CORPORATE REFERENCE DOCUMENT

STANDARD SPECIFICATION

FOR

EARTHING OF INSTRUMENTATION AND COMMUNICATION SYSTEMS

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1.0  INTRODUCTION

This Standard Technical Specification specifies the minimum technical requirements for the design of effective and safe earthing of instrumentation and communication systems used in the water, wastewater and associated industries.

2.0  SCOPE

The Specification covers, in particular, instrument earthing requirements. It is not intended to cover all earthing techniques. For plant earthing systems this Specification shall be read in conjunction with the "Standard Specification for Electrical Installation" and the reference documents listed in Sections 4.0 and 5.0 below.

Intrinsically safe (IS) earthing is not covered in this Specification as this form of earthing is associated with hazardous areas.

3.0  DEFINITIONS

In referring to "earthing" a wide variety of terms are in use, several of which have the same meaning. The first terms mentioned and bracketed ( ) letters below shall be the preferred ones to be used within the Brown & Root NA Ltd (BRNA) environment. Alternative terms used in some other reference documentation are shown in brackets ( ).

Earthing Definitions for Instrumentation and Communication Systems (ICS)

Bonding (Equi-potential Bonding)

The connection of metallic parts to ensure that they are at the same potential. One of the bonding points is then taken to an earth point or bar.
Earth Bar (EB)

A metal bus bar, which shall be copper, to which several earthing conductors are connected for marshalling purposes. They shall always be identified by type (e.g. reference, protective, IS, instrument, etc.).

Earth Fault Loop Impedance

The electrical vector sum of resistance and reactance that represents the total opposition to current flow in an a.c. electrical circuit, measured in ohms.

The earth loop impedance is the impedance of the earth fault current loop starting and ending at the point of earth fault.

Independent Earth System

An earth system in which the installation earth bed is physically separated from the incoming supply earth bed at such a distance that the maximum current likely to flow through one does not significantly affect the potential of the other and there is no electrical connection between them.

Combined Earth System

An earth system in which the earths are physically connected to the incoming power supply protective conductor and earths.

Main Plant Earth (MPE) (Plant Earth, Main Earth, Main Plant Electrical Earth)

The point on the plant used as the main earth point for the whole earthing system, and to which all other earthing systems directly connect.

Protective Conductor (Earth Continuity Conductors, Equipotential Bonding Conductors, Earthing Conductors)
A conductor used for some measure of protection against electric shock and intended for connecting together any of the following parts:

- Exposed conductive metal parts.
- Main earthing terminal.
- Earth electrode (rods, mats etc.).
- The source earthed point, for example, star point of transformer.

Protective Earth (PE) (“Dirty” Earth, Chassis Earth)

An earthing point to which earthing conductors, from metallic items, are connected in order to ensure the item does not become elevated in potential so as to cause danger to personnel safety or damage to equipment. Connected at one point to the plant electrical earth.

Reference Earth (RE) (Clean Earth, Instrument Earth)

A unique earthing point, preferably outside the resistance area of a dirty earth, used solely to provide an electrical datum level in instrumentation and telecommunication systems.

Screen Earth (SE)

An earthing system designed to minimise interference in sensitive low current equipment caused by electrostatic fields.

System Earth

The total earth configuration which shall include dirty earth points, reference earth points and the earth ring conductor network. This shall include all earth bars.
True Earth, Remote Earth

Terms used in differing engineering applications, both referring to connections to the general mass of Planet Earth.

4.0 REGULATIONS, CODES AND STANDARDS

Unless indicated otherwise in this Specification, the requirements of the following regulations codes and standards shall apply:-

**British Standards Institution (BSI)**

- BS 6651 Code of Practice for Protection of Structures Against Lightning.
- BS 7430 Code of Practice for Earthing.

**International Electrotechnical Commission (IEC)**

- IEC 364 Electrical Installations of Buildings.
- IEC 446 Identification of Conductors by Colours or Numerals.
5.0 OTHER REFERENCE DOCUMENTS

Brown & Root NA Ltd (BRNA)

BRNA-SP-EL-010 Standard Specification for Power and Control Cables.
BRNA-SP-EL-012 Standard Specification for Electrical Installation.
BRNA-SP-IN-001 Standard Specification for General Requirements for Controls and Communications.

6.0 TECHNICAL REQUIREMENTS

The following Figures shall be referred to as necessary:

- Figure 1 Instrumentation Earthing System.
- Figure 2 Earthing of Cable Screens and Armour.

6.1 Purpose

Earthing shall be installed to guard against the invasion of circuits by unwanted electrical energy, either man-made or naturally occurring static, for example, lightning.

Earthing shall perform two protective roles:

- Plant operation, i.e. preventing signal, hence operating, errors.
- Personnel/plant protection from damage, for example, shock, lightning.

The system installed shall be fit-for-purpose and shall be designed, installed and maintained to appropriate standards acceptable to Owner.

The whole system shall be easily identified as an earth system. The design shall ensure that during operation and maintenance no alterations or disconnections can inadvertently occur so as to endanger plant or personnel.
The following shall be undertaken:

- Cabling and associated items, for example earth bars, earth-rods, equipment etc., shall be clearly labelled and identifiable.
- Routing shall be traceable.
- Items installed shall be of known and correct quality.

6.2 Types of Invasion

6.2.1 Faults and Interference

Conductors and cable screens shall be connected to the earthing network to avoid unwanted circulating currents that may cause instrument malfunction or damage due to overheating or sparking.

An earth return path for the fault current shall be ensured. This path shall ensure that voltages will be reduced to a non-injurious level and that equipment protective circuits will be operated to prevent hazardous conditions.

All systems shall have high quality connections at all cable screens, cable armour and at metallic case bonding points so that any earth fault currents returning to the supply point cannot cause, in themselves, dangerous temperature rises at that point.

6.2.2 Lightning

Lightning is covered in this Specification only in respect of instrumentation and communication as follows:

- Field instruments.
- Control room instrumentation and communication equipment and panels.
- Microwave towers and aerial masts.
Reference shall be made to "Standard Specification for Electrical Equipment and Materials" and "Standard Specification for Electrical Installation" for earth protection, including lightning and protective earthing, of the following:

- Electrical plant for example, pumps, motors, generators, vessels, compressors, ductwork, traywork etc.
- Power supply and distribution systems.
- Pipework and pipe-racks.
- Buildings and HVAC systems.
- Fences and barbed wire, structural steelwork.
- Lighting and lighting standards.
- Standby generation.

6.3 Components of the Instrument Earthing System

6.3.1 General

The earthing system shall comprise:

- An item of equipment such as instrument, cable, panel, aerial mast etc.
- Some form of inter-connection.
- A method of marshalling similar types of connection.
- A final earth point connection.

Two items shall be provided under the "Standard Specification for Electrical Installation":

- An earthing grid.
- A supply earth return connection point, for example star point of the supply transformer.

6.3.2 Items of Equipment
Where items of equipment have earth connection points provided by the manufacturer or a standard method of connection, this shall be used for earthing.

If earthing requires the utilisation of bolts and clamps installed at site into newly or pre-drilled holes, the correct surface preparation shall be detailed to ensure connection to bare metal and the use of anti-vibration washers and anti corrosion techniques shall be used to ensure a permanent and satisfactory low impedance joint. Contractor shall submit appropriate details to Owner for approval.

6.3.3 Equipment Marking

Where equipment which has pre-designated and identified earthing points, the earthing points shall conform to the identification of equipment terminals as specified in IEC 445:

- PE - protective conductor.
- E - earthing conductor.
- TE - low noise earth conductor.
- MM - frame or chassis.
- CC - equipotential connection.

The size of the protective earthing and bonding conductors shall be as stated in IEC 364-5-54.

6.3.4 Protective Earthing

Every piece of metalwork, including doors, gland plates etc. shall be solidly bonded and taken to earth to prevent any personnel hazard arising during fault conditions.

There shall be no likelihood of any high voltages appearing between adjacent apparatus or cubicles that can be touched at the same time.
A panel protective earth bar may be provided within the panel to marshal multiple protective earths. These earths shall not be connected to or via the reference earth bar.

6.3.5 Instruments not Associated with Cathodically Protected Pipelines

The metal of the body, associated valves, manifold and instrument stand shall be equipotentially bonded and one bonding point shall be earthed to the nearest protective earth.

6.3.6 Instruments Associated with Cathodically Protected Pipelines

If the instrument is connected to a cathodically protected pipeline, it shall not cause the pipeline to be earthed. In order achieve this either:

- The instrument shall be allowed to "float" at pipeline potential by using insulating glands on the cable to prevent the cable armour from earthing the instrument.
- The instrument shall be directly mounted on the pipework.
- The cable screen(s) shall be isolated and insulated at the instruments end and only earthed at the control room end.
- The armour shall be isolated from the instrument at the instrument end, and armour on the panel end insulation shall be taken to earth.

or:

- The instrument shall be earthed but isolated from the process line by fitting the process tubing between the instrument and the pipeline valve with an isolating fitting. In this case the cable armour/instrument may be earthed.
6.3.7 Equipment Instrument Supply/Transformers

The instrument supply isolating transformer secondary winding, the transformer metallic inter-winding screen and the primary mains (a.c.) supply earth shall be connected directly to the protective earth bar.

All earthing and bonding terminations shall be made such that they do not self loosen. Earthing conductors shall be fitted with crimped compression or soldered style ring lugs.

6.3.8 Instrument Power Supply Earth Returns

Where a power supply unit supplies a number of instruments, earth return paths shall be designed so that there shall be no unwanted interaction between circuits due to a common impedance, even under fault conditions. The earth returns from individual instruments shall be separately routed back to the power supply unit. Earthing cables shall be sized to comply with BS 7671 Table 54G giving the minimum size of the corresponding protective conductor with respect to the supply (phase) conductor. In practice the earthing conductor may be the same size as the supply conductor.

Earth conductors shall be sized so that with the maximum possible value of fault current, the protective devices can operate and no potentially damaging temperature rises or hazards to personnel can occur.

Under normal conditions, earth conductors shall not carry any currents other than fault induced currents.

6.3.9 Instrument Distributed Control System (DCS) Earths

Signal zero conductors, zero voltage reference conductors, high quality earths (typically < 0.5 ohm impedance to the earth point with low measurable noise) and signal earths which may carry signal currents shall be separately returned to zero or the reference earth point. Where required, these conductors shall be screened to reduce electrical interference.
When signals span two equipment locations galvanic isolation shall be used to prevent earthing problems. Remote DCS equipment cubicles shall be considered as separate locations for earthing with a reference earth point in each location.

Each location shall have its own protective earth and, where required, a power central earth point or mat.

Unless otherwise specified/approved by Owner, instrument earth conductors between equipment cubicles within the same location shall generally be run in 6 mm² cable for mechanical strength as well as minimum resistance.

6.3.10 D.C. Supply Earthing

If the d.c. supply is required to be earthed, the appropriate negative (or positive) terminal shall be connected to the reference earth bar by an insulated conductor.

It is common practice in communication systems to use positive earthing whereas instrument systems are more usually negatively earthed.

Battery systems shall not be left "floating" but shall have one side earthed.

6.3.11 Communication Equipment Earthing

Where a communication system is located on the plant it shall be incorporated into the plant main earthing system.
6.4 Earth System Interconnection

6.4.1 Earth Conductors

The earth system shall be interconnected by insulated conductors. Where this is not practical, Contractor shall submit alternative proposals for Owner approval.

The conductors shall be stranded copper.

The conductors shall be positively connected at each end, for example by ring type crimped lugs. Crimping shall be performed by a tool specially designed to give the correct compression onto the conductor strands. Lugs shall be fitted using a tool specially designed for the purpose. The use of standard general hand-tools such as pliers shall not be permitted.

In the case of light current earthing duty crimped ferrules may be used into clamp type terminal blocks.

For connections in large cables for passing heavy electrical currents fusion welded jointing shall be used.

Where large cross sectional areas are required for heavy current carrying capacity, covered copper earthing bars may be used in place of cables.

6.4.2 Marshalling

Multiple conductors shall be marshalled at convenient points to reduce the number of earth conductors.

The reference earths and the protective earths shall be marshalled separately.

These systems shall have separate earth bars which shall be arranged such that they cannot be simultaneously touched to ensure that there is no flash-over due to differing potentials.
6.4.3 Reference Earths

Each individual item shall be earthed by its own conductor to the common reference earth.

6.4.4 Protective Earth

All metallic items of plant, unless specifically excluded for operational reasons and protected by other forms of protection, shall be positively and securely connected to earth via a protective conductor, appropriately sized, to carry fault currents, and in accordance with BS 7671.

The following items shall be connected to the protective earth:

- Cable armour.
- Panel framework and cladding.
- Traywork, ductwork, cable ladders and conduits.
- Instrument enclosures, manifolds and stands, unless connected to cathodically protected pipework.
- Equipment enclosures, including doors, and gland plates.
- Transformer interwinding screens.
- Line mounted instrumentation.
- Local manual control/pushbutton station.
- ICS cable gland plates and transits.
- Fire and gas detection sensor enclosures and baffle plates.
6.4.5 Overall Connection Concept

The overall connection concept, showing the interconnection of various earth bars, conductors, cable armour and screens shall be as shown in Figures 1 and 2. Where necessary, isolating techniques shall be used to ensure the following:

- Earth loops are avoided.
- Signal screens are effective.

Screens on cables between the main and local control centres shall be earthed at the reference earth bar in the main control centre and shall be isolated from the local control centre earth.

6.4.6 Disconnect Links

Periodic testing shall be carried out to ensure that the integrity of the earth system is maintained. To facilitate this and to ensure that the impedances of the systems are correct for their reference or protective functions and to meet the required test standards, system disconnect links shall be provided. Disconnect links shall allow the inspection and testing of each system independently. The disconnect links shall only be disconnected when all power to the system being protected by the earth system is removed.

The following disconnect links shall be provided within the earthing system:

- Disconnect links as specified for the electrical distribution system covered by "Standard Specification for Electrical Equipment and Materials".

- Disconnect links between the main plant earth bus bar and the following:
  - Reference earths.
  - Building lightning protection systems.
  - Microwave/radio/communications tower lightning protection system.
  - Supply earth point.
Any other earth electrode systems such as fencing or lighting.

6.4.7 Cable Screen and Armouring

The design of the earthing system shall be such that cable screens and cable armouring are kept electrically separate throughout the installation as shown in Figure 2. Armoured cable shall have insulation between screen and armour.

The cable screen shall be connected to the reference earth and the armour shall be connected to the protective earth.

The reference and protective earths shall be maintained separate until the two are deliberately connected together at one central earthing point. This technique avoids the introduction of earth loops and minimises interference pick-up.

Earthing connection shall be as follows:

- Armour at both ends connected to protective earth.
- Screen separate from armour.
- Screen earthed at one end only with the other end insulated.

6.5 Main Plant Earth

On each site (or zone within a large site) there shall be only one system earth point which will be connected to the main plant earth.

The main plant earth shall be designed in accordance with:

- "Standard Specification for Electrical Equipment and Materials".
- "Standard Specification for Electrical Installation".
- BS 7430
- BS 6651

The protective earth and reference earth shall each be connected to the main plant earth bar.
Where there is a microwave or radio tower earth system which cannot be considered as an independent earth system, it shall be connected to the main plant earth bar. Under these circumstances the impedance criteria for the earth shall be:

- The microwave tower "electrode system resistance to earth" shall be less than 10 ohms in accordance with BS 6651 section 3 paragraph 16.
- The microwave tower "electrode system resistance to earth" shall be less than the main plant earth.

6.6 Control Centres

6.6.1 Control Centre Reference Earth Bar

Each control centre shall have its reference earth bar directly connected by the shortest route to the main plant earth bar or ring.

Two insulated conductors shall be run in parallel and spaced 150mm apart between the control centre instrument earth bar and the main plant earth bar or ring to ensure high integrity and ease of testing.

The reference earth bar shall be made of hard drawn copper with a minimum cross section of 50 mm x 6mm and shall be mounted on insulators to ensure complete isolation from panel/framework. The insulators shall ensure that bar stands off by a minimum of 50mm.

The cables connecting the reference earth bar with the main plant earth bar shall be sized in accordance with BS 7671 but shall have a cross sectional area of not less than 6mm².
6.6.2 Control Centre Protective Earth Bar

The control centre protective earth bar shall be connected by cable in accordance with BS 7671 to the main plant earth. The protective earth bar shall be bonded to the local metalwork.

6.7 Control and Equipment Panels

6.7.1 General

Control and equipment may contain both a reference earth bar and a protective earth bar.

These shall be easily accessible and positioned or protected such that no inadvertent crosslinking can occur between them.

6.7.2 Control Panel Earth Bars

Each instrument and control sub-assembly unit shall have a reference earth bar and a protective earth bar.

Each shall be directly connected by the most direct route to the respective control centre earth bar by an insulated colour coded earth conductor.

The panel reference and protective earth bars shall be made of hard drawn copper with a minimum cross section of 25mm x 3mm, with only the reference earth bar mounted on insulators to ensure complete isolation from the panel/framework. The insulators shall ensure that the reference earth bar stands off by a minimum of 25mm.

The cables connecting the panel earth bars with the control centre earth bars shall be sized in accordance with the BS 7671 but shall have a cross sectional area of not less than 6mm².

6.8 Telecommunications, PABX and Operator Order Wire (OOW) Earthing
The armouring shall be bonded to the protective earth system and the screen drain wires shall be connected to the reference earth terminal or bar.

Further details of earthing are contained in the regulations, codes and standards referenced in the "Standard Specification for Telecommunications".

For the fibre optic systems, the armour of the fibre optic cable shall be earthed to the protective earth system at each end of the cable.

### 6.9 Lightning Protection Units (LPUs)

LPUs shall be installed on all external lines which enter electrically sensitive, expensive and/or plant safety sensitive equipment including:

- Remote telemetry equipment.
- Programmable logic controllers (PLCs).
- Radio telemetry modems.
- Microwave/aerial feeders.

As lightning current will take the easiest path to earth the location of the LPU(s) is critical. The LPU earth conductor shall be designed to provide the preferred lightning path by virtue of size, route and location to the protective earth system.

Lightning protected versions of standard field instrument transmitters shall be considered for use in areas subject to frequent lightning strikes, especially in safety critical applications.

### 6.10 Lightning Protection

Unless otherwise agreed by the Owner, microwave or radio towers shall be located at such a distance from other structures that their earth electrode system is outside the influence of any other earth electrode system and provides an independent earth system. The earthing of microwave or radio towers shall be in accordance with BS 6651. Particular attention is drawn to Appendix C paragraph 7.4 and figure 47.
6.11 Identification and Labelling of the Earthing System

The two earthing systems, reference and protective, shall be easily identifiable. The earth conductor sheath of each system shall have the following colour:

- GREEN for the reference earth.
- GREEN with YELLOW stripe for the protective earth.

The use of green/yellow (Gn/Y) marking for identifying protective conductors is covered in IEC 446.

All items of equipment, cables, electrodes, earthbars, test-points shall be adequately identifiable and labelled to ensure that the earth system can be verified fit-for-purpose, and tested/maintained as such. In particular:

- All earth bars shall have appropriate nameplates located adjacent to the bar as follows:
  - Reference earth bar.
  - Protective earth bar.
- Cables interconnecting the earth system and links shall also be fitted with a warning notice indicating that:
  - "Authorisation/Permit is required prior to disconnection"
  or
  - "Protective earth. DO NOT disconnect without Authorisation/Permit".
- All cables shall be identifiable as to whether they are part of the reference earth system or protective earth system.
- In cases where isolation is required, for example from a cathodically protected pipeline a warning label shall be provided as follows:
  - "Attention CP Isolation", (for example).
For earth bars with a "disconnect test link", a label shall be affixed as follows:

- "Test-Link". DO NOT disconnect without Authorisation/Permit.

7.0 DOCUMENTATION TO BE SUBMITTED

Contractor shall submit the following documentation to Owner for review and approval:-

- ICS earthing layout - plot plan.
- Plant earthing system diagrammatic.
- Cable specification (full - physical/electrical).
- Manufacturer's catalogues and full descriptive data.
- Materials lists/certificates/specifications.
- Installation, maintenance and test procedures.
- General arrangement of installations and assemblies (dimensioned).
- Cable and equipment schedules.
- Details and test/calibration equipment required.
- Details of any specialised tools or equipment required.
- Earth electrodes calculations.
- Site earth connection procedure.

The ICS earthing forms part of the overall plant earthing system and appropriate references shall be made to the documentation required for:

- "Standard Specification for Electrical Equipment and Materials".
- "Standard Specification for Electrical Installation".
**INSTRUMENTATION EARTHING SYSTEM**

**FIG 1**