Ref No: PW01
Issue No: 1.0
Issue date: May 2018

IRSE///
Institution of Railway Signal Engineers
Minor Railways Section

INSTITUTION OF RAILWAY SIGNAL ENGINEERS
MINOR RAILWAYS SECTION

GUIDELINE ON

POWER SUPPLIES FOR SIGNALLING AND TELECOMMUNICATIONS EQUIPMENT ON MINOR RAILWAYS

Record of Amendments		
Issue	**Date**	**Amendments**
1.0	May 2018	Initial Issue

Anyone who wishes to contribute additional items or correct / amend any of the entries or wants further information may contact the IRSE Minor Railways Section Guideline co-ordinator at mrsdc@irse.org or via the IRSE Headquarters.

TABLE OF CONTENTS

1 INTRODUCTION

This document provides information on power supplies used on minor railways, primarily to provide guidance on when IET edition 18th rules (BS7671) should apply in relation to power supplies provided for signalling or telecommunication purposes.

It is not intended to be a definitive document on how to design, install, test and maintain power supplies but to disseminate information on best practice.

The IRSE Minor Railways Section has used its best endeavours to ensure that the contents of this document are factually and technically correct and is suitable for its stated purpose but the IRSE Minor Railways Section cannot be liable for any subsequent use to which the document may be put.

Any railway seeking to follow the guidelines in this document should ensure that it is suitable for their particular railway concern. Duty holders are reminded that they must be satisfied that they are doing all that is needed under health and safety duties to control risks. Compliance with this guideline issued by the IRSE is not mandatory as it provides advice on how an issue may be addressed.

2 DEFINITIONS

The following is a list of the more common definitions (most taken from BS7671), a fuller description may be found in subsequent sections. Some of the definitions are included so that the reader has an understanding of the more common terms rather than finding references within the main text of the document. In this document terms relating to gender apply equally to male and female.

Term	Definition
BS7671	BS7671:2018 – the IET 18th Edition of the IET wiring regulations
Accessory	A device, other than current-using equipment, associated with such equipment or with the wiring of an installation.
Arms Reach	A zone of accessibility to touch, extending from any point on a surface where persons usually stand or move about to the limits which a person can reach with a hand in any direction without assistance.
Circuit	An assembly of electrical equipment supplied from the same origin and protected against overcurrent by the same protective device(s)
Circuit Breaker	A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overcurrent, typically resulting from an overload or short circuit. Its basic function is to interrupt current flow after a fault is detected. Unlike a fuse, which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation.
Circuit Breaker, linked	A circuit breaker the contacts of which are so arranged as to make or break all poles simultaneously.
Competent Person	A person who possess sufficient technical knowledge, relevant practical skills and experience for the nature of the electrical work undertaken and is able at all times to prevent danger and, where appropriate, injury to him/herself and others
Dead	A supply that has been isolated and has been tested to ensure that there is no voltage present.
DNO	Designated Network Operator – the supplier of electrical energy to the railway system. See also ES below.
Earth	The conductive mass of the earth, whose electrical potential at any point is conventionally taken as zero

Term	Definition
Earth Leakage Detectors (ELD)	A device that monitors the potential to earth on supplies that are designed to be earth free. Normally alarms to a control centre of signal technician when a fault has occurred. Prior to commissioning or replacement the supply should be tested that they are earth free by the use of conventional methods. Some ELD's (such as those supplied by Bender) display the resistance of the system in relation to earth.
Electric Shock	A dangerous physiological effect resulting from the passing of an electrical current through a human body
Electrical equipment	Any item for such purposes as generation, conversion, transmission, distribution, or utilisation of electrical energy, such as machines, transformers, apparatus, measuring instruments, protective devices, wiring systems, accessories, appliances, and luminaires.
Electrical installation	An assembly of associated electrical equipment having co-ordinated characteristics to fulfil specific purpose
Enclosure	A part providing protection of equipment against certain external influences and in any direction providing basic protection
Equipotential bonding	Electrical connection maintaining various exposed-conductive-parts and extraneous-conductive-parts at substantially the same potential
ES	Electrical Supplier – the supplier of electrical energy to the railway system. See also DNO. Not to be confused with Engineering Supervisor
Functional earth	Earthing of a point or points in a system or in an installation or in equipment, for purposes other than electrical safety, such as for proper functioning of electrical equipment.
Fuse	A device which, by the melting of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time, the fuse comprises all the parts that forms the complete device.
Hazard	A hazard is anything that has the potential to cause actual harm
Injury	Injury means death or injury by electric shock, burns, explosions or arcing
Insulation	Suitable non-conductive material enclosing , surrounding or supporting a conductor
Invertor	Equipment that converts a DC supply into an AC supply.
Isolation	A function intended to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation or section from every source of electrical energy
Leakage current	Electrical current in an unwanted conductive path under normal operating conditions
Main Earthing Terminal (MET)	The terminal or bar provided for the connection of protective conductors, including protective bonding conductors, and conductors for function earthing, if any, to the means of earthing
Origin of an installation	The position at which electrical energy is delivered to an electrical installation
Primary supply	The input into a transformer or transformer rectifier.
Protective conductor	A conductor used for some measures of protection against electric shock and intending for connecting together any of the following: Exposed-conductive parts; extraneous-conductive parts; the main earthing terminal; earth electrodes; earth electrode(s); the earthed point of the source or an artificial neutral.

Term	Definition
Reduced Low voltage system	A system in which the nominal line to line voltage does not exceed 110v and the nominal line to earth voltage does not exceed 63.5v.
Residual current	Algebraic sum of the currents in the live conductors of a circuit at a point in the electrical installation.
Residual current device (RCD) or (RCBO)	A switching device designed to monitor the current in the supply and return conductors simultaneously and to open circuit the load when the difference exceeds a pre- determined level. These are often incorporated in current overload trips to form an RCBO.
Risk	A risk is how likely it is that a hazard will cause harm
Secondary supply	The output from a transformer or transformer rectifier.
Spur	A branch from a ring or radial final circuit
System	An electrical system is one in which all the electrical equipment is, or is capable of, connection to a common source of electrical energy and includes such equipment; the source of electrical energy (generator); and an associated installation of conductors switchgear and loads
System, IT	A system having no direct connection between live parts and earth, the exposed-conductive parts of the electrical installation being earthed.
System, TN-C-S	This will be the most usual form of incoming arrangement from the Supplier. The Neutral and protective functions are provided by the same conductor
System, Wiring	An assembly made up of cable or busbars and parts which secure and, if necessary, enclose the cable or busbars
Telecommunications Earth	An earth specifically for telecommunications connected directly to the main earth terminal/bar
UNINTERUPTABLE POWER SUPPLIES	Uninterruptable power supply. A supply that in the event of an interruption of the supply from the DNO, the supply is maintained for a defined period. Normally backed up by batteries and can involve high currents.
Voltage, Extra Low	Not exceeding 50V ac or 120V ripple free dc whether between conductors or to earth
Voltage, High	Normally exceeding low voltage
Voltage, Low	Exceeding extra low but not exceeding 1000V ac or 1500V dc between conductors or 600V ac or 900V dc between conductors and earth

3 SAFETY CONSIDERATIONS

Electrical energy can cause shock, burns, other injury or death.

Any work undertaken on electrical systems must comply with the Electricity at Work Regulations 1989. These require that, wherever practicable, work on electrical systems must be done with the supply isolated. Such isolation may be achieved by using a lock out procedure on the supply side of the work. It may also be achieved by the expedient of removing, and keeping the possession of, the appropriate fuse and link, so long as the fuse and links that are removed isolate BOTH sides of the supply. The simple switching off of an unattended switch is not an acceptable method of isolation. Any isolation that is made should be labelled to ensure that others are aware that it has been isolated deliberately.

Care must be taken to ensure that the circuit being worked on cannot be energised from a another source. Special care needs to be taken whilst working on and around telecommunication batteries where the positive pole of the battery is normally taken direct to the main earth terminal. Earthed mains connected tools should not be used in the vicinity of any telecommunications batteries.

Before opening up conductive equipment housings that are known to contain voltages above 50V AC and 120V DC, it is good practice to test the equipment housing to earth to ensure that the equipment housing is not live before touching the housing. If a battery powered multi-meter is

used for testing, then it should be tested against a known electrical supply before and after testing the housing and / or equipment. A self-testing meter is ideal for use under these circumstances.

4 ELECTRICAL SYSTEMS

4.1 BS7671

The requirements for electrical systems should be followed for all connections to the supply until such time that the supply is functionally separate. Normally this point is at the windings of any transformer that provides galvanic isolation between the input (primary) and output (secondary) terminals. Auto transformers (which have a common winding) and some inverters, uninterruptable power supplies and switch mode power supplies do not provide such isolation.

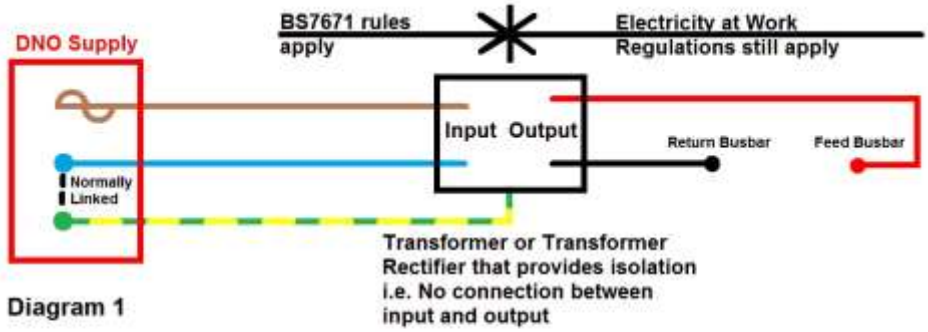

Diagram 1

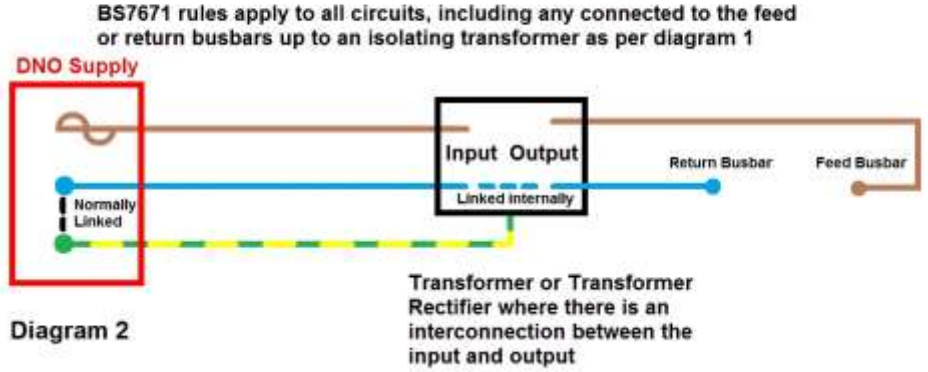

Diagram 2

It is good practice for any wiring that does not need to comply to BS7671 to run the wires in the more traditional black (or red and black) so that there is clear definition between the relevant regulations.

4.2 Signalling / Telecommunications Power Supplies

It is normal in a traditional mechanical signal box that the signalling and telecommunication supplies are deliberately bonded to earth or a common return. If the common return method is used at a signal box which is not referenced to earth, then regular testing of the supplies to earth should be undertaken. A signalling power supply using plug in relays does not normally have conductor bonded to earth and the supply is floating in relation to earth.

Other than extra low voltage equipment, the system components should be shrouded so that access to the live conductors is not possible other than to be able to make measurements. The traditional 2BA / 0BA fuse holders, links and bus-bars should ideally be shrouded from accidental contact by the use of Perspex sheets or, in the case of 2BA links, shrouds over the links that carry the higher voltages (such as 110vAC).

4.2.1 AC Systems

Normally railway power supplies use 110V as the primary source for power. If the power is to be distributed over long distances then supplies can be increased to 240V, 415V or 650V as required. All supplies are NORMALLY earth free so that two faults need to be present to cause a fault. Due to the nature of electrical systems, anyone coming into contact to live conductors may form part of the electrical system and injury could be caused as a result. Staff working on electrical systems must make arrangements to protect themselves from contact with the electrical supply before starting work.

Should higher voltage (other than 110VAC supplies be used) then consideration should be taken to ensure that any trackside cabling is adequately protected from mechanical damage.

Earth free supplies are increasing monitored by earth leakage detectors, although the use of these devices is not mandatory for low voltage systems. The use of regular testing techniques can detect faults – see section five.

Any measurement points should be only accessible with meter probes that have 2mm of exposed metal to reduce the likelihood of electric shock.

The use of switch mode power supplies, uninterruptable power supplies and inverter supplies has seen an increasing use on Minor Railways. If there is a direct connection to the DNO supply then they should be connected and tested as per the requirements in BS7671. Some uninterruptable power supplies may provide isolation between the input and output, but if any form of bypass is provided (for maintenance etc) then the output circuits will still be subject to the requirements of BS7671.

An uninterruptable power supplies or invertor supply is used they should be treated in a similar way as trickle charged battery supplies with regards to standby availability.

Extra low voltage AC systems are normally used for the provision of indications to signalmen.

4.2.2 DC Systems

DC systems can either be a trickle charged battery supply or a transformer rectified supply either smoothed or unsmoothed dependent on the application.

If a battery supply is used, then the load needs to be taken into consideration to ensure that the battery will maintain the supply for the required period of time. This should normally cover the period that the railway is not normally manned and could be up to six days if it is a weekend only operation. This is because if the batteries are allowed to go completely flat then they may never recover fully to maintain the signalling / Telecommunications equipment in an operational state. Mains failure alarms, when provided, are normally located or extended to a normally manned location. This can be by a physical link or by a paging system.

Earth free supplies are increasing monitored by earth leakage detectors, although the use of these devices is not mandatory for low voltage systems. The use of regular testing techniques can detect faults – see section five.

The normal railway supplies are:

- 120VDC – Normally used for point operating equipment. Normally it is formed of a trickle charged battery from the 110V AC supply or from the DNO supply. Exceptionally the supply can be direct to the machine but this can introduce peak volt drop problems on the whole overall system as the load is only taken for a short period of time. Checks should be made that this will not affect the system.

- 50VDC Signalling. Normally used for signalling relays. The signalling supply is normally earth free and is bridge rectified AC with no smoothing, however, smoothed power supplies are perfectly acceptable for use with signalling relays. Need to be aware that the re are regional variations as to the fused polarity – most signalling systems the positive (B50) is fused but in some locations (particularly in the former Western Region and Telecoms circuits the fuses may appear in the negative side (N50).
  Where the circuits require high availability of the supply, the supply can be a trickle charged battery supply.
  It is good practice to separate the supplies for different applications:

    - A supply that feeds equipment in an apparatus housing that does not go external to the housing – a “local” supply. The circuits in use are normally only single cut.

- A supply that feeds equipment that goes external to the equipment housing. The circuits are normally double cut to ensure that any single fault that may occur does not lead to a dangerous situation arising. It is common to find earth leakage detectors fitted to warn of any earth faults occurring. It is also common to find that if the supplies are feeding a long way, a limit of 2000M is used to minimise the effects of induced voltages, particularly where the cable runs adjacent to power lines or electrified railways.

- A supply where the circuit integrity needs to be maintained, such as token or block circuits.

The supply can be as high as 80V when a supply is required to feed circuits over long distances to overcome the effects of losses in the cable. Typically a 50V circuit sent over a cable of a distance of four miles could need a feed voltage of 70V to maintain the 50V nominal coil voltage on a relay. Sometimes a circuit will have a 50V supply feeding a 24V relay under these circumstances, but careful calculation should be made at the design stage to ensure that the circuit will operate correctly.

- 48VDC Telecoms. This supply is normally a trickle charged battery, so that the supply is maintained when there is a failure of the DNO supply. Normally the positive side of the battery is earthed.

- 24VDC signalling. Normally feeds level crossing equipment but can also be used to feed train warning systems. Level crossing equipment is normally a trickle charged battery supply with a 9A charger.

- 24VDC Telecoms. Normally an extension of the signalling 12V supply in mechanical signal box areas, where batteries are added to each side of the 12V supply to give a total potential difference of 48V.

- 12VDC. Normally used to feed mechanical signalling equipment; and where a battery backup is required, for train warning systems. Normally found in a Positive – Common / Earth return – negative configuration and run on batteries in a mechanical signal box. It is normal that separate chargers are used for both the positive and negative supply. A centre tapped 24V battery supply may be used but care should be taken to ensure that each side of the supply is balanced, i.e. the load on each leg of the supply is similar.

4.2.3 Earth Systems.

Any equipment that is required to be earthed should be connected in a star arrangement, i.e. each piece of equipment should be connected by a separate wire to a central earthing point, rather than wiring the equipment in series. The central earthing point should have also have connections to any metal frame work and to the equipment housing. The central earthing point (sometimes know as a MET (Main Earth Terminal)) should then be connected to an earth mat or rod via a link. The purpose of the link is enable the earth system to be tested without any other equipment connected to rule out any parallel paths to earth under fault conditions.

Note: if a signalling power supply is connected to earth, it should be connected by an independent earth to ensure separation from the DNO earth. If the supply is connected directly to the DNO earth then the requirements to BS7671 will apply to all the circuits connected to the shared earth supply.

5 TESTING

The testing of supplies should take into consideration the Electricity At Work Regulations and BS7671. If the supply comes under the BS7671 guidelines then certification must be done by a person that is deemed competent in the regulations. If the supply is deemed to be a signalling / telecommunications supply then the testing should be undertaken by staff that are deemed to be competent in accordance with the railways safety management system.

Typically voltage readings are taken by the use of high impedance multi-meters. While this can give true readings when reading the busbar voltage, readings to earth can be difficult as no discernible current is being drawn. A resistive shunt, typically 150KΩ, may be used to reduce the meter impedance to give an accurate reading. This shunt resistor must not be used on low or high voltage systems as damage will occur to the shunt resistor and could expose the user to unacceptable risk.

Recording of the condition of the supply can only be carried out with the supplies live, so the recommendation is that the supplies should be tested with meter probes having finger guards and the probes should have an exposed metal area of 2mm. When testing supplies that are not extra low voltage, fused meter leads should be used and the functionality of the meter leads should be checked against a known supply before and after use.

The testing of AC supplies to earth can be very difficult. These supplies are best monitored by earth leakage detectors, however the use of an AC busbar adaptor has been developed for use on AC supplies at 110V or **below**. Voltages over 110V AC should be tested with the power isolated due to the risks of electric shock, by the use of an insulation tester once the supply that has been proven to be dead.

The AC busbar adaptor basically superimposes a DC supply on the AC supply and you measure the DC leakage to earth. The safe levels are included in Appendix 1.

The testing of DC supplies to earth and the safe levels are included in Appendix 1.

The current drawn in a circuit should be measured by the use of a clamp meter where ever possible, especially when high currents are involved, typically when measuring currents to uninterruptable power supplies, level crossing barriers and point machines. If the expected current draw is low than a multi-meter may be used to record accurate readings.

Testing of supplies with respect to earth are only as good as the earthing network they are connected to. The earthing system should be regularly tested to ensure that they are providing the safety protection that they are intended to provide. When testing the earthing system, the equipment housings as well as the earth reference point contained in the equipment should be tested to ensure they are connected to an adequate earth. This can be done simply by connecting a multi-meter in ohms between the equipment housing, the earth reference point and the local ground. The recommended values are 8 ohms for a typical equipment case, although in practice a value up to 200 ohms is acceptable, but this will depend on the type of circuits in use. Care should be taken where earth return circuits are in use. A self-testing meter such as a Fluke T130 (£70 - £100) is a useful instrument in these circumstances (there are other suitable instruments available) as it will also indicate if there is a voltage present in relation to earth on the equipment housing or earth reference point.

When testing of supplies it is recommended to record the weather conditions at the time of testing. The quality of the earth and the effect of moisture can affect the readings. If the weather is dry or frosty it is likely that the earth can be high resistant which will give a different result; if the weather is damp or wet then you may get a higher reading to earth. Testing in wet or damp conditions is ideal.

Where the testing of trickle charged battery supplies are concerned then the measurements should be taken with both the charger connected and when the charger is off load to ensure that batteries are in good condition. Often a failure of a single battery in a bank can cause a significant failure. Each cell, or bank of cells, should be tested off charge to ensure that they are operating within their operational parameters.

It is good practice to record the serial number of the meter used when undertaking the readings. Should a different meter used they may be a slight variation in the readings recorded due to the difference in the impedance of the meter. Should the meter fail its calibration tests then it is a useful record of what readings may need to be retaken.

5.1 Commissioning

When testing new supplies they should be tested not only for compliance to the nominal voltage (the norm is ± 10% of the supply voltage) but a check that there are no interconnections between supplies. The exception to this obviously is where the supplies are deliberately interconnected. Care should be taken where the voltages are higher than extra low voltage levels.

Normally the busbar voltage will be recorded, together with the voltage to earth on each leg. If an ELD is to fitted then the ELD should be isolated and the busbar checked to ensure that it is free from earth prior to the commissioning of the ELD. Once it has been confirmed that the supply is free of earth then the ELD can be set up to its operating characteristics.

Once the supply is energised then an assessment should be taken of the total load to ensure that under normal operating conditions that the main fuse will not blow. A check should be made that an excessive current in a single fuse / circuit breaker will not blow the main busbar feed fuse / circuit breaker to minimise the effect of a single fuse / circuit breaker failure not affecting the whole system.

5.2 Maintenance

Regular busbar testing is a good way of monitoring power supplies. Naturally there will be variation in supplies dependent on load and the time of day and the season. Variations up to 5% of the nominal supply can be expected.

It is normal to monitor the busbar voltage and the voltage to earth on each leg. If ELD's are fitted, then the ELD's should be tested regularly to check that they are operational. Most come with a test function, however it is good practice to check with a known value of resistance applied to the busbar to ensure that the ELD responds appropriately.

If the supply is remote from a central location and an ELD is not fitted, then tests can be carried out on an energised circuit at the central location to ensure that the supply is operating correctly within its operational parameters. Using this method any variation in the supply voltage can be influenced by the cable resistance so is not 100% fool proof. However, the reading to earth should be reliable.

6 MAINTENANCE REQUIREMENTS

From October 1st 2010 maintenance has been subject to the Railways and Other Guided Transport Systems (Safety) Regulations requirements on Minor Railways.

See IRSE Minor Railways section guides PO01, PO03, and PO05 for more detailed information, but the following gives some items to consider specifically relevant to power supplies.

6.1 Maintenance Standards / Intervals

The frequency of maintenance will be different for each railway, based on the following factors, this list is not exhaustive:

- Usage
- Weather and/or exposure to salt spray or other corrosives
- Liability to vandalism
- Presence of batteries
- Operational periods of the railway.

6.2 Maintenance Records

It is recommended that every test or replacement is recorded in a logbook, record card or database. Generally the following items are recorded:

- Identity of the asset.
- The date of installation of the asset (especially when testing the condition of batteries).
- Date of the test.
- Who undertook the test (Competence management)
- The instrumentation used to carry out the test (in case of instrumentation failure giving incorrect results).
- Condition of the equipment.
- The weather at the time of the test
- Any repairs undertaken

6.3 Development of Maintenance Plan

The use of the detailed maintenance records will enable the development of a maintenance plan, which will make the best use of the available staff or volunteers. See IRSE Minor Railways section guides PO05 for more information.

7 REFERENCES / FURTHER READING

REQUIREMENTS FOR ELECTRICAL INSTALLATIONS
BS7671:2018, as amended in 2011 (otherwise known as IET wiring Regulations, 18th edition)

ORR / HSE
Electricity at Work Regulations, 1989
Memorandum of guidance on the Electricity at Work Regulations 1989
Electrical Equipment (Safety) Regulations, 1994
GS38 - Electrical test equipment for use by electricians.

Department for Transport
Railways and Other Guided Transport Systems (Safety) Regulations 2006; Statutory Instrument No 2006/599.

8 APPENDICES

Appendix 1
Acceptable levels for Earth Leakage.

Appendix 2
Typical power supply record card format.

APPENDIX 1 – ACCEPTABLE READINGS FOR POWER SUPPLIES

Note:
Reportable means that the Signal Engineer should be informed, but there is no immediate danger. Between Reportable and Maximum Acceptable the fault should be investigated. Readings between Maximum Acceptable and Safety Maximum should be risk assessed and any reading above the safety maximum will present a significant risk to the security of the installation.

DC Supplies

In the tables below, V1 is the voltage between the feed voltage to earth and V2 is the return voltage to earth.

Supply / Busbar Voltage	Supply / Busbar Recommended Limits		DC Busbar Earth Leakage Values					
			Reportable		Maximum Acceptable		Safety Maximum	
	Minimum	Maximum	V1 or V2	V1 + V2	V1 or V2	V1 + V2	V1 or V2	V1 + V2
10	9.0	11.0	5	7	6	8	7.5	9
11	9.9	12.1	5.5	7.7	6.6	8.8	8.25	9.9
12 #	10.8	13.2	6	8.4	7.2	9.6	9	10.8
12 $	12.0 @	14.7 %	6	8.4	7.2	9.6	9	10.8
20	18.0	22.0	10	14	12	16	15	18
22	19.8	24.2	11	15.4	13.2	17.6	16.5	19.8
24 #	21.6	26.4	12	16.8	14.4	19.2	18	21.6
24 $	24.0 @	30.5 %	12	16.8	14.4	19.2	18	21.6
42	37.8	46.2	21	29.4	25.2	33.6	31.5	37.8
46	41.4	50.6	23	32.2	27.6	36.8	34.5	41.4
48 #	43.2	52.8	24	33.6	28.8	38.4	36	43.2
48 $	48.0 @	58.8 %	24	33.6	28.8	38.4	36	43.2
50	45.0	55.0	25	35	30	40	37.5	45
60	54.0	66.0	30	42	36	48	45	54
70	63.0	77.0	35	49	42	56	52.5	63
80	72.0	88.0	40	56	48	64	60	72
100	90.0	110.0	50	70	60	80	75	90
110	99.0	121.0	55	77	66	88	82.5	99
120 #	108.0	132.0	60	84	72	96	90	108
120 $	114.0 @	139.65 %	60	84	72	96	90	108

- Rectifier supply
$ - Float Charged Battery Supply @ - Charger off % - Charger on, and depends on the type of battery in use

AC Supplies

In the table below, V1 is the measurement with the earth lead on the bus-bar adaptor connected to earth, V2 is with the earth lead on the bus-bar adaptor connected to the busbar. The test should be made to the return busbar only.

Supply / Busbar Voltage	Supply / Busbar Recommended Limits		AC Busbar Earth Leakage Values – Must not be used on voltages greater than 110V							
			Battery Voltage	Reportable		Maximum Acceptable		Safety Maximum	
	Minimum	Maximum		V1 or V2	V1 + V2 *	V1 or V2	V1 + V2 *	V1 or V2	V1 + V2 *
110	99.0	121.0	9.5	7.6	1	8.55	1	14.25	1
230	207.0	253.0	9	7.2	1	8.1	1	13.5	1
415	373.5	456.5	8.5	6.8	1	7.65	1	12.75	1
650	585.0	715.0	8	6.4	1	7.2	1	12	1

* Or V2 – V1 if V2 is greater than V1

APPENDIX 2 – TYPICAL RECORD CARDS

AC Record Card											
Signal Box:				**Location:**				**A Heritage Railway Co**			
Supply				Supply				Meter No	Testers Name	Date	Weather
Busbar Voltage	Vb	V1	V2	Busbar Voltage	Vb	V1	V2				

DC Record Card										
Signal Box:			**Location:**				**A Heritage Railway Co**			
Supply			Supply			Value of Meter shunt	Meter No	Testers Name	Date	Weather
Busbar Voltage	V1	V2	Busbar Voltage	V1	V2					

DC Record Card – Remote Monitoring										
Signal Box:			**Location:**				**A Heritage Railway Co**			
Circuit			Circuit			Value of Meter shunt	Meter No	Testers Name	Date	Weather
Relay energised voltage	V1	V2	Relay energised voltage	V1	V2					

DC Record Card – Battery Fed Supplies												
Signal Box:				**Location:**				**A Heritage Railway Co**				
Supply				Supply				Value of Meter shunt	Meter No	Testers Name	Date	Weather
Busbar Voltage Power on	Busbar Voltage Power off	V1	V2	Busbar Voltage Power on	Busbar Voltage Power off	V1	V2					

Earth Potential Record							
Signal Box:		**Location:**		**A Heritage Railway Co**			
Earth System Resistance	Resistance between Earth Reference and Equipment Housing	Voltage between Equipment Housing and Earth	Comments	Meter No	Testers Name	Date	Weather
Ω	Ω						
Ω	Ω						

Earth Leakage Detector Testing Record									
Signal Box:			**Location:**			**A Heritage Railway Co**			
Supply			Tick or add reading as required		Value of Meter shunt	Meter No	Testers Name	Date	Weather
Busbar Voltage	V1	V2	Fault	Test					

These are just typical of what could be used; additional columns can be added for comments etc. What is recorded is at the discretion of the particular railway organisation. If the supply is monitored by and earth leakage detector, it is still good practice to record the main bus-bar voltage.