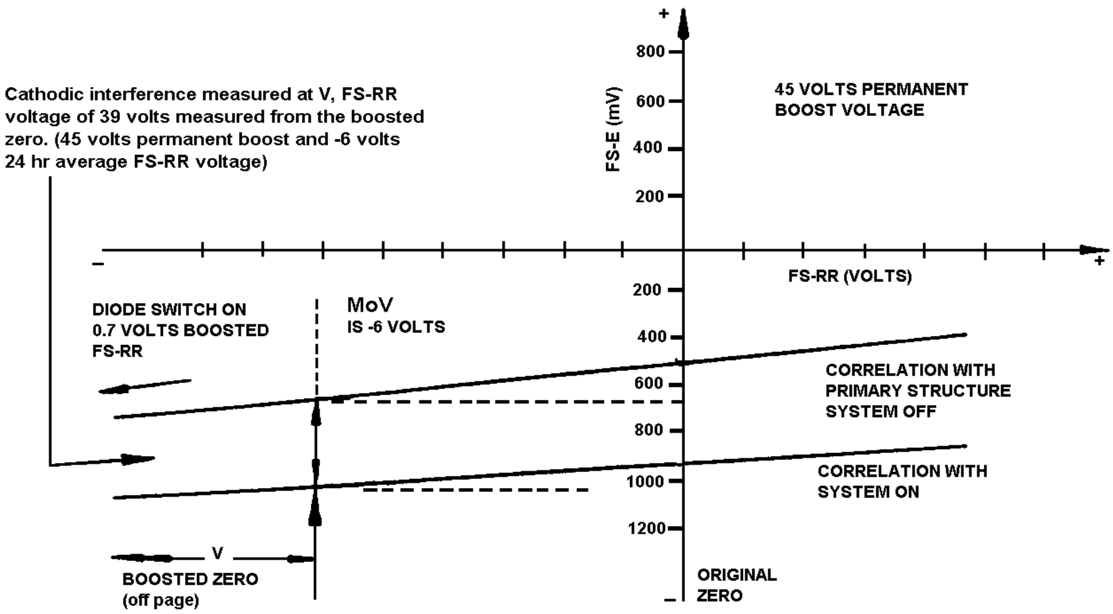


Figure 24 - Cathodic interference - permanent boost

5.3.5.4. Modified Interference Criteria

The owner of foreign structures that are affected by interference may consider accepting greater levels of interference than are presented in the tables of criteria in Appendix II. This approach may be taken when anodic interference is recorded on a foreign structure that already has a strongly indirect correlation or, when, cathodic interference is recorded on a structure that already has a strongly direct correlation. A structure that is already very negative with respect to earth (indirect correlation) can accept substantial anodic interference without entering the corrosion hazard zone. Similarly a structure that is very positive with respect to earth (direct correlation) can accept substantial cathodic interference without detriment. If there is a connection between the primary and foreign structures, then an apparent cathodic interference is in reality not interference at all but instead, the foreign structure has become part of the protected structure.

This acceptance of increased levels of interference is more appropriate for less critical Category 3 structures than for structures in Categories 1 and 2.

5.3.5.5. Interlocking Railway Drainage Systems

In some cases a railway drainage system will only be accepted if it is connected to the railway rail through an automatic electrical interlock controlled by another existing drainage system. This is necessary where the connection of a new system causes substantial anodic interference to another structure/system. The interlock disconnects the new interference producing system if the existing circuit becomes inoperable. In these cases, larger than usual interference may be acceptable.

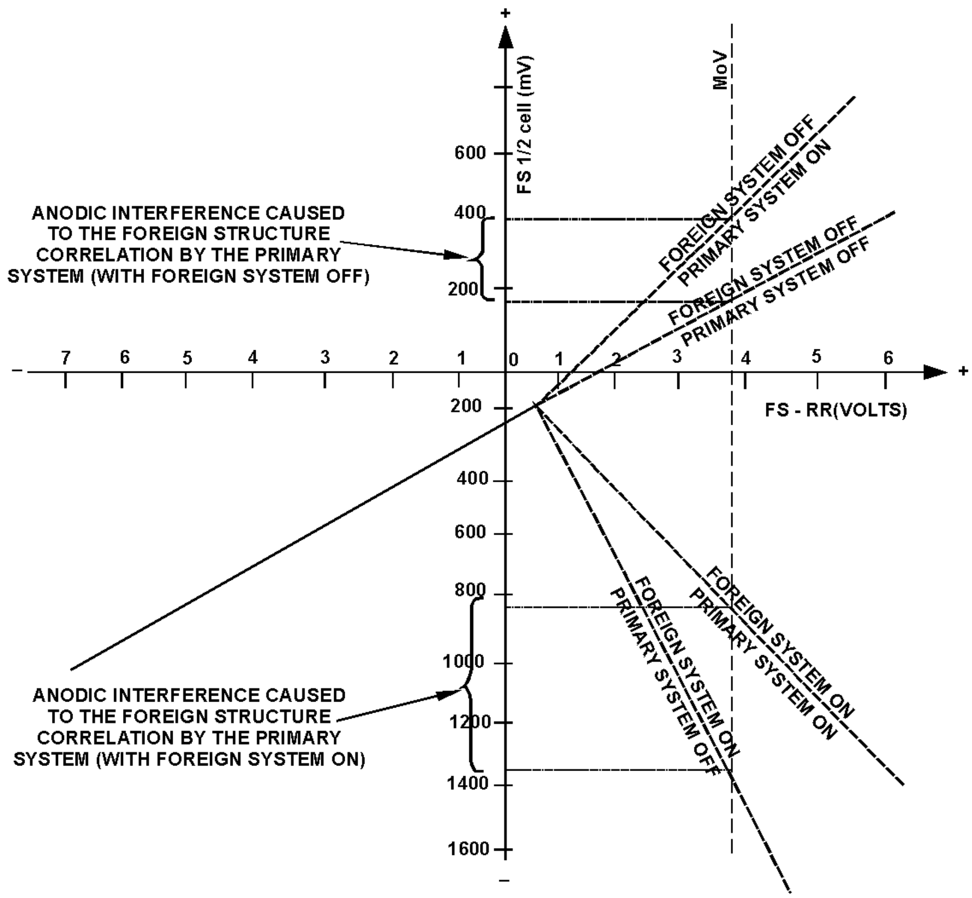


Figure 25 - Foreign Structure Correlation - Interlocking Railway Drainage Systems

5.4. Transformer Rectifier Assisted Drainage Systems (TRAD)

5.4.1. Information Required

The information required for TRAD systems is identical to that for Drainage Systems.

5.4.2. Interpretation

Interpretation is identical to Drainage Bonds.

5.5. Combination TRAD and Drainage Systems (TDB)

5.5.1. General

TDB systems consist of a TRAD and a DB connected in parallel to the same connection point on both the track and the protected structure and are thus treated as a single system for the purpose of registration.

5.5.2. Information and Interpretation

This is the same as for the DB and TRAD systems.

6. Standardisation and Use of Instruments

6.1. Connection of Instruments

6.1.1. General

The general efficiency of field testing and the accuracy and reliability of the data obtained and its interpretation depends to a large degree on the proper use and standardisation of instruments and associated equipment.

6.1.2. Position of Half-Cells

The half-cell must be positioned as close as possible to the structure the potential of which is being measured.

Note: *Large distances between the half-cell and structure can produce a large soil potential gradient (IR drop) in the measuring circuit and thereby produce misleading interference measurements. For well coated structures, although the half-cell may be very close to the pipe surface, the half-cell may still be remote from the nearest coating defect, thus producing a large soil gradient in the measurement. When objectionable interference is measured, and where practical, the nearest coating defect should be identified and interference measured with a half-cell adjacent to the defect.*

6.1.3. Digital Voltmeters

Connect the red positive lead to the structure and the black negative lead to the half-cell.

Note: *When connected in this manner the negative sign on the meter indicates that the structure is negative with respect to the soil (half-cell).*

6.1.4. Analogue Voltmeters

Connect the red positive lead to the structure and the black negative lead to the half-cell.

Note: *Centre-zero meters will display negative potential readings (i.e. structure negative with respect to soil) to the left of the zero.*

Left-hand zero meters should be provided with a polarity-reversing switch. With the switch in the reverse-polarity position the meter then indicates that the structure is negative with respect to soil (half-cell).

6.1.5. Ammeters

When measuring current returning to the rail line, connect the ammeter in series with the RD system with the negative terminal to rail. When measuring current in cathodic protection circuits connect the negative terminal of the meter to the anode-side of the circuit. Correct direction of current flow is indicated by a positive reading on the ammeter, when connected as described.

6.1.6. Recording Voltmeters and Ammeters

Recording voltmeters and ammeters are to be connected to produce a chart that conforms with Figure 26.

Figure 26 - Format for Charts with Time Base

6.1.7. Connection of Recording Voltmeter

The correct method of connection for single pen recording is shown in Figures 27 (primary structure) and 28 (foreign structure).

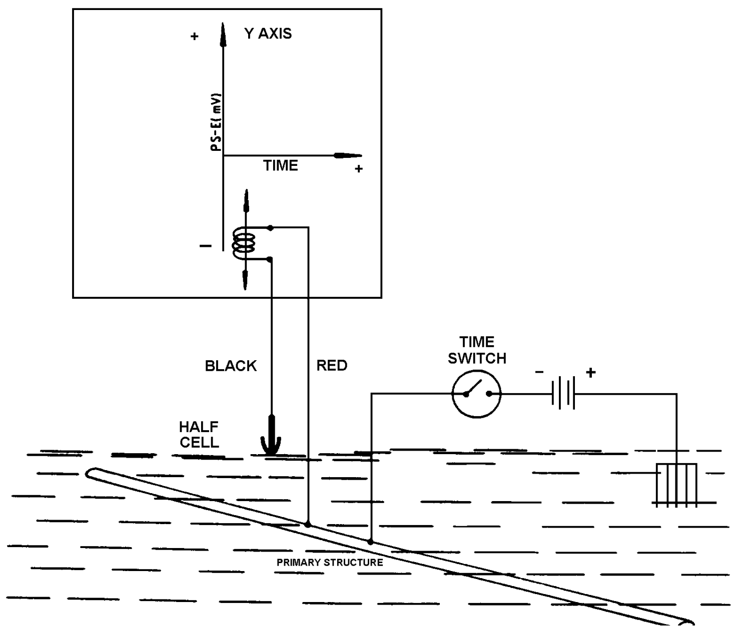


Figure 27 - Connection of Y-T recorder-primary structure, impressed current system

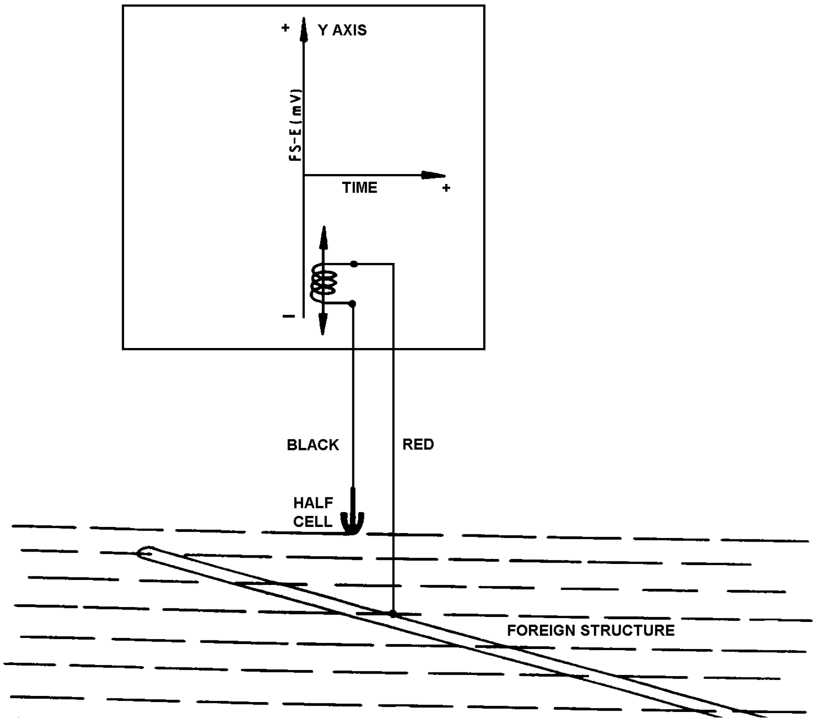


Figure 28 - Connection of Y-T recorder-foreign structure, Impressed current system

6.1.8. Connection of Dual-Pen Recorders

The correct method of connection for dual-pen recording of current and potential is shown in Figure 29 (primary structure) and Figure 30 (foreign structure).

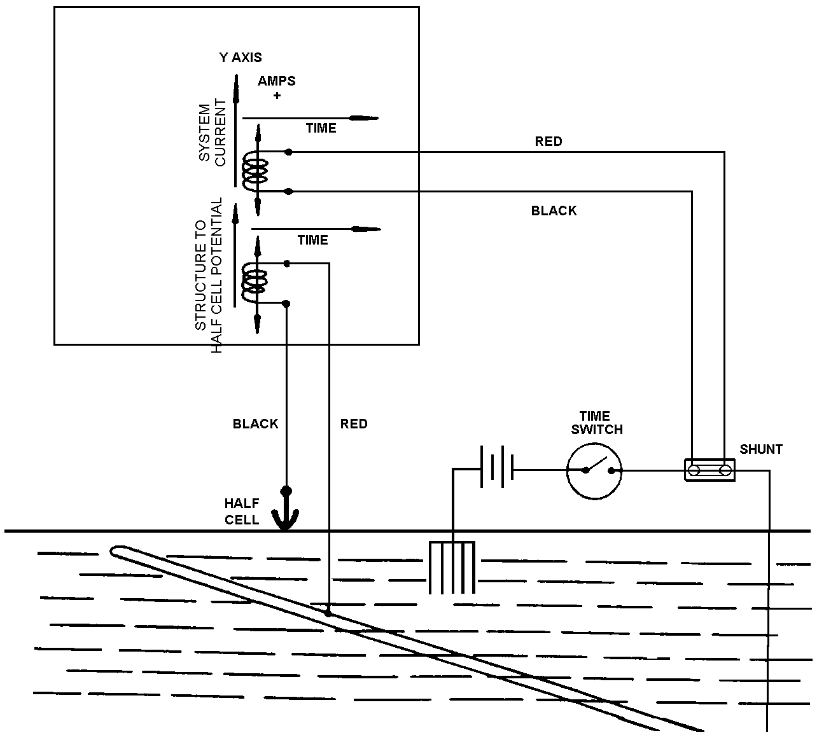


Figure 29 - Connection to Y-T recorder for dual recording of current and potential for a primary structure

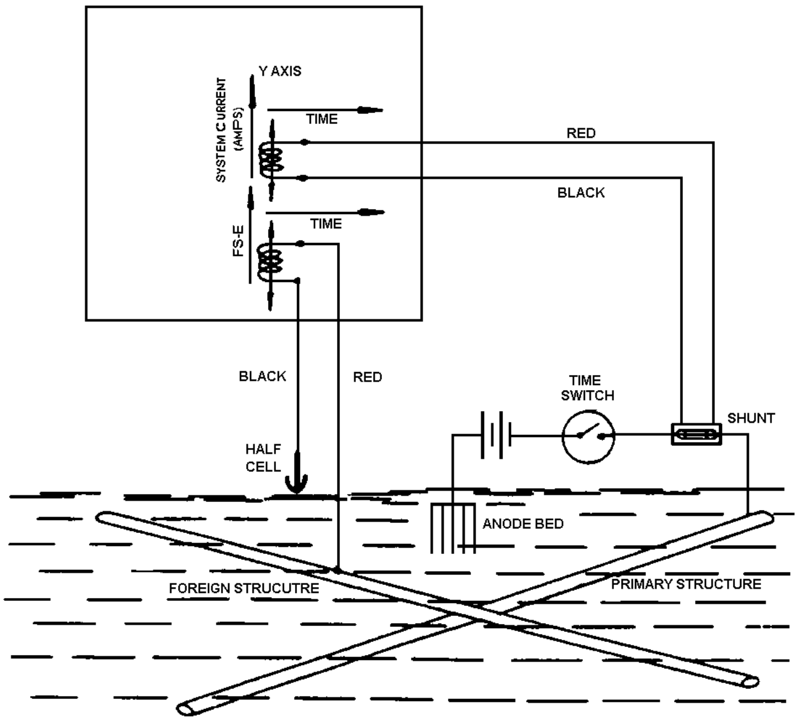


Figure 30 - Connection of Y-T recorder for dual recording of foreign structure potential and system current

6.1.9. Connection of X-Y Recorder for Railway Drainage Systems

Connections are as follows:

(a) Primary structure correlation is recorded with the potential of the structure to a half-cell recorded on the vertical Y-axis, refer to Figure 31.

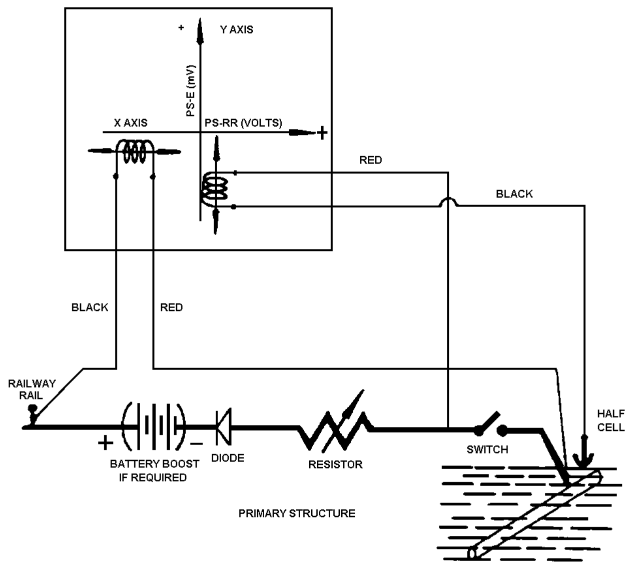


Figure 31 - Connection of X-Y Recorder for the primary structure correlation chart

(b) System conductance chart is recorded using the connections shown in Figure 32.

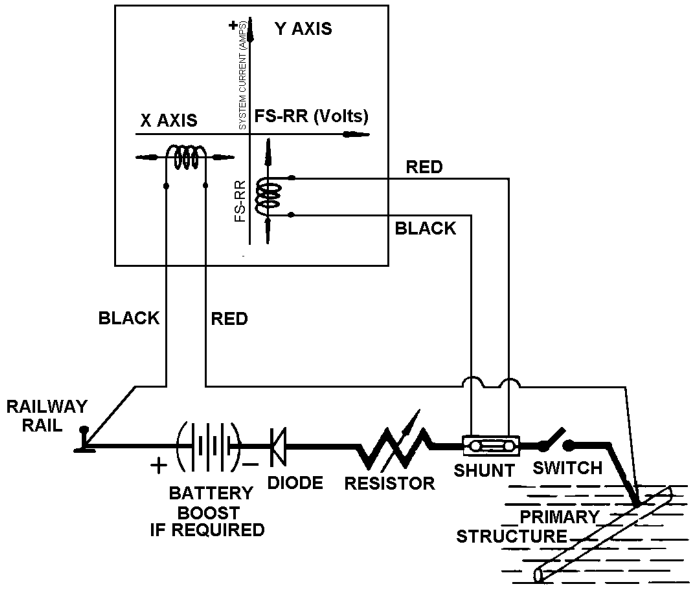


Figure 32 - Connection of X-Y recorder for measurement of conductance

(c) Foreign structure correlation is recorded with the connections shown in Figure 33.

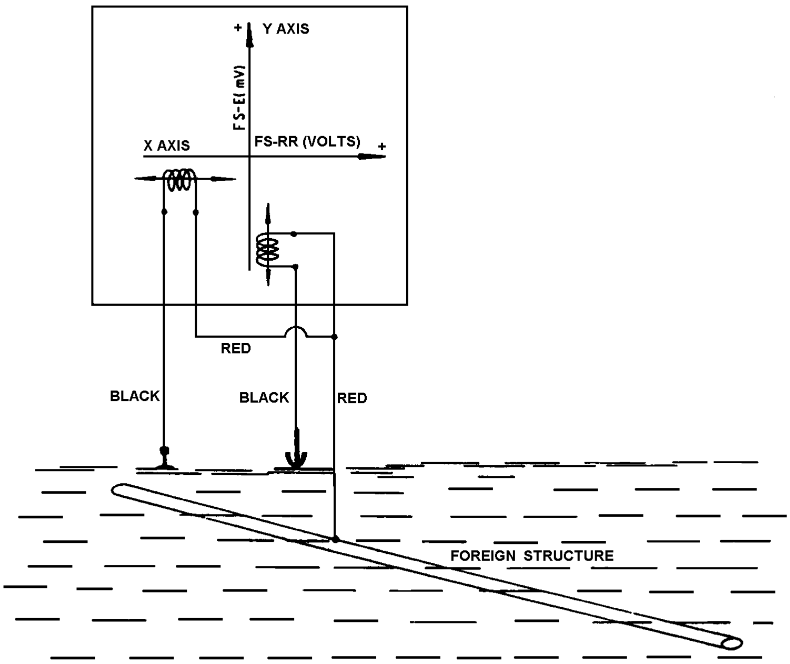


Figure 33 - Connection of X-Y recorder for measurement of interference - foreign structure correlation

6.2. Standardised Test Equipment

The reasons for standardising equipment are:

(a) The recommended equipment is considered to be most suitable for the tasks, both in terms of accuracy of the reading obtained, and the convenience of use.

(b) The use of common equipment, combined with a standardised approach to use of the equipment, minimise the probability of misunderstanding and misinterpretation of data.

6.2.1. Portable Voltmeters (Direct Current)

(a) Internal Impedance: 1.0 Megohm minimum for both digital and analogue. A more desirable impedance is 10.0 Megohm.

(b) Suggested Ranges:

Analogue: 150mV, 300mV, 1.5V, 15V, 30V
Digital: 200mV, 2V, 20V, 200V

(c) Limitation on Use:

Digital meters can be difficult to read in traction-affected areas because of the constant fluctuations in voltage. Where strong traction exists, a recording voltmeter is recommended.

6.2.2. Portable Ammeters (Direct Current)

Ammeters are to be used with caution because of the possibility of inaccurate measurement caused by the additional resistance inserted into low resistance circuits by the ammeter. Use of low resistance shunt and voltmeter is recommended (see clause 6.2.10 for details of shunts).

6.2.3. Recording Voltmeters

(a) Internal impedance:

1.0 Megohm minimum, higher impedance is desirable.

(b) Desirable Ranges:

10, 20, 50, 100, 200, 500mV;
1, 2, 5, 10, 20, 50V

(c) Chart Speeds:

20mm per minute and 20mm per hour, are the minimum requirements.

(d) The instrument should be equipped with an AC filter. A centre zero with adjustable zero offset facility is desirable.

6.2.4. Current Recording

Use a low resistance shunt and a recording voltmeter (see clause 6.2.10).

6.2.5. XY-YT Recorder

(a) Input impedance:

1.0 Megohm minimum, higher impedance is desirable.

(b) Desirable ranges (both axes):

50, 100, 200, 500 millivolts and 1, 2, 5, 10, 20 Volts.

(c) Time base speeds, s/cm:

1, 2, 5, 10, 20, 50.

A convenient speed is 20s/cm which is normally used by the SETC.

(d) AC interference should be filtered out.

(e) A 3 volt range offset box may be required for use with copper/copper-sulphate (and similar) half-cells.

6.2.6. Reference Electrodes (Half-Cells)

(a) A copper/copper sulphate ($Cu/CuS0_4$) half-cell is recommended except for marine environments where silver/silver chloride (Ag/Ag C1) is used. Data must be standardised to copper/copper sulphate in those cases where alternative metal reference electrodes are used. The cell should have a minimum diameter over the porous plug of 25mm. For high resistivity soils (soils above 100 ohm-metre) larger diameter half-cells are recommended. All half-cells should be used with high impedance voltmeters.

Refer to Appendix VII for details of electrode calibration and to Australian Standard AS2832.1 for further information.

Diagrams in this Guide use both the copper/copper sulphate half-cell and metal electrodes. to express the structure to earth potential.

(b) Refer to Appendix V for further details about use of half-cells.

6.2.7. Data Loggers

(a) Data loggers should be capable of frequent sampling over a minimum period of 48 hours.

(b) Facilities should be available (usually a desk-top or portable computer and software) for production of 24 hour average data and Time of Operation

(c) The instrument should be self-contained and weather-proof and capable of connection to a printer and/or computer for production of graphical output.

6.2.8. Metal Earth Reference Electrodes

(a) Copper/copper sulphate (Cu/CuS0$_4$) and silver/silver chloride (Ag/Ag C1) should be used in preference to metal electrodes. Silver/silver chloride should be used in salt or brackish water.

(b) Metal earth electrodes should be of a practical minimum diameter (e.g. 12 to 25mm diameter). Lengths as convenient to allow a minimum insertion of 150mm. Refer to Appendix VII for calibration of metal reference electrodes. Data must be standardised to copper/copper sulphate in those cases where alternative metal reference electrodes are used (refer to Appendix VII for details of electrode calibration).

(c) Polarization of metal stakes may occur and produce a drift in measured potential over a time period ranging from minutes to days - refer to paragraph 5.1.2.4 and Figure 8 for details.

6.2.9. Interference Probes

Interference probes (which claim to minimise IR drop) and coupons(which directly measure metal loss) may be used as complements to conventional half-cells and electrodes.

6.2.10. Shunts

(a) Shunt characteristics are as follows:

1A - 100mV (for use with system current up to 0.5A only)
10A - 100mV
100A - 100mV

With accuracy equal to or better than $\pm$ 1%.

(b) Shunts must be of robust construction including a substantial base-plate and heavy duty terminals.

6.2.11. Trial Railway Drainage Panel

See Appendix VIII.

6.2.12. CP Unit Switching Timers

(a) The timers may switch either the AC supply or the DC output of transformer - rectifier units. It may be difficult to switch heavy DC current without damaging the contacts.

(b) Timers should be calibrated in units of real time (seconds) and should be controlled by a quartz crystal electronic timing circuit for DC timers and by mains frequency for AC timers. The timing cycle should be adjustable but must include 5 seconds "ON" and 15 seconds "OFF".

6.2.13. Test Cables

Cable reels should have a minimum length of 100 metres of cable and consist of red and black figure eight cable. The reel should be fitted with heavy duty non-interchangeable two-pin plugs. Red coloured cable is used to connect structure and black coloured cable is used to connect half-cell to voltmeter.

6.2.14. Potential Offset Device

The offset device to have a continuously variable range between zero and 3.0 volts. Refer to Appendix IX for use of offset devices.

6.2.15. Instrument Accuracy

Instruments should conform to Australia Standards AS 1042-1973 and AS 1024-1971.

Appendix I - Structure Categories

The separation of underground structures into categories is considered necessary as an integral part of the selection of the interference criteria outlined in APPENDIX II. The underlying assumptions are that certain structures pose a greater risk to life and property and/or have greater asset value, and the cost of failure is higher and should therefore have more restrictive interference criteria than less risk-prone structures.

CATEGORY ONE

Category one is the highest category and these structures include the following:

1. High pressure (> 250 kPa) gas and petroleum pipelines.
2. LPG and propane gas tanks.
3. ATC Coaxial, Trunk and Junction telecommunication cables.
4. Underground power cables of 11 kV and greater, including associated pilot cables.
5. Pipelines containing toxic materials.

CATEGORY TWO

Category two structures include the following:

1. All steel and other metallic pipelines containing flammable materials, not included in CATEGORY ONE.
2. ATC Main telecommunication cables.
3. All steel, cast iron and ductile iron water pipelines equal to or greater than 600mm diameter.
4. Underground power distribution cables 240V and greater but less than 11kV and associated pilot cables.
5. Electrical system earthing structures.

CATEGORY THREE

Category three structures include the following:

1. All metallic water pipelines not already included in CATEGORY TWO.
2. ATC Subscriber's telecommunication cables.
3. All other low voltage (< 415V) cables which do not form part of the main distribution system, e.g. street lighting and other individual service cables.

Appendix II - Guidelines For Interference Acceptance/Rejection Criteria

Table 1 shows values for interference acceptance/rejection criteria based on practical experience.and should not be varied except by agreement between the parties concerned.

Use of Table 1

The owners of foreign structures should determine the interference criteria appropriate for their structures. The appropriate interference acceptance/rejection criteria are obtained from Table 1 by using the following procedure:

1. Identify the appropriate structure category from the table in Appendix I.
2. Determine if the structure is affected by stray current and select the acceptable level of protection.
3. Determine the actual potential and select the appropriate criteria from Table 1 by selecting the appropriate criterion line.

For Example

1. If the foreign structure is a high pressure oil pipeline then the category is CAT 1, Steel.
2. If stray current is present in this pipeline then the acceptable minimum level of protection is negative 1100mV to copper copper sulphate.
3. If the actual potential to earth is measured as - 1600mV then the appropriate criterion line is "acceptable to - 2500" and the criteria are 20mV anodic and 100mV cathodic.
4. If the recorded interference on this pipeline is (say) 23mV anodic, then the table indicates that an objection may be made to the operation of the system producing this interference.

   Note: In the example, if the recorded interference can be reduced to 20mV anodic or less, than the objection should be withdrawn.

   Anodic interference means a change in potential in the positive direction, for example a change from -650mV to -630mV (conversely for cathodic interference).

Notes:

1. Cathodic interference criteria apply only where there is no metallic connection between the protected and foreign structures (refer also to Appendix III).
2. **Multiple Interference**

Where a foreign structure is affected by interference from more than one source and the foreign structure owner has taken all reasonable measures to mitigate this background interference, then the owner may object to additional interference, using Appendix II as a guide. However, if any party has not taken all reasonable measures to mitigate background interference, then the party will be expected to accept greater levels of additional interference than are listed in Appendix II.

3 All potentials, used in Appendix 11 are measured by conventional techniques, as described in this Guide. Therefore, values determined by the "instant-off" and polarisation-probe techniques are **not** used in conjunction with Appendix II criteria.

4. The actual potential is measured with the *interfering* cathodic protection system turned off.

5. All potentials are measured relative to a copper/copper sulphate half-cell.

6. **Interference from railway drainage systems.**

The owner of a foreign structure may, after considering the correlation slope of their structure, accept larger levels of interference on the structure than listed in the table below. Refer to paragraph 5.3.5.4.

7. **Current Measurement**

Where unacceptable interference has been measured on uncoated structures, the parties concerned may agree to consider the magnitude of the current in a cross-bond between the primary and uncoated foreign structures as an additional criterion. This approach may be acceptable because very low interference currents may be involved, indicating that interference corrosion would be insignificant even though the foreign structure potential shift exceeds the criteria. If this approach is adopted then the following steps are taken:

(a) provide a cross bond between the primary and foreign structures,

(b) measure the current required to offset the interference, with the system operating and,

(c) decide if the apparent increase in corrosion hazard is objectionable, taking into consideration the following factors:

(i) the change in potential on the foreign structure before and after applying the cross bond,

(ii) the cross bond current,

(iii) the Appendix I Category,

(iv) the electrical continuity of the foreign structure.

TABLE 1 - INTERFERENCE CRITERIA#

Structure Category	Theoretical Level Of Protection mV	Acceptable Level Of Protection mV		Actual Measured Potential To Earth mV*	Criteria For Interference	
		Stray Current Present	Free From Stray Current		Maximum Anodic mV	Maximum Cathodic mV
CAT 1 Steel	-850	-1100	-1000	more anodic than acceptable	10	100
				acceptable to -2500	20	100
				more cathodic than -2500	20	10
CAT 1 Lead	-650	-850	-800	more anodic than acceptable	10	150
				acceptable to -1400	20	100
				more cathodic than -1400	30	20
CAT 2 Steel, Ductile and Cast Iron	-850	-1100	-1000	more anodic than acceptable	20	100
				acceptable to -2500	20	100
				more cathodic than -2500	30	50
CAT 2 Lead	-650	-850	-800	more anodic than acceptable	20	150
				acceptable to -1400	30	100
				more cathodic than -1400	40	50
CAT 3 Steel And Ductile Iron	-850	-1100	-1000	more anodic than acceptable	20	100
				acceptable to -2500	40	100
				more cathodic than -2500	60	50
CAT 3 Lead	-650	-850	-800	more anodic than acceptable	20	200
				acceptable than -1400	40	100
				more cathodic than -1400	60	50

CAT 3 Copper	-650	-850	-700	more anodic than acceptable	20	200
				acceptable to -1000	40	100
				more cathodic than -1000	60	50

* Foreign structure # In this Table earth is a copper copper sulphate half-cell.

Appendix III - Determination and Mitigation of the Effects of Fortuitous Connections

Introduction

Cathodic potential changes may be caused by three mechanism as follows:

1. Significant stray current entering isolated foreign structures (interference),
2. A metallic (fortuitous) connection between the primary and foreign structures,
3. Location of the foreign structures in the strong potential field surrounding a ground bed.

Note: The foreign structure owner should identify which mechanism is effecting his structure, before objecting to excessive cathodic potential change. A cathodic change due to electrical connection to the primary structure is not generally a corrosion threat as the foreign structure has become part of the protected structure.

Determination of Fortuitous Connection

Temporarily connect the foreign and primary structures with a cable and note any change in potential. Negligible change in foreign structure potential indicates there is already a connection between the two structures (fortuitous connection). Conversely, if a change in potential of the foreign structure is measured, this indicates there is no fortuitous connection and therefore the measured potential change is true interference.

Mitigating Actions

Where it is demonstrated that the primary and secondary structures are fortuitously connected, the following shall be considered:

(a) Locating and breaking the connection thus removing the cathodic potential shift, or

(b) Providing an additional and permanent connection (cross-bond) to stabilise the situation, provided the foreign structure is electrically continuous, or

(c) Objecting to the primary structure system on the grounds that the cathodic potential change on the foreign structure is unacceptable.

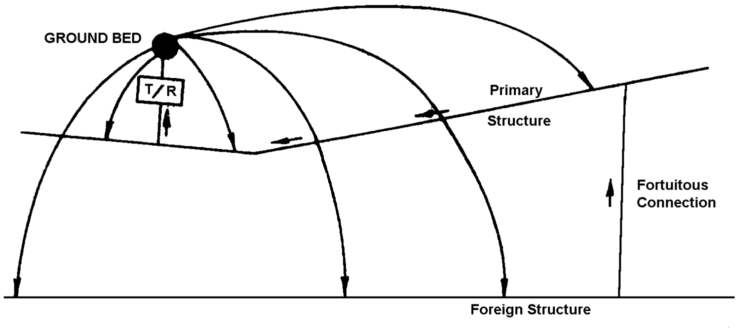


Figure 34 - Illustration of a fortuitous connection to a foreign structure

Appendix IV - Production Of X-Y Recorder Charts

The correlation, conductance and potential-time charts are an important part of the interference measuring process. The techniques of construction are detailed in the sections below. Interpretation of these charts is covered in the body of the Guide.

Potential Time Charts

The chart is used for two purposes:

1. Evaluation of the protection provided by a cathodic protection system to the primary structure, and
2. Measurement of the interference caused on foreign structures by the cathodic protection system.

Production of foreign structure to earth charts on a single pen X-Y recorder for the purpose of measuring interference, is fairly straight forward, although it can be difficult to read the switching points on structures heavily affected by stray DC current from railways. In these cases, the system "ON" and "OFF" points will need to be hand-marked on the chart by the Testing Officer at the moment of system switching. The following scale ranges have been found to be convenient: 20 s/cm time scale and potential scales of 500 mV to 2.0V full scale.

Generally it is better to use a two-pen chart recorder that simultaneously records both system current and structure potential. This allows precise identification of the exact point of switching on the potential graph.

Correlation Charts (Potential-Potential)

The correlation chart is used for three purposes:

1. Measurement of the effect of stray traction DC current on structures,
2. Evaluation of the "protection" provided by the railway drainage system to the primary (bonded) structure, and
3. Measurement of the interference caused on foreign structures by a drainage bond applied to a primary structure.

These charts are plots of structure to rail (S-RR) potential against structure to earth (S-E) potential and two straight lines are constructed for this relationship, one line for the system "ON", and one for system "OFF". See Figures 12, 18 and 19 in the body of this Guide.

The main difficulty with production of the correlation chart is drawing a correct line through the data points. It is normal for the S-RR voltage to fluctuate rapidly at all locations and for the correlation to change at some locations. This means that careful attention must be paid to the rapidly moving pen to pick the switching points through which the lines are subsequently drawn. The chart must contain only one correlation so that the effect of system switching on this correlation is clearly seen and is not confused with changes in the correlation. It may be necessary to hand-mark the switching points whilst switching the bond with a remote-controlled DC contactor.

The following copies of actual examples illustrate the drawing of the correlation lines through the pen markings.

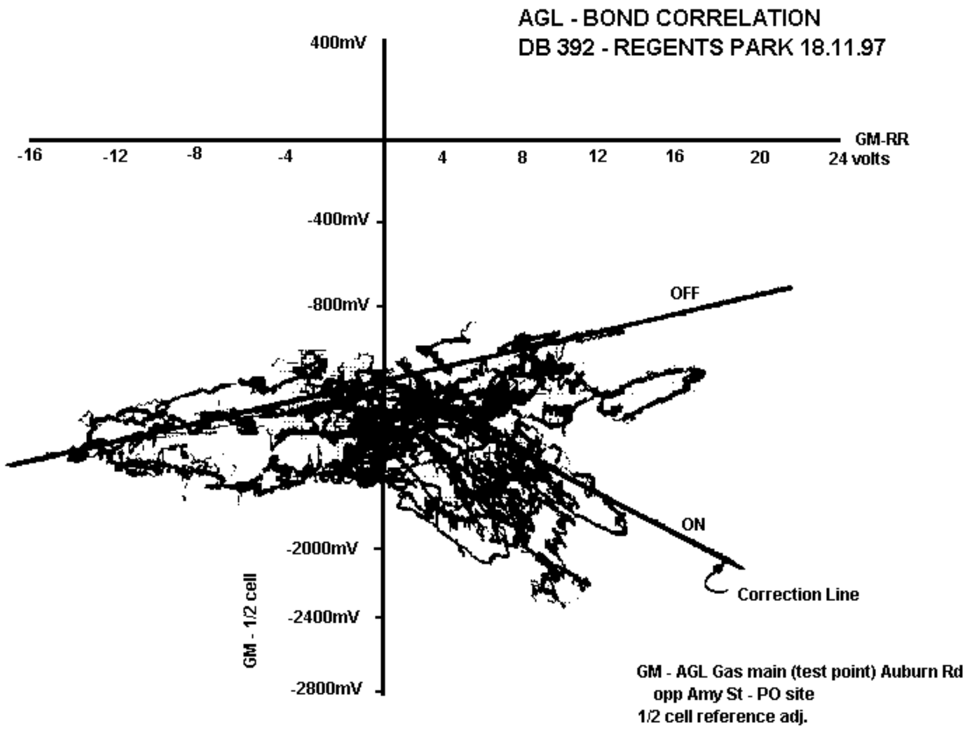


Figure 35 - Construction of the correlation line - example one - a gas main

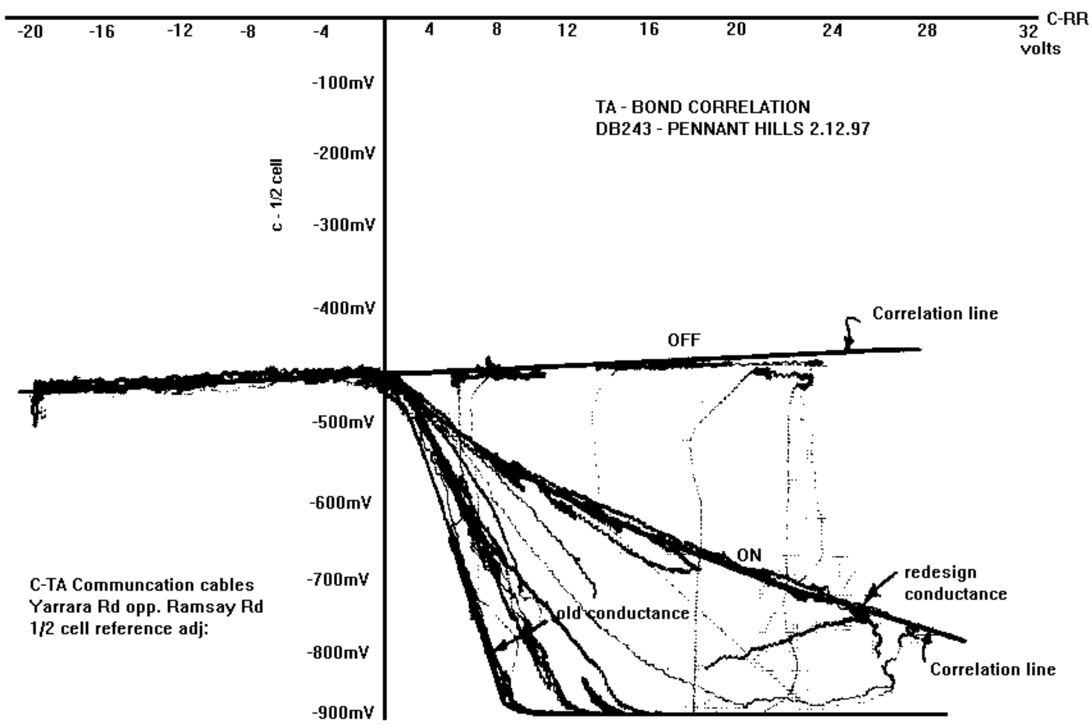


Figure 36 - Construction of the correlation line - example two
Australian Telecommunications Corporation cable

Conductance Charts (Current-Voltage)

The conductance of a railway drainage system is defined as the system current divided by the structure to rail voltage (SRR). The accepted conductance value is obtained by charting the system current against S-RR voltage and calculating conductance at the appropriate structure-to-rail voltage. (Refer to Figure 11).

Points to note when producing the conductance chart are:

1. The chart can only be produced when the system is conducting, that is when S-RR voltage is more positive than +0.7 volts, the “switch-on” voltage for the diode normally included in the circuit...

2. The conductance line is a straight line drawn through the plotter pen markings and passing through the zero amperes +0.7 volts point. Heating of lamps in the bond circuit can cause curving of this line.

3. The recording needs to be taken at a time when S-RR voltage is varying sufficiently to allow drawing of a valid line, for example, over a 3 volt range.

Appendix V - Potential Measurements And The Half-Cell

Potential Measurement

Potential differences between underground structures and the surrounding electrolyte are measured with the help of reference electrodes. The most commonly used reference electrodes are half-cells. The half-cell normally used is a copper/copper sulphate half-cell which consists of a copper rod placed in a saturated solution of copper sulphate in a container having a porous plug at the base (see Figure 37 below).

In non-traction areas, the "actual" or "natural" potential difference between the structure and the surrounding electrolyte is generally determined by galvanic action. The potentials are generally steady or subject only to long term fluctuation. In traction affected areas the potential may fluctuate rapidly as stray current from the tracks alternately enters and leaves the structure.

When a potential measurement is being taken the half-cell is placed on the ground as near as possible to the underground structure. The copper rod is connected to the negative terminal of a voltmeter and the positive terminal is connected to the underground structure. In the circuit shown, there are a number of potential differences across the various segments but some of these are very small and/or relatively constant in value. Neglecting the very small potential differences that occur across the metallic connections, the potential differences are:

E1 Potential between the copper rod and the saturated copper sulphate solution.

E2 A small potential exists between the copper sulphate solution in the porous plug and the soil due to differences in ionic concentrations. This potential is also relatively constant.

E3 This voltage drop is made up of the IR drops in the soil. It must be kept as small as possible by placing the half-cell as near as possible to the underground structure. This is most important in locations where steep potential gradients exist in the soil.

E4 This is the metal to metal contact potential between the connecting wire and the metal of the underground structure. It is not readily measurable but it is relatively constant and can be minimised by using connection clips made of the same metal as the metal to which contact is being made.

E5 Is the structure to electrolyte potential. This potential varies through wide limits and it is the value of this potential that it is desired to ascertain.

E Is the potential difference measured by the voltmeter.

Potential differences E1-E4 inclusive are assumed to be small or relatively constant so that the value of E5 is predominant in the measured voltage E.

Maintenance of $Cu/CuSO_4$ Half-Cells

Copper in saturated copper sulphate solution will maintain stable potentials within reasonable limits, under practical field conditions. However, with regular use in different soil conditions, copper/copper sulphate ($Cu/CuS0_4$) half-cells may become contaminated and the potential may deviate.

To maintain a stable potential the half-cell should always be kept in good condition. This is achieved by monthly replacement of the copper sulphate solution, cleaning the copper rod with fine grade emery paper, washing of all components in distilled or demineralised water, and adding crystals of copper sulphate to ensure solution saturation. Distilled or demineralised water should be used for the cell electrolyte.

Use of $Cu/CuSO_4$ Half-Cells

To obtain reliable results in monitoring cathodic protection potentials there must be a conductive path between the half-cell and the structure under test. The half-cell must therefore be placed in intimate contact with the soil. Good results in different environments are achieved as follows:

1. Moist sand and soil - ensure intimate contact between half-cell and sand/soil.
2. Dry soil - dig a small depression and fill with water or $CuS0_4$ solution.
3. Dry sand - pour water or $CuS0_4$ solution around the half-cell.
4. Concrete - saturate a rag with water or $CuS0_4$ solution and place between the concrete and half-cell.
5. Bitumen - do not use $Cu/CuS0_4$ half-cells, use a metal earth electrode driven through the bitumen to contact the underlying soil.
6. Salt and Brackish Water - use silver/silver chloride (Ag/AgC1) half-cells.

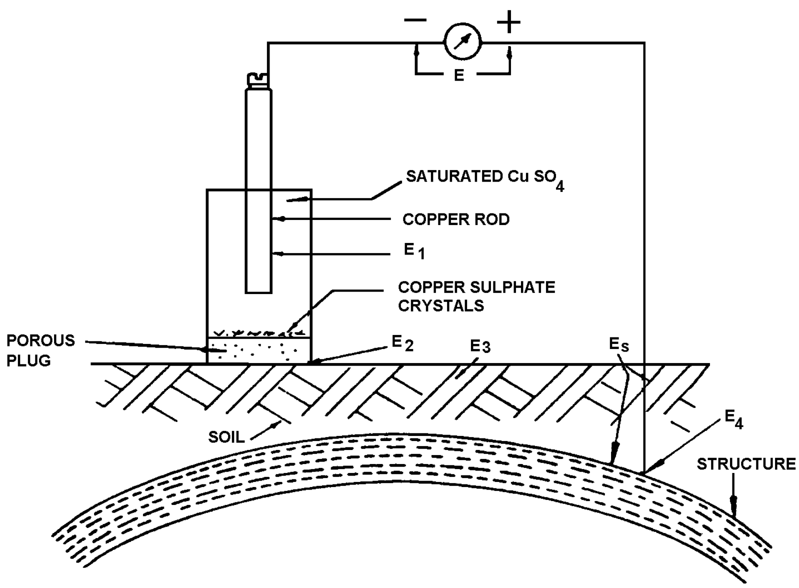


Figure 37 - Structure to earth potential measurements with a half-cell as reference electrode

Appendix VI - Test Points

Test points are installed to provide conveniently accessible connections to buried structures or to buried reference electrodes (refer to Figures 38, 39, 40). Test points are used to give information about the level of interference or the effectiveness of protection from a cathodic protection system. They may also be used to facilitate a cross bond between the structures or connection of RD or CP systems.

Cables from the structure and reference electrode are terminated in a robust housing, which can be a buried cast iron box with hinged lid at ground level, or a vertical column provided with either fixed exposed terminals or a terminal box.

Structure Connections

Two separate cables should be provided between the test point and the structure. The two cables are separately connected to the structure. The reason for two cables is that in the event of the test point being converted for use as a current carrying cable connection for a cathodic protection or railway drainage system, or as a cross bond, one cable remains for measuring potentials. Two cables also provide for continuity testing. In the case of intersecting structures, it is recommended that two cables be provided on both structures.

Earth Plates

A reference electrode may be in the form of an earth plate. The earth plates may be connected with two cables to provide a circuit for verification of the integrity of the cable connections to the earth plate.

Location of Test Points

Test points are installed at critical areas of a structure where problems are likely to be encountered or where extra precautions are required or structure potentials need to be known. Further details are contained in Australian Standard Series 2832. Examples of typical installation points are:

1. At likely areas of stray current pick-up, discharge, and
2. In close proximity to foreign structures.

Test points should be sited where they will be accessible but unlikely to be damaged after installation. They should be so located as to minimise hindrance to site usage and be sited to avoid attracting vandalism.

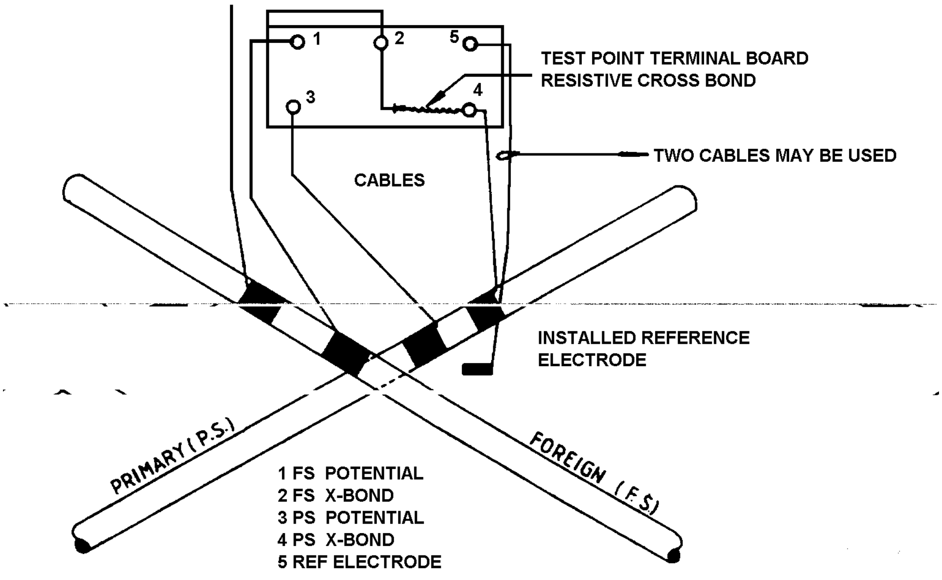


Figure 38 - Test points for intersecting structures

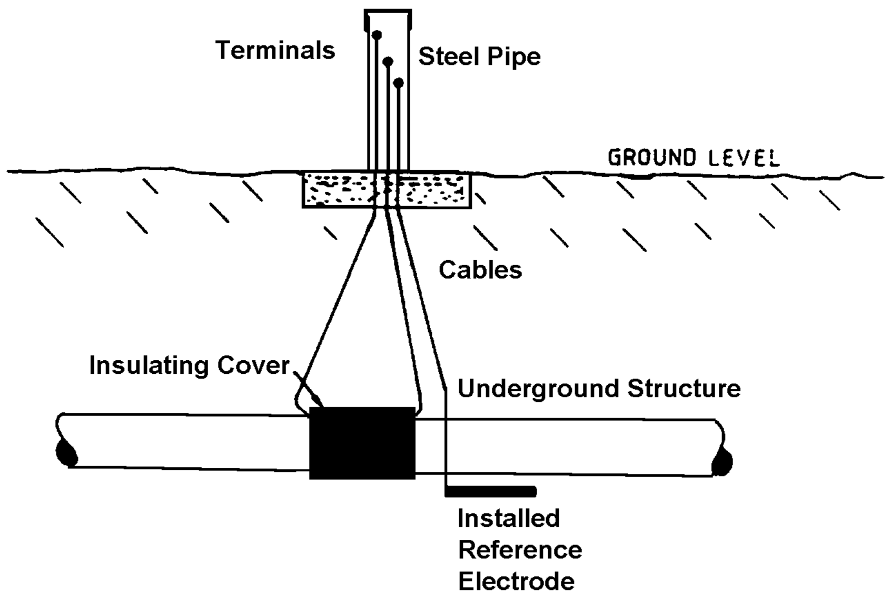


Figure 39 - Test points - above ground stand pipe

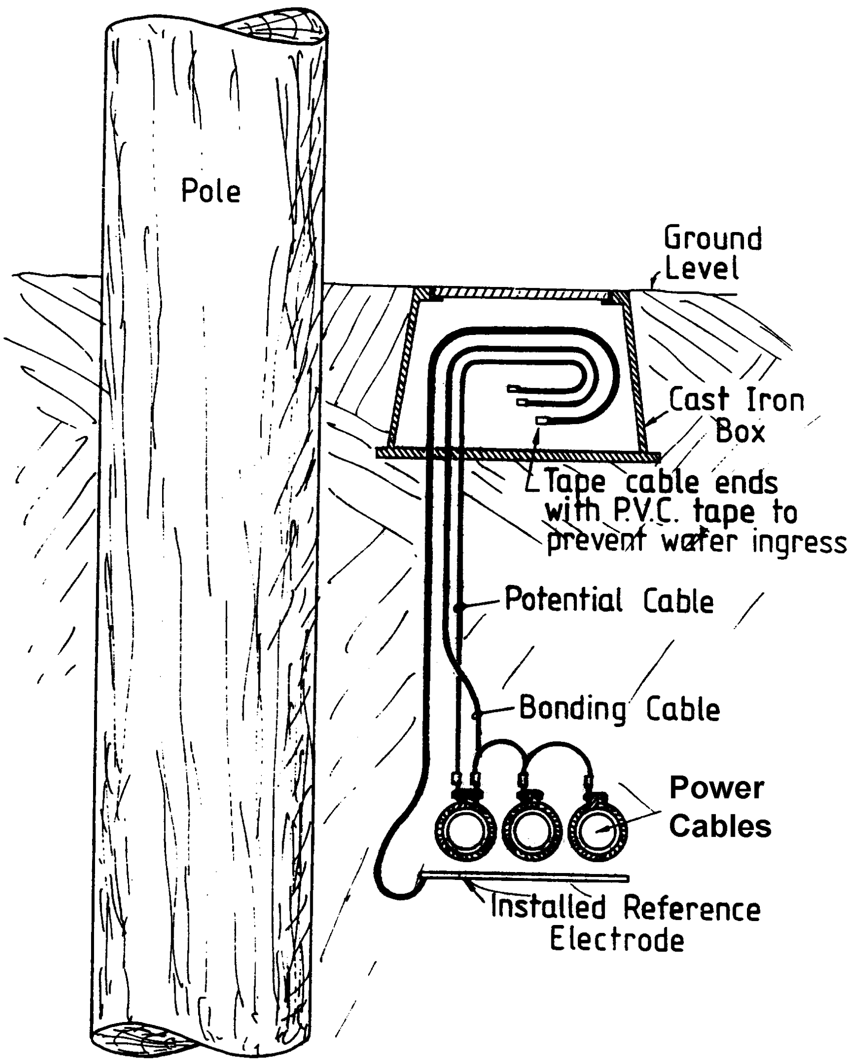


Figure 40 - Test points - details for inground box

Appendix VII - Calibration Of Metal Reference Electrodes

Potential measurements are usually made between the structure and a half-cell. In certain cases the use of a reference electrode other than a half-cell is required. Examples of such cases are:

1. Where a temporary reference is required (say for a 24 hour test) in a - public area where a half-cell may be interfered with or vandalised.

2. Where a reference electrode is required to be installed in close proximity to a deeply buried structure.

3. Where a structure is buried under hard cover or is not easily accessible.

4. Long term installation of half-cells is not satisfactory due to the need for maintenance.

   Note: The connection of cables to permanently installed earth plates or other reference electrodes must be secure, with durable soldering or welding being preferred. In addition, if different metals or alloys are used, the connections must also be completely insulated to prevent the occurrence of galvanic corrosion and consequent loss of connection.

It is desirable to have the reference electrode made of a metal with a similar potential to that of the structure. This means that the potential developed between the structure and the reference is minimised and a lower instrument full-scale range can be used and therefore small potential changes are more easily measured.

Calibration

Calibration of a metal reference electrode means determining its potential and polarity with respect to a half-cell (usually copper/copper sulphate).

When the potential V1, is added algebraically to V2, the measured potential of the metal electrode to structure, to give a resultant potential V3, which is the equivalent to that which would be read if the structure was measured directly to a half-cell (see Figure 41).

The method to be used for calibration is as follows:

1. Measure the potential of the metal electrode to half-cell (V1) with the negative electrode terminal of the voltmeter connected to the half-cell.

2. Measure the potential of structure being tested to the metal electrode (V2), this time with the negative terminal of the voltmeter connected to the metal electrode.

3. The potential of the structure with respect to the half-cell is the algebraic sum of the two potentials measured above.

Notes:

1. *In traction-affected areas it is necessary to take voltage measurements V1 and V2 simultaneously, due to the rapid traction-induced fluctuations in the values. Care should be exercised in interpretation of these results due to fluctuating potential gradients.*

2. *If either the metal electrode or the half-cell is moved before calibration is completed, then re-calibration is necessary.*

3. *The potential of a metal electrode may vary after insertion as it polarizes. Therefore it is advisable to insert temporary electrodes for several hours, before measurement. In high resistivity soils, polarization takes place more slowly and, therefore, the final polarization will take longer to achieve.*

   The error introduced into the measurement by polarization can be minimised by using a high impedance voltmeter (10 M-ohm).

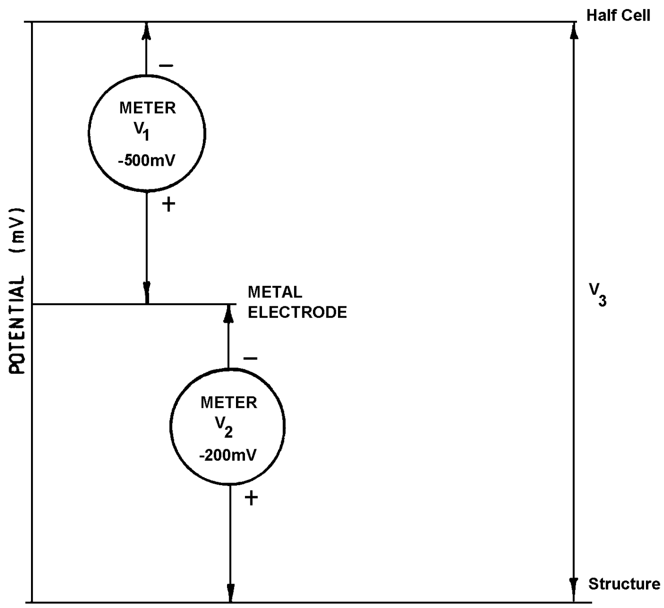


Figure 41

d V3 = V1 + V2
= -500 + (-200)mV
= -700mV
= The potential of the structure relative to the half-cell.

Note: *Two separate measurements must be made. In this practical case a metal electrode has been used to measure the potential to earth (-200mV) but this value has been corrected to -700mV relative to a half-cell.*

Two separate measurements must be made.

Appendix VIII - Trial Railway Drainage Panel

For those cases where a railway drainage system is required to offset the effect of strong traction current, it is advisable to temporarily set up a trial drainage bond so that interference effects can be measured.

Therefore, all parties who require systems should equip themselves with a suitable drainage panel. The circuit diagram shown at Figure 42 is a suitable panel that will provide a wide range of conductance characteristics and will facilitate accurate measurement of system conductance.

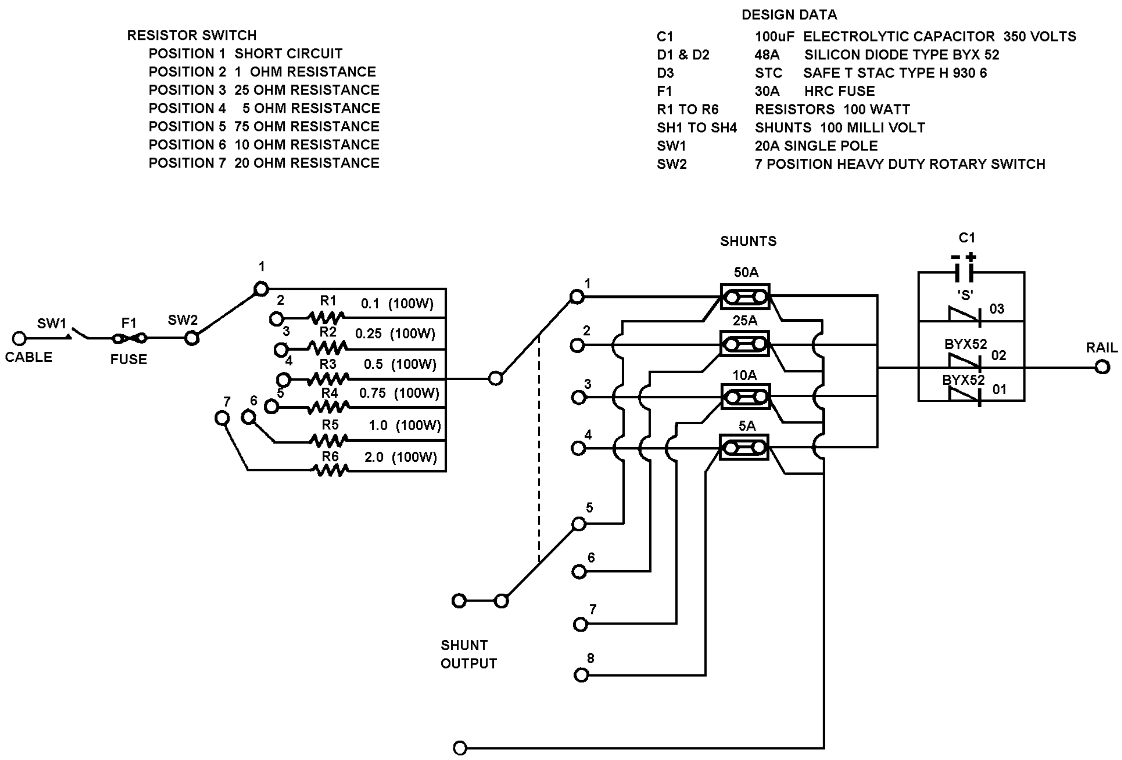


Figure 42 - Railway drainage system design panel

Appendix IX - Potential Offset Device

Where, because of interference or, for any other reason, it is desired to measure the change in potential of a structure with respect to a half-cell (or metal reference) and the structure potential is large in magnitude in comparison to the value of the change in potential, then a potential offset device may be used to obtain more accurate measurements. For example, where the potential of a structure with respect to a half-cell is 1500 mV the most likely full scale range used to make such a measurement would be 3.0 V or 5.0V, depending on the scales available. If it is desired to measure a change in this potential of, say, 15mV then an accurate reading is impossible to obtain. To accurately measure 15 millivolts, an instrument with a full scale range of 50, 100 or 300 mV would need to be used. To overcome this difficulty, a multi-range instrument and a potential offset device should be used to clearly show the 15mV change and to prevent the instrument going off-scale.

A potential offset device consists of a DC voltage supply of 3.0 volts and a voltage divider wired such that an output voltage of from zero to 3.0 volts is provided. Alternatively, some recorders contain an in-built offset device.

The procedure to be adopted for an offset box is as follows (refer to Figure 43):

1. Measure structure to half-cell potential on a suitable voltmeter range.
2. With the instrument on the same range insert the potential offset device in series with the measuring circuit, with the polarity of the offset device opposite to that of the voltmeter.
3. Adjust the potential offset device output so that the overall voltage of the circuit (i.e. the algebraic sum of the potentials of the structure to half-cell and the offset device) is approximately zero.
4. Alter the instrument range to that appropriate for measuring the change in potential and record the potentials.

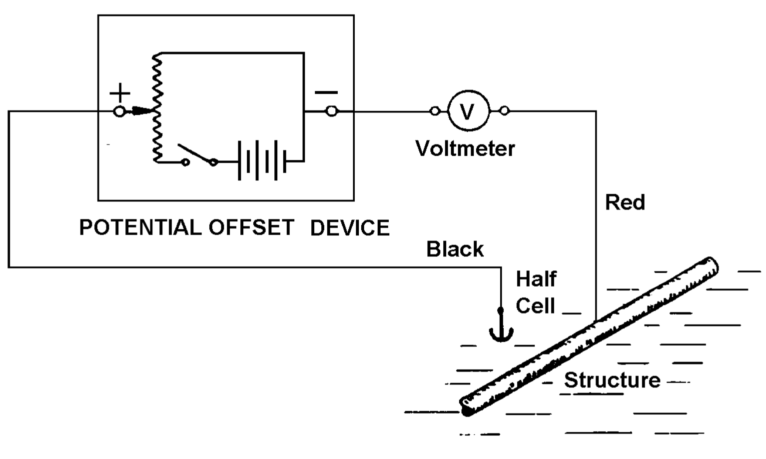


Figure 43 - Connection of a potential offset device

Appendix X - Determination Of Interference From A Railway Drainage System

(Also applies to transformer rectifier assisted drainage systems)

This appendix describes the procedures for determining an interference value for a railway drainage system and the TRAD system or combinations of these systems.

Previous to late 1996, drainage bonds were registered in terms of Siemens but since that time they have been registered in terms of 24 hr average current. This has resulted in changes in the methods described in this revision of the Guide.

The introduction of radio-telemetry of data during 1996 has also allowed much greater use of correlation charts where previously these were restricted to structures situated very close together. Nevertheless, the 48 hr recording method (refer Section 5.3.2.b) remains a valid alternative for application as a matter of individual preference or where the radio-telemetry system fails due to poor transmission.

Step One – Record System Current and Det. Mod. Current

The permanent drainage system or a temporary drainage panel must be installed to allow operation of the system over 24 hours whilst the current is recorded. This is done using a suitable weather-proof data logger that is loaded with appropriate software. The 24 hour data is recorded including the zero current values. Data is downloaded to a computer and analysed to produce the modified 24 hour average current (MoC). A Time Of Operation is calculated and expressed as a fraction of the 24 hours that current exceeds 0.1 amps. The raw 24 hour average is then multiplied by the inverse of the operating time to produce the modified 24 hour average current.

Example: If the raw 24 Hr average is 10 amps and the actual current exceeds 0.1 amps for half the 24 hour period then the modified 24 hour current is calculated as follows: $\frac{\mathbf{10}}{\mathbf{0.5}} = 20$ amps

Note: The raw 24 hour average is used to register the bond.

Step Two – Determine Modified Voltage

A conductance chart showing system current plotted against primary structure to rail voltage is produced, see Figure 44. Note that conductance charts illustrated earlier in the manual show current on the vertical axis. Both formats are acceptable. The modified 24 hr average current is entered onto the current axis and a line projected to the hot lamp conductance curve and then further projected onto the FS-RR axis. This produces the modified voltage (MoV) for application to the correlation chart.

Step Three

Use of the Correlation Chart to Determine a Value of Interference

The degree of interference is represented by the change in slope of the correlation line; however, it is necessary to determine a single measure of interference for comparison with the criteria and when deciding to object or accept a proposed drainage system. This single measure of interference is the change in FS-E potential measured at the modified voltage (MoV) as shown in Figure 45. A vertical line is drawn from the modified voltage to intersect the two correlation lines and interference is the interval marked "Interference" in Figure 45.

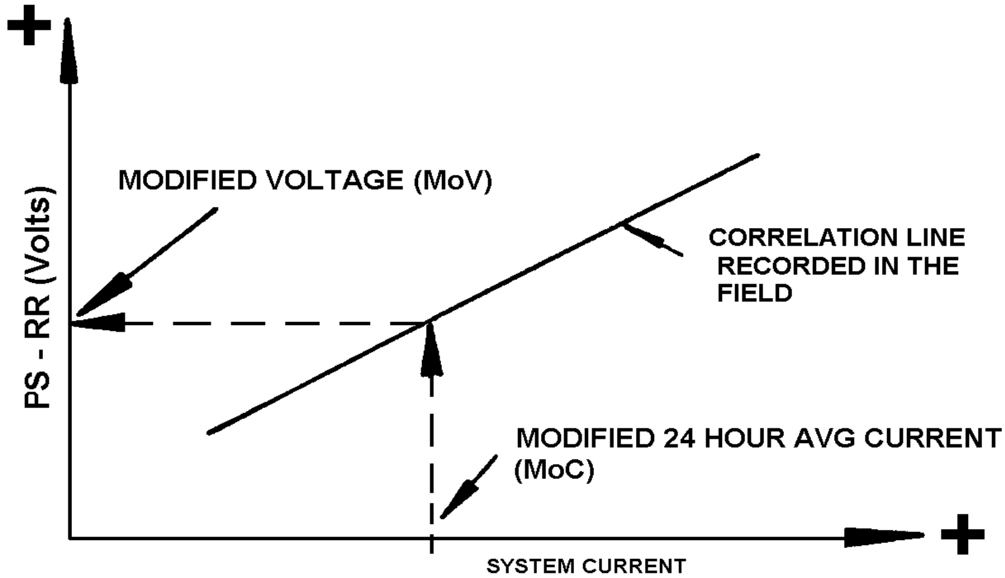


Figure 44 - Determination of MoV (PS-RR voltage corresponding to the Modified System Current)

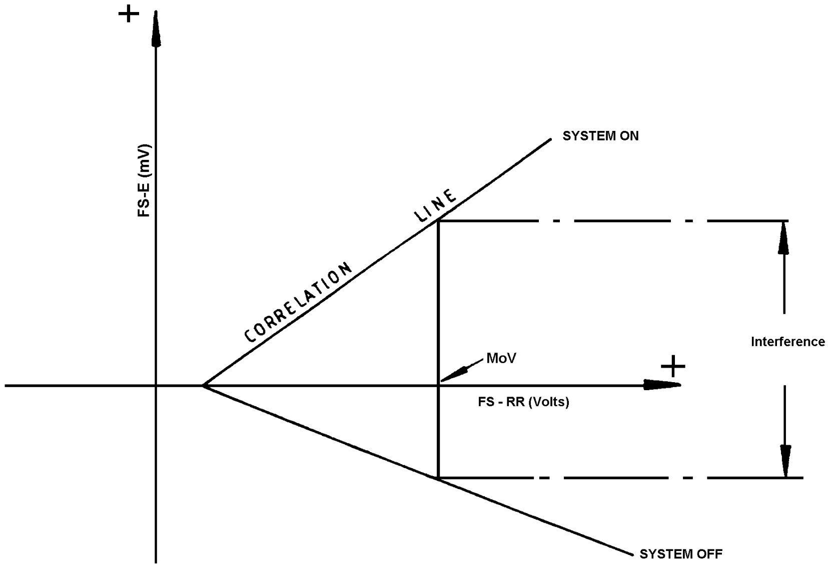


Figure 45 - Determination of interference using the correlation chart for "in-phase" structures

Appendix XI - Administrative Procedures*

General

The Electricity Act 1945, and the Electricity (Corrosion Protection) Regulation 1993 require that cathodic protection, railway drainage and variations of these systems installed in the State of NSW must be approved and registered by appropriate authority. The authority is currently delegated to the Department of Energy (referred to herein as the Authority).

The New South Wales Electrolysis Committee (NSWEC) has assisted the Authority over many years in the assessment of systems and has also, through its Technical Committees, coordinated testing and resolved many issues between the parties who own the primary and foreign structures involved. It has been normal practice for the Authority to accept the recommendations of the NSWEC when considering approval of CP systems and other related matters. The NSWEC is supported by Technical Committees in Sydney, Newcastle and the Illawarra whose members represent the owners of the majority of primary and foreign structures in NSW.

Approval Procedure

When a person intends to operate a CP or RD system an application must be submitted to the Authority and the Authority's approval must be granted prior to operation. Stages in the approval process are as follows:

1. The Authority may grant the necessary approval or refer it to one of the three Technical Committees for examination.

2. Upon examination, the Technical Committee will determine what tests, if any, are required and will co-ordinate the necessary testing with all interested parties.

3. Modifications and additional tests may be necessary to ensure that the proposed system will not adversely effect any foreign structures.

4. The test results together with comments will be forwarded to the NSW Electrolysis Committee for review and recommendation to the Authority.

5. Final approval to operate the system may then be granted by the Authority.

6. Under the Regulations, systems may be operated for the purpose of testing and then only in accordance with the conditions laid down by the Authority.

7. The Authority prepares the Certificates of approval in accordance with the system specifications provided by the Technical Committees. The Authority's delegate then signs the Certificate thereby providing legal approval for operation of the system.

Approval by the Authority to operate a system is not to be construed as providing any level of corrosion protection to the primary structure.

Electrolysis Engineer

The Electrolysis Engineer (EE) of the Department of Energy (the Authority)is a member of all the committees, and provides an administrative service and continuity throughout the testing and approval process.

Retesting

The NSWEC and the Authority has established a regular system of retesting of all registered systems to detect unacceptable interference that may occur due to expansion or modification of underground structures. The retesting procedures are the same as for new systems, except that re-issue of Certificates is not usually required. However, retesting can find interference or other problems that may require modification of the systems and issue of a new Certificate or cancellation of the system. The Authority has the power to retest a system at any time, however, the Technical Committees now routinely recommend nominal retest times for existing systems, typically ranging from two to eight years.

Financial Arrangements

The Regulations provide for recovery of the Authority's costs of administration of the Regulations, including the costs of interference testing. These costs are usually shared by the members of the NSWEC according to an agreed formula. There is provision for charging non-members for testing. The NSWEC establishes a budget each year and the members are invoiced quarterly.

Administrative Support

The Department of Energy provides administrative support to the NSWEC and the Technical Committees. This includes the provision of the Chairperson and Secretaries as well as preparation, typing and distribution of agendas, minutes and reports. The Department operates the Electrolysis Test Van and provides a Testing Officer who conducts the field testing and records interference data for the Technical Committees.

Considerations for the Technical Committees

On-site test methods are determined by consensus between the members of the Technical Committees. Individual parties determine which of their structures require interference testing.

The Authority role on-site is to:

1. Ensure that appropriate testing is completed and examine the site to determine if any parties not represented may be affected.

2. Provide impartial recording of results for later presentation to Technical Committees.

3. Provide specialised equipment for use on-site (e.g. X-Y Recorder, 2-way radios, DC meters, etc.).

The Technical Committee establishes, with reference to the NSWEC and the Authority, the criteria for foreign structure interference which, in usual circumstances, form the basis for acceptance or rejection of proposed systems (detailed in Table 1 in Appendix II). The Technical Committees strive at all times to achieve unanimous agreement for acceptance of a system. However, a right of veto applies for any party affected by a system.

Where interference does occur, flexibility is encouraged to determine a level at which the proposed system may operate, which is an acceptable compromise to all affected parties, e.g. the recommended operating conditions may result in a lower level of protection than that originally sought by the proposer.

Further, the criteria for interference are not absolute and an affected party may present reasons for a reduced or increased level of interference in the circumstances under consideration.

The Technical Committees do not determine the level of corrosion protection achieved for the protected structure. The Certificates issued by the Authority do not indicate whether a structure is, or is not protected from electrolytic corrosion. The effectiveness of the cathodic protection system is the responsibility of the system owner.

A Technical Committee member, or any other party may seek retesting of a system if they consider conditions have changed in a way which may effect that party.

For proposed systems to be installed in New South Wales beyond the areas usually covered by the established Technical Committees, the Authority requires that the party proposing the system provides written confirmation that all other underground structure owners do not object to the proposed system. The Authority may arrange for the system operator to carry out interference testing and report to the Authority. Country systems may or may not be considered by the Technical Committees

The Sydney Technical Committee meets monthly (excepting January), the NSWEC meets twice per year and the Newcastle and Illawarra Technical Committees also meet twice per year.

Current at February 1998

Appendix XII - Testing Of Non-Members' Assets For Stray Traction Current Affect And Cathodic Protection System Interference

PART 1: Testing for Stray Traction Current Affect

The Committee will, where practical and reasonable, take steps to minimise the adverse impact of stray traction current on Members assets, including reducing escape of stray current from the electrical rail track system. Steps may include:

(a) potential and correlation surveys of Members structures, either carried out by the individual Member on his own structures or, as agreed by the Technical Committee, cooperatively, and

(b) use of the services of the Electrolysis Testing Officer and Committee electrolysis equipment.

The Committee acknowledges, that such action may benefit nearby assets of non-members and this is accepted as a valuable community benefit.

The Committee will not routinely carry out tests on non-members assets nor provide electrolysis advice to non-members, but Technical Committees are free to do so if they judge the particular circumstances justify the committee's involvement.

Where testing is planned to be carried out on a non-member's asset, the Committee Secretariat or a Member will, as far as is practical, inform the owner and request the owner's presence at the test site(s). In any event, testing will only proceed where it is not illegal to access the site or to connect test cables to the structure.

It is recognised that resource restraints and legal implications limit the opportunities to assist non-members. Where such assistance is provided the Committee recognises that it will be unable to charge a fee to defray expenses, except by agreement of the owner of the asset.

PART 2: Testing for Interference from Cathodic Protection (CP) Systems

The Members will not generally carry out testing on non-member assets. However, testing to evaluate the impact of the CP system on non-members assets may be carried out, where practical, in response to a request for assistance from either:

(a) a non- member, or

(b) The Department of Energy

Where non-members assets are tested, then the Committee will, as far as is practical, invite the non-members to be present at the test site(s), and to participate in testing of there assets, and will inform the non-member of the results either orally or in writing.

The Department of Energy may decide not to carry out testing of a CP system before approval. The Corporation may request confirmation in writing from adjacent utility owners stating they have no objection to operation of the system, before granting approval of the system. In the above cases the Committee has no obligation to participate in interference testing. The Committee may request that the Department of Energy carry out testing prior to approval of the system.

Notwithstanding the above, the Technical Committees (including the Department as a Member) may elect to carry out interference testing on a CP system belonging to a non-member, at any time and in any location that it believes is appropriate. In these cases, testing will only proceed if access to the site is legal and connection of test cables is legally permitted. The Committee may elect to inform the structure owner of the results.

Installation by a consultant

Where a Consultant Member is installing a system, the Consultant should actively seek to identify nearby foreign structures and test as appropriate. If in the opinion of the Consultant Member the tests show significant interference, the Consultant Member shall inform the owner of the foreign structure and the Department of Energy of the existence of the cathodic protection system and relevant foreign structures and test results.

Appendix XIII - Railway Traction Drainage Systems - Guide to Electrical Safety

(for use by members of the NSW Electrolysis Committee)

PURPOSE

This document provides guidance to electrolysis field staff with respect to safe electrical work practices to be followed when they are employed on maintaining or testing railway stray traction current drainage systems (including panels and bond boxes of conventional and Transformer Rectifier Assisted Drainage systems .

SCOPE

This document covers the required personal and other protective equipment plus relevant testing procedures, if any, as well as the practices to be followed when working or testing near or within railway drainage systems.

SUMMARY

The safe working practices and procedures contained in this document are intended to ensure a safe and healthy environment for electrolysis staff to work in when testing and maintaining railway traction drainage systems.

PRECIS OF THE PROBLEM

Over voltage

Over a period of time electrolysis field staff have detected large increases in electrical potential measured between the underground metallic structures of utility's plant and the railway D.C. traction systems. In some areas a negative 270 volts D.C. has been recorded. Not only can this voltage appear on the utility structures but it can also appear on drainage panels and, under certain fault conditions, it may also appear on bond cabinets. This increase in voltage has been brought about by an increase in the number of electric locomotives attached to the freight hauling trains on certain lines, increased power of urban trains and improved track isolation.

Because of the very low source impedance (the track) of this voltage, it can generate dangerously high currents through the body of any person who may accidentally come into contact with it and earth at the same time. These high currents represent a hazardous situation to the staff working on these systems, and as such there are mandatory practices that must be followed to reduce the possibility of dangerous occurrences.

NOTE: The recommended limit for DC s voltage exposure is 60 volts. For information on the effects of current passing through the human body refer to reference 1.

Faults in the electrical system can produce voltages up to 1500 VDC for short periods until the fault is cleared. The probability of this occurring is remote but still represents a risk that should be allowed for in safety procedures.

Safety Equipment to be used

To mitigate the effect of the above high voltages the following protective equipment must be used. The safe working procedures to be observed at the same time are set out below.

Rubber Gloves (Reference No. 2)

(i) Type

There are two recommended types of rubber gloves that can be used for electrical protection and they are medium and light weight.

The preferred type for this work are the **lightweight** gloves, because they give the user greater control of the tools, etc. but with the same degree of electrical protection. These gloves are a gauntlet style that are dipped and proof tested to 5,000 Vrms for a working voltage of 650V (See Ref No. 2). **Gloves must be worn at all times whilst working on stray traction current drainage systems.**

(ii) Testing

For this type of glove the only tests required are visual as the voltage test is only to be applied when new (see (a) below). The necessary tests to be carried out on these gloves are:

(a) Expiry Date Check

Once the gloves have been in use longer than 12 months from the date of manufacture, as shown on the cuff of the gloves, the gloves must then be disposed of and a new pair requested. These gloves are not to be retested for electrical integrity.

(b) Field Examination

The supervisor shall ensure that every glove is visually examined to determine whether it is satisfactory to use before being placed in service. Briefly the important defects to look for are:

Surface cracks, cuts or nicks
Signs of perished rubber or softening
Abrasive wear
Moisture

Once the gloves pass the above test then they are inflated with air to test for small holes in the rubber.

Safety Footwear (Reference No. 3)

(i) Type

Safety shoes type 1, in accordance with AS 2210.2 and other relevant company documents, must be worn at all times. However, from an electrical safety point of view, these shoes must not be relied upon as the only means of preventing an electrical incident. Safety will depend primarily on the use of insulating gloves and insulated tools.

(ii) Testing

There are no specific tests for safety shoes, however Section 5.2 of Reference No. 4 sets out the recommended practices for the care of protective footwear.

Insulated Hand Tools (Reference 5, 7 and 8)

All hand tools such as spanners, adjustable spanners, pliers, srewdrivers, etc. used in work on the railway traction drainage systems should be electrically insulated to withstand 1,000 VAC or 1,500 VDC and marked accordingly. However the rating only applies to new tools and subsequent use or misuse may effect the insulating properties. Tools may need to be tested for insulation integrity every 6 months.

NOTE: Insulated tools must be replaced if any damage or noticeable deterioration occurs

The only Australian reference for insulated tools is AS 3527.2 and this reference only covers screwdrivers (See Ref. 5).

However, tools are available in Australia that are manufactured to comply with International Electrotechnical Commission Standard 900 (1987) (up to 1000 VAC and 1500 VDC) and with Electricity Association (Great Britain) Technical Specification 26.3 1984 (1000 VAC). (Ref. 7 & 8)

Clothing

It is desirable to wear long sleeves as an added safety precaution to limit the danger of accidental contact with live equipment.

WORK PRACTICES

Due to the intermittent and unpredictable nature of the voltages that occur on the rail tracks and drainage systems, it is dangerous to rely on the voltage measurement taken at the time to indicate whether the voltage is safe or not. Lethal voltages could occur at any moment in time. Always assume that dangerous voltages do exist and therefore before any testing or maintenance work is carried out observe the following practices:

(a) Always wear the safety equipment (gloves and boots) mentioned above and wear long sleeves

(b) While wearing the rubber gloves unlock the drainage bond cabinet.

(c) Use only insulated tools and gloves to perform the necessary work.

(d) Once the work has been completed the safety equipment is to be stored in the correct manner as set out in the relevant references.

Note: All safety equipment must be worn at all times until the work is completed

Note: Use similar procedures when working at locations remote from the bond cabinet where electrical connection to the rail track exist.

REFERENCES

1.	AS 3859-1991	Effects of current passing through the human body
2.	AS 2225-1994	Insulating gloves for electrical purposes
3.	AS 2210.2:1994	Occupational protective footwear Part 2: Specification
4.	AS 2210.1:1994	Occupational protective footwear Part 1: Guide to selection, care and use
5.	AS 3527.2:1990	Hand-operated screwdrivers and screwdriver bits Part 2: Insulated screwdrivers
6.	NACE RP-01 -77 (1983)	Electrical Safety
7.	IEC 900,1987	Hand Tools For Live Work Up To 1,000 VAC and 1,500 VDC
8.	EA TP26-3,1984	Hand Held Insulated Tools For Live Working Up to 1000 Volts.

DEFINITIONS

The following words, acronyms and abbreviations are referred to in this document:

Term	**Definition**
AS	Australian Standard
EA	Electricity Association (Great Britain)
IEC	International Electrotechnical Commission
NACE	National Association of Corrosion Engineers (USA)
TRADS	Transformer Rectifier Assisted Drainage Systems

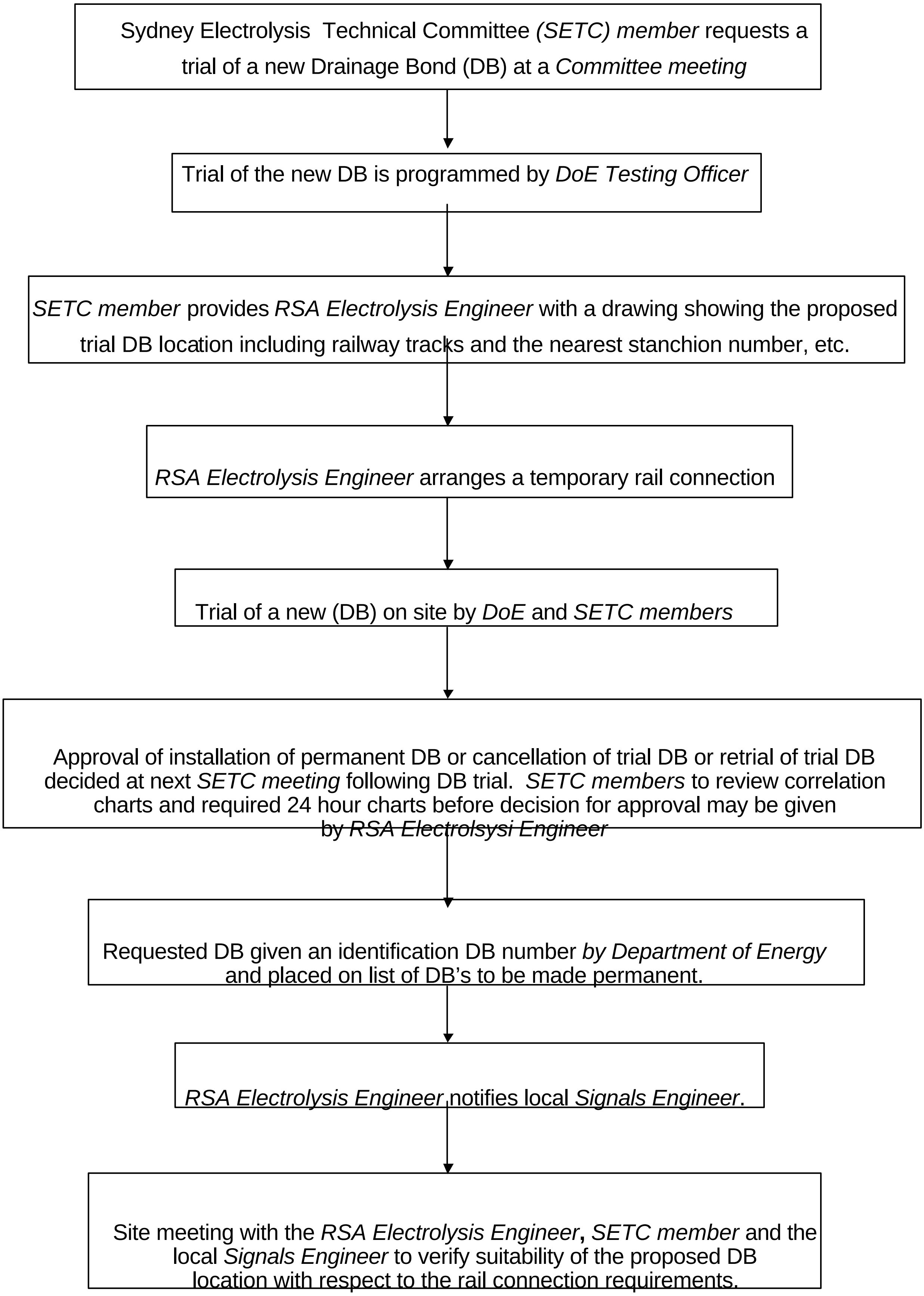
Appendix XIV - Rail Access Corporation (RAC)- Railway Drainage Bond Procedures

The procedure for installation of a new Electrolysis bond (Railway Drainage Bond) on a new site is as detailed below.

1. Sydney Electrolysis Technical Committee (SETC) member requests a trial of a new Drainage Bond (DB) at a Committee meeting.
2. Trial of the new DB is programmed by Department of Energy (DoE) Testing Officer.
3. SETC member provides Rail Services Authority (RSA) Electrolysis Engineer with a drawing showing the proposed trial DB location including railway tracks and the nearest stanchion number, etc.
4. RSA Electrolysis Engineer arranges a temporary rail connection.
5. Trial of a new DB on site by DoE and SETC members.
6. Approval of installation of permanent DB or cancellation of trial DB or retrial of trial DB decided at next SETC meeting following DB trial. SETC members to review correlation charts and 24 hour structure to rail voltage charts before the decision for approval may be given by the RSA Electrolysis Engineer.
7. Requested DB given an identification DB number by Department of Energy and placed on list of DB's to be made permanent.
8. RSA Electrolysis Engineer notifies local Signals Engineer.
9. Site meeting with the Electrolysis Engineer, SETC member and local Signals Engineer to verify suitability of the proposed DB location with respect to the rail connection requirements.
10. Signals Engineer draws a plan showing track insulation and rail connection details and sends it to Signals Design Section.
11. SETC member provides RSA Electrolysis Engineer with any outstanding design information required, eg. 24 hour voltage and current charts showing peaks and averages.
12. RSA Electrolysis Engineer designs the new DB.
13. Signals Design Section completes the signal track circuit design and returns it to the Signals Engineer for the installation of the new DB rail connection.
14. A search for services must be carried out before any excavation is commenced on Railway property.
15. Installation of post, box and DB panel.
16. RSA Electrolysis Engineer advises SETC members their cables can be installed.
17. Local Signals Engineer advises the Electrolysis Engineer that a new Electrolysis Bond rail connection has been installed.
18. New DB ready to be connected by Electrolysis Engineer or Assistant.
19. Testing of new DB by DoE and SETC members.

20 Final approval, with regard to interference criteria,. by SETC members at SETC meeting.

R.A.C. RAILWAY DRAINAGE BOND - FLOWCHART



Signals Engineer draws a plan showing track insulation and rail connection details and sends it to *Signals Design Section*

↓

SETC member provides *RSA Electrolysis Engineer* with any outstanding design information required eg. 24 hour voltage and current charts showing peaks and averages

↓

RSA Electrolysis Engineer designs the new DB

↓

Signals Design Engineer completes the signal track circuit design and returns it to the *Signal Engineer* for the installation of the new DB rail connection

↓

A search for services must be carried out before any excavation is commenced on Railway property.

↓

Installation of post, box and DB panel.

↓

RSA Electroysis Engineer advised *SETC member* their cables can be installed

↓

Local Signals Engineer advises the *RSA Electrolysis Engineer* that a new Electrolysis Bond rail connection has been installed.

↓

New DB ready to be connected by *RSA Electrolysis Engineer* or *Assistant*

↓

Testing of the new DB by DoE and *SETC members*

↓

Final approval, with regard to interference criteria, by SETC members at SETC meeting

Current at August 1998

Appendix XV- Personnel Safety

PART 1: GENERAL

Worker Safety legislation in NSW covers safety in the workplace and all members are encouraged to familiarised themselves with their responsibilities under legislation to ensure a safe workplace.

Safety matters that are of particular concern to the members of the New South Wales Electrolysis Committee include the following:

1. Access to rail tracks
2. Traffic hazards when working directly adjacent to busy roads;
3. Hazards to pedestrians from open manholes;
4. Electrical hazards that we usually associated with electrical equipment. Part 2 of this appendix details safety precautions associated with electrolysis testing; and
5. Underground safety.

Access to rail tracks

Access to rail tracks, other than railway stations, is strictly prohibited by the railway authorities, unless there is a clear need to gain access and the persons are properly clothed including prescribed safety vests and they have been duly trained and authorised by the Rail Access Corporation. Great care must be exercised at all times to avoid being struck by a passing train. Electrolysis personnel should avoid the tracks unless they have a clear need to be there.

Traffic Hazard

Points of access to cables and pipes is frequently in footpaths or otherwise adjacent to busy roads. Therefore there is a constant danger of accident and all staff must remain alert and work with great care and caution. Wearing of bright coloured safety vests is very strongly recommended.

Where it is necessary to convey an electrical signal across a busy road, use of the radio data telemetry equipment, normally carried by the Electrolysis Testing Officer, is recommended. Laying wires across roads is hazardous although the risk is tolerable in light traffic secondary roads.

Pedestrian Hazard

Access to pipes and cables is often via manholes in footpaths and adjacent areas. Where a manholes is opened then orange coloured safety cones must be placed on all sides of the hole.

Cables laid along and across footpaths are also a hazard and care must be exercised at all times to minimise the risk to pedestrians by choosing the least-risk path to lay the cables and using orange safety cones where appropriate.

Underground Safety

Access to pipe cables is often via manholes and hazards that exist include; explosive gas mixtures, poisonous gas mixtures, deep water and insects. Personnel must always enter manholes with care and follow the procedures prescribed under safety legislation and organisation safety policy. Testing for explosive gas mixtures is compulsory in most organisations and there must always be a second person on standby in case of difficulties.

PART 2: RAILWAY TRACTION DRAINAGE SYSTEMS

GUIDE TO ELECTRICAL SAFETY

(for use by members of the NSW Electrolysis Committee)

1. PURPOSE

This document will provide guidance to electrolysis field staff with respect to safe electrical work practices to be followed when they are employed on maintaining or testing railway stray traction current drainage systems (including panels and bond boxes of conventional and Transformer Rectifier Assisted Drainage systems (TRADS)).

2. SCOPE

This document will cover the required personal and other protective equipment plus relevant testing procedures, if any, as well as the practices to be followed when working or testing near or within railway drainage systems.

3. SUMMARY

The safe working practices and procedures contained in this document will generate a safe and healthy environment for electrolysis staff to work in when testing and maintaining railway traction drainage systems.

4. PRECIS OF THE PROBLEM

4.1 Over voltage

Over a period of time electrolysis field staff have detected large increases in electrical potential measured between the underground metallic structures of Utility's plant and the Railway D.C. traction systems. In some areas a negative 270 volts D.C. has been recorded. Not only can this voltage appear on the utility structures but it can also appear on drainage panels and, under certain fault conditions, it may also appear on bond cabinets. This increase in voltage has been brought about by a need of the NSW State Rail Authority to increase the number of electric locomotives attached to the freight hauling trains on certain lines, increased power of urban trains and improved track isolation.

Because of the very low source impedance (the track) of this voltage, it can generate dangerously high currents through the body of any person who may accidentally come into contact with it and earth at the same time. These high currents represent a hazardous situation to the staff working on these systems, and as such there are mandatory practices that must be followed to eliminate any possible dangerous occurrences.

NOTE: The recommended limit for DC hazardous voltage is 60 volts. For information on the effects of current passing through the human body see Ref. No. 1

Faults in the electrical system can produce voltages up to 1500 VDC for very short periods. The probability of this occurring is remote but still represents a risk that should be accounted for in safety procedures.

4.2 Safety Equipment to be used

To mitigate the effect of the above high voltages the following protective equipment must be used. The safe working procedures to be observed at the same time are set out in Section 5 of this document.

4.2.1 Rubber Gloves (Reference No. 2)

(i) Type

There are two recommended types of rubber gloves that can be used for electrical protection and they are medium and light weight.

The preferred type for this work are the **lightweight** gloves, because they gives the user greater control of the tools, etc. but with the same degree of electrical protection. These gloves are a gauntlet style that are dipped and proof tested to 5,000 Vrms for a working voltage of 650 (See Ref No. 2). **Gloves must be worn at all times whilst working on stray traction current drainage systems.**

(ii) Testing

For this type of glove the only tests required are visual as the voltage test is only to be applied when new (see (a) below). The necessary tests to be carried out on these gloves are:

(a) Expiry Date Check

Once the gloves have been in use longer than 12 months from the date of manufacture, as shown on the cuff of the gloves, the gloves must then be disposed of and a new pair requested. **These gloves are not to be retested for electrical integrity.**

(b) Field Examination

The supervisor shall ensure that every glove is visually examined to determine whether it is satisfactory to use before being placed in service. Briefly the important defects to look for are:

- Surface cracks, cuts or nicks
- Signs of perished rubber or softening
- Abrasive wear
- Moisture.

Once the gloves pass the above test then they are inflated with air to test for small holes in the rubber.

4.2.2 Safety Footwear (Ref No. 3)

Type

Safety shoes type 1, in accordance with AS 2210.2 and other relevant company documents, must be worn at all times. However, from an electrical safety point of view, these shoes must not be relied upon as the only means of preventing an electrical incident. Safety will depend primarily on the use of insulating gloves and insulated tools.

Testing

There are no specific tests for safety shoes, however Section 5.2 of Reference No. 4 sets out the recommended practices for the care of protective footwear.

4.2.3 Insulated Hand Tools (Ref 5, 7 and 8)

All hand tools such as spanners, adjustable spanners, pliers, srewdrivers, etc. used in work on the railway traction drainage systems should be electrically insulated to withstand 1,000 VAC or 1,500 VDC and marked accordingly. However the rating only applies to new tools and subsequent use or misuse may effect the insulating properties. Tools may need to be tested for insulation integrity every 6 months.

NOTE: Insulated tools must be replaced if any damageor noticeable deterioration occurs.

The only Australian reference for insulated tools is AS 3527.2 and this reference only covers screwdrivers (See Ref. 5).

However, tools are available in Australia that are manufactured to comply with International Electrotechnical Commission Standard 900 (1987) (up to 1000 VAC and 1500 VDC) and with Electricity Association (Great Britain) Technical Specification 26.3 1984 (1000 VAC). (Ref. 7 & 8)

4.2.4 Clothing

It is desirable to wear long sleeves as an added safety precaution to limit the danger of accidental contact with live equipment.

5. WORK PRACTICES

Due to the intermittent and unpredictable nature of the voltages that occur on the rail tracks and drainage systems, it is dangerous to rely on the voltage measurement taken at the time to indicate as to whether the voltage is safe or not. Lethal voltages could occur at any moment in time. Always assume that dangerous voltages do exist and therefore before any testing or maintenance work is carried out observe the following practices:

(a) Always wear the safety equipment (gloves and boots) mentioned above and wear long sleeves

(b) While wearing the rubber gloves unlock the drainage bond Cabinet.

(c) Use only insulated tools and gloves to perform the necessary work.

(d) Once the work had been completed the safety equipment is to be stored in the correct manner as set out in the relevant references.

Note:

1. All safety equipment must be worn at all times until the work is completed.
2. Use similar procedures when working at locations remote from the Bond Cabinet where electrical connection to the rail track do exist.

6. REFERENCES

1.	AS 3859-1991	Effects of current passing through the human body
2.	AS 2225-1994	Insulating gloves for electrical purposes
3.	AS 2210.2:1994	Occupational protective footwear Part 2: Specification
4.	AS 2210.1:1994	Occupational protective footwear Part 1: Guide to selection, care and use
5.	AS 3527.2:1990	Hand-operated screwdrivers and screwdriver bits Part 2: Insulated screwdrivers
6.	NACE RP-01 -77 (1983)	Electrical Safety
7.	IEC 900,1987	Hand Tools For Live Work Up To 1,000 VAC and 1,500 VDC
8.	EA TP26-3,1984	Hand Held Insulated Tools For Live Working Up to 1000 Volts.

7. DEFINITIONS

The following words, acronyms and abbreviations are referred to in this document:

Term	**Definition**
AS	Australian Standard
EA	Electricity Association (Great Britain)
IEC	International Electrotechnical Commission
NACE	National Association of Corrosion Engineers (USA)
TRADS	Transformer Rectifier Assisted Drainage Systems

NSW ELECTROLYSIS COMMITTEE

JULY 1996

Appendix XVI - Forms

1 Application for approval of a cathodic protection and drainage systems

2 Certificates for nil foreign structures and for no objections to foreign structures

To be forwarded to:
Leader - Electrolysis
Department of Energy
New South Wales
PO Box 536
ST LEONARDS NSW 2065

Electricity Safety (Corrosion Protection)
Regulation 1998

APPLICATION

For approval to operate a cathodic protection or railway drainage system

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Application is made for approval to operate the cathodic protection or railway drainage system described hereunder:

1 Owner of System

Name:

Address:

2 Location of System
(full description, including UBD map reference)

3 Structures to be protected

This application is/is not accompanied by:

(a) a plan showing the location of each structure to be protected and in the case of cathodic protection systems, the position of each anode;

(b) a description of the cathodic protection or drainage system and the structures to be protected;

(c) the facilities provided for interrupting the system current for testing;

(d) maximum system current (24 hour average);

(e) interference test charts;

(f) letters of consent from owners of foreign structures and a letter from an Authorised Testing Officer that identifies foreign structures;

(g) statement from an Authorised Testing Officer regarding absence of foreign structures.

______________________________ ______________________
Title/Name of applicant Signature of applicant

______________________________ ______________________
Address of applicant Date

EXPLANATORY NOTES

1 The description should include:

- a description of the type of system installed (e.g. a Transformer Rectifier Assistant Drainage System);
- a description of the structure and its coating including diameter, material conveyed and in the case of gas and petroleum pipelines, the operating pressure;
- the position of insulating joints and interconnections, if any;
- the extent and location of the structure affected by the proposed cathodic protection (foreign structures);
- the points of application of protection, and
- location of the anodes or anode bed;
- what provision there is for testing the installation both for its effect on the structure to which it is applied and for its effect on other structures;
- the potential of the protected structure, relative to the appropriate half cell, in its natural state and with protection applied;
- any other information thought to be necessary for the protection of the protected structure or other structures in its vicinity.

2 Clause 6 specifies the application of the Regulation as follows:

(1) A person must not operate a cathodic protection system to which this Regulation applies otherwise than in accordance with an approval in force with respect to the system.
Maximum penalty: 200 penalty units, in the case of a body corporate, or 50 penalty units in any other case.

(2) This clause does not prevent a person from operating a cathodic protection system, for the purpose only of testing it, for no more than 24 hours after completion of:

(a) the installation or extension of the system, or
(b) any maintenance or repairs carried out on the system.

3 Clause 7 specifies approvals:

(1) An application for an approval:
(a) must be in the form approved by the Director-General, and
(b) must be accompanied by the fee determined by the Director-General with respect to the application, and
(c) must indicate any conditions that the applicant proposes be imposed on the operation of the cathodic protection system, and
(d) must be accompanied by the results of interference tests that have been conducted by an authorised tester for the purpose of the application, and
(e) must be accompanied by such other documentation as the approved form requires, and
(f) must be lodged at an office of the Department.

(2) The applicant is not required to attach the results of an interference test:
(a) if the applicant attaches to the application a certificate from an authorised tester stating that there are no foreign structures in the vicinity of the system concerned, or
(b) if the applicant attaches to the application:
(i) a certificate from an authorised tester identifying all foreign structures that appear to be in the vicinity of the system concerned, and
(ii) statements from the owners of each foreign structure identified in the certificate to the effect that they do not object to the operation of the system. The description should include:

	To be forwarded to:
	Leader - Electrolysis
Electricity Safety (Corrosion Protection)	Department of Energy
Regulation 1998	New South Wales
	PO Box 536
	ST LEONARDS NSW 2065

CERTIFICATE (No Foreign Structures)

Demonstrating there are no foreign structures

Pursuant to clause 7(2)(a) of the Electricity Safety (Corrosion Protection) Regulation 1998,

I (state full name) ____ being an Authorised Tester pursuant to clause 15 of the same Regulation, do state that there are no foreign structures (as defined in clause 3 of the same Regulation) in the vicinity of the cathodic protection system described below:

1 Owner of System:

Name:

Address:

2 Location of System:

3 Structures to be protected:

4 System Registration Number (if known):

______________________________ ______________________

Title/Name of applicant Signature of applicant

____ ______________________

Address of applicant Date

EXPLANATORY NOTES

Sections from the Electricity Safety (Corrosion Protection) Regulation 1998:

Clause 3-Definitions; **Foreign Structure**-in relation to a cathodic protection system, means any metallic structure (other than the primary structure that the system is installed to protect) that is situated in the vicinity of the system, whether in or on the ground or in or on water.

Clause 7-Approvals for cathodic protection systems;

(1) An application for an approval:
- (a) must be in the form approved by the Director-General, and
- (b) must be accompanied by the fee determined by the Director-General with respect to the application, and
- (c) must indicate any conditions that the applicant proposes be imposed on the operation of the cathodic protection system, and
- (d) must be accompanied by the results of interference tests that have been conducted by an authorised tester for the purpose of application, and
- (e) must be accompanied by such other documentation as the approved form requires, and
- (f) must be lodged at an office of the Department.

(2) The applicant is not required to attach the results of an interference test:
- (a) if the applicant attached tpo the application a certificate from an authorised tester stating that there are no foreign structures in the vicinity of the system concerned, or
- (b) if the applicant attaches to the application:
  - (i) a certificate from an authorised tester identifying all foreign structures that appear to be in the vicinity of the system concerned, and
  - (ii) statements from the owners of each foreign structure identified in the certificate to the effect that they do not object to the operation of the system.

Clause 14-Departmental Guidelines:

(1) The Director-General may from time to time approve guidelines in relation to the following:
- (a) the carrying out of an interference test,
- (b) the form in which the results of an interference test are to be presented,
- (c) the form of a certificate referred to in clause 7 (2)(a) or (b).

(2) A copy of the Departmental guidelines is to be available for the inspection by members of the public, free of charge, and for purchase, at any office of the Department during its ordinary hours of business.

Clause 15-Interference Tests:

(1) The Director-General may appoint any suitably qualified person to be an authorised tester to conduct interference tests.
(2) An interference test is to be carried out in accordance with Departmental guidelines.
(3) The results of an interference test are to be presented in a form set out in Departmental guidelines.

Electricity Safety (Corrosion Protection) Regulation 1998

To be forwarded to:
Leader - Electrolysis
Department of Energy
New South Wales
PO Box 536
ST LEONARDS NSW 2065

CERTIFICATE (Foreign Structures)

Demonstrating no objections from owners of foreign structures.

Pursuant to clause 7(2)(b) of the Electricity Safety (Corrosion Protection) Regulation 1998,

I (state full name) ____, being an Authorised Tester pursuant to clause 15 of the same Regulation, have identified all foreign structures (as defined in clause 3 of the same Regulation) in relation to the cathodic protection system defined below and have attached (state number of statements) ________ statements from the owners of the foreign structures to the effect that they do not object to the operation of the identified cathodic protection system:

1 Owner of System:

Name:

Address:

2 Location of System:

3 Structures to be protected:

5 System Registration Number (if known):

____ _______________________

Title/Name of applicant Signature of applicant

____ _______________________

Address of applicant Date

____
Number of attached statements

EXPLANATORY NOTES

Sections from the Electricity Safety (Corrosion Protection) Regulation 1998:

Clause 3-Definitions; **Foreign Structure**-in relation to a cathodic protection system, means any metallic structure (other than the primary structure that the system is installed to protect) that is situated in the vicinity of the system, whether in or on the ground or in or on water.

Clause 7-Approvals for cathodic protection systems;

(1) An application for an approval:
  (a) must be in the form approved by the Director-General, and
  (b) must be accompanied by the fee determined by the Director-General with respect to the application, and
  (c) must indicate any conditions that the applicant proposes be imposed on the operation of the cathodic protection system, and
  (d) must be accompanied by the results of interference tests that have been conducted by an authorised tester for the purpose of application, and
  (e) must be accompanied by such other documentation as the approved form requires, and
  (f) must be lodged at an office of the Department.

(2) The applicant is not required to attach the results of an interference test:
  (a) if the applicant attached tpo the application a certificate from an authorised tester stating that there are no foreign structures in the vicinity of the system concerned, or
  (b) if the applicant attaches to the application:
    (iii) a certificate from an authorised tester identifying all foreign structures that appear to be in the vicinity of the system concerned, and
    (iv) statements from the owners of each foreign structure identified in the certificate to the effect that they do not object to the operation of the system.

Clause 14-Departmental Guidelines:

(1) The Director-General may from time to time approve guidelines in relation to the following:
  (a) the carrying out of an interference test,
  (b) the form in which the results of an interference test are to be presented,
  (c) the form of a certificate referred to in clause 7 (2)(a) or (b).

(2) A copy of the Departmental guidelines is to be available for the inspection by members of the public, free of charge, and for purchase, at any office of the Department during its ordinary hours of business.

Clause 15-Interference Tests:

(1) The Director-General may appoint any suitably qualified person to be an authorised tester to conduct interference tests.
(2) An interference test is to be carried out in accordance with Departmental guidelines.
(3) The results of an interference test are to be presented in a form set out in Departmental guidelines.

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