Earthing in Signalling Installations

(Based on Latest TAN, RDSO, CAMTECH, IRSEM & IRISET)

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Chapter- 1

Concept of Earthing

1.1 Introduction

The earth is made up of materials that are conductive such as mineral bodies containing metallic contents. Whenever lightning strikes near a building or structure, electromagnetic/electrostatic induction is produced due to nearby high voltage power lines, due to which fault currents are generated. These currents will travel through the metallic bodies of the nearby structures and induce dangerous potential (voltages) in cables or exposed metallic bodies of electrical equipment.

This may give electric shock to the person coming in contact with the metallic bodies and cause extensive damage to the equipment. If these equipments are connected to earth by means of a metallic conductor, the fault current will flow to the earth thereby preventing shock to the user and damage to the equipment. Hence all exposed metal parts of an electrical installation or electrical appliances must be earthed.

1.2 Importance of Earthing

The earthing is essential because of the following reasons

- The earthing protects the personnel from the short-circuit current.
- The earthing provides the easiest path to the flow of short-circuit current even after the failure of the insulation.
- The earthing protects the apparatus and personnel from the high voltage surges and lightning discharge.

Earthing can be done by electrically connecting the respective parts in the installation to some system of electrical conductors or electrodes placed near the soil or below the ground level. The earthing mat or electrode under the ground level have flat iron riser through which all the non-current-carrying metallic parts of the equipment are connected.

1.3 Electrical Earthing

The process of transferring the immediate discharge of the electrical energy directly to the earth by the help of the low resistance wire is known as the electrical earthing. The electrical earthing is done by connecting the non-current carrying part of the equipment or neutral of supply system to the ground.

Mostly, the galvanised iron is used for the earthing. The earthing provides the simple path to the leakage current. The short-circuit current of the equipment passes to the earth which has zero potential. Thus, protects the system and equipment from damage.

1.4 What is Earth Resistance?

Whenever we talk about resistance, it is a two terminal device and the value of resistance is with respect to two terminals. Whereas, in case of earth there is only one terminal and the earth resistance is basically the resistance between the electrode and the reference earth at infinity.

Earth resistance is defined as the resistance offered by the earth electrode to the flow of current into the ground. It is also known as resistance to earth or ground resistance. The ideal

earth resistance is considered to be zero, such that there is a quick flow of fault current into the ground, but this is practically impossible. The earth resistance value is different in different locations. Earthing value as per Indian Standard gives a tolerable resistance value for different structures and is mainly depending on the soil resistivity.

Earth resistance is an important parameter for designing and maintaining earthing systems, as it affects the safety and performance of electrical installations.

It is a measure of the resistance between an earth electrode and the surrounding soil, which ultimately affects the effectiveness of the grounding system.

International standards such as IEC 62305 and BS 7430 play a crucial role in ensuring safety by defining earthing design practices for various electrical installations. Earthing systems consist of earth electrodes, clamps, conductors, and equipotential bonding bars that maintain a consistent potential gradient throughout a substation.

British Standard BS 7430 provides guidance on the earthing design for various electrical installations.

1.5 What is an Earth Electrode?

An earth electrode is a metal rod or plate that is buried in the soil and connected to the earth terminal of an electrical system. It provides a low-resistance path for fault currents and lightning surges to dissipate into the ground. It also helps to stabilize the voltage of the system and reduce electromagnetic interference.

1.6 What are the Factors that affect Earth Resistance?

According to IS 3043, the earthing resistance value is dependent on three factors:

(i) The resistance of the earth electrode

(ii) The soil resistivity

(iii) The contact resistance between the electrode surface and the soil

The factors at (i) & (iii) are considered negligible compared to the soil resistivity (at ii) therefore they are practically avoided. The earth‟s resistance mainly depends on the resistivity of the soil between the electrode and the point of zero potential (infinite earth). This is the reason why we mainly focus on soil resistivity measurement when we consider the earthing value as per Indian Standard. The resistivity of the soil is influenced by several factors, such as:

- The electrical conductivity of the soil, which is mainly due to electrolysis. The concentration of water, salt, and other chemical components in the soil determines its conductivity. Moist soil with high salt content has lower resistivity than dry soil with low salt content.
- The chemical composition of the soil, which affects its pH value and corrosion properties. Acidic or alkaline soil can corrode the earth‟s electrodes and increase its resistance.
- The grain size, uniformity, and packing of the soil particles affect its porosity and moisture retention capacity. Fine-grained soil with uniform distribution and compact packing has lower resistivity than coarse-grained soil with irregular distribution and loose packing.
- The temperature of the soil, which affects its thermal expansion and freezing point. High temperature can increase the conductivity of the soil by increasing its ion mobility. Low temperatures can decrease the conductivity of the soil by freezing its water content.

1.7 Significance of Earth Resistance

Suppose if a current is injected (high current due to surge or traction sub station) in an earth electrode, then there will be rise in potential at the electrode which will depend upon the earth resistance. A low earth resistance value is desirable as it helps to reduce touch and step voltages, minimize the risk of electrical shock, and improve the overall performance of the earthing system.

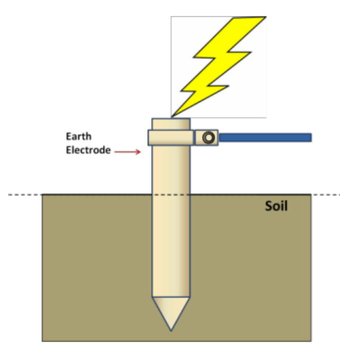

Figure 1 : Current flow during lightning strike in an earth electrode

Hence, higher the earth resistance, higher is the voltage developed at the earthing system for dissipating same current.
Now the question arises: Earth is a bad conductor then how it offers low resistance ($\leq$1 Ohm).
The explanation is given in following paragraphs.

1.8 Principle of earth resistance calculation-

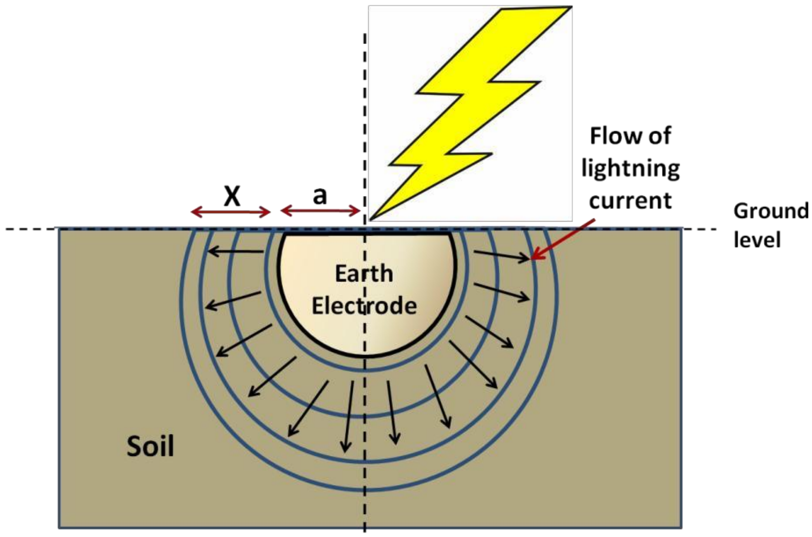

Figure 2 : Current dissipation in the earth through earth electrode

- Soil resistivity (ρ) varies widely (few Ω-m to 1000 Ω-m) and is much higher than metals, but earth behaves as a large sink due to its huge mass.
- When current is injected into an earth electrode, it spreads into the surrounding soil in all directions. As the area of spread increases, current density decreases, leading to reduction in electric field and voltage.
- Most of the voltage drop occurs within a short distance from the electrode.
- For theoretical analysis, the earth electrode is assumed as a hemisphere. The earth resistance is given by:

$$R = \frac{\rho}{2\pi a}$$

(where ρ = soil resistivity, a = radius of hemisphere)

- From the formula:
    - Increase in surface area (larger electrode/effective radius) → lower resistance
    - Lower soil resistivity → lower earth resistance
- **Earth resistance mainly depends on soil properties; electrode material (Cu/GI) has negligible effect**.
- Example (Single Electrode):

  In Indian Railways, normally earth electrode of following dimensions is used:

Length L = 3 Mtr, Diameter d = 38 mm, Radius a = 17 mm = 0.017 Mtr.

The value of Earth Resistance can be calculated as given formula -

R = ρ/ 2лL (ln 4L/a – 1)

Where ln denotes logarithm base 10

- ρ = 40 Ω-m → R ≈ 11.78 Ω
- ρ = 20 Ω-m → R ≈ 6 Ω
- ρ = 4 Ω-m → R ≈ 1.2 Ω

- Rocky or poorly compacted soil has higher resistivity → higher earth resistance.
- Therefore, soil resistivity survey is essential to decide the number of electrodes required for achieving desired earth resistance.

1.9 Effect of inter-electrode spacing

Sometimes if the required earth resistance value is not achieved with the help of single earth electrode, then more than one electrodes are provided.
Earth resistance of single earth electrode calculated as above R= 11.78 Ohm

The following table shows the calculation of earth resistance of two earth electrodes placed at a distance 'S' interconnected with GI wire or metal strip

Inter Electrode Spacing S	Net Earth Resistance R_E	% of Single Electrode Earth Resistance R (=11.78 Ohm)
0.5 M	8.29 Ohm	70.3%
2 M	7.06 Ohm	60%
3 M	6.8 Ohm	57.7%
4 M	6.64 Ohm	56.4%
6 M	6.39 Ohm	54.2%
15 M	6.11 Ohm	51.8%
30 M	6.0 Ohm	50.9%
1 Km	5.91 Ohm	50.1%

It can be seen from the above table that when the distance between the two electrodes is 6 Meter, the earth resistance value is dropped upto 54.2% of the single electrode earth resistance. By increasing the inter electrode distance further, no significant improvement in earth resistance is observed. As earth electrode of 3 meter length is used in Indian Railways, inter electrode spacing should be kept twice the electrode length i.e. 6 meter for best results. Coming closer upto 3-4 meter due to space constraint is not optimum but can be done if unavoidable as it will not compromise upto that extent.

1.10 Effect of interconnecting electrodes-

Case 1 : Single Electrode

In this case whenever any current comes to the electrode, it dissipates in all directions. This is shown in ***Figure 3*** below:

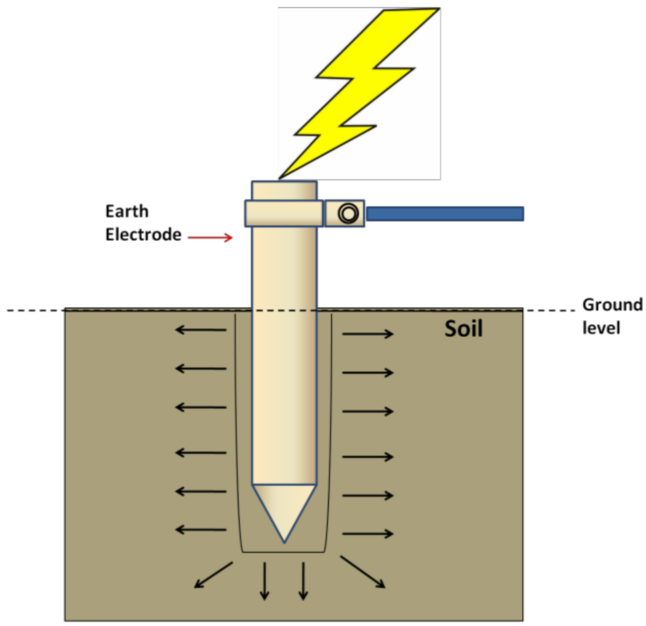

Figure 3 : Current dissipation through single electrode

Case 2 : Two Electrodes joined at a terminal

If two electrodes are used and joined by GI wire or strip at a common terminal say at a location box, then the effective resistance becomes less as compared to the resistance of single earth electrode as their path of dissipation becomes common. (***Figure 4***)

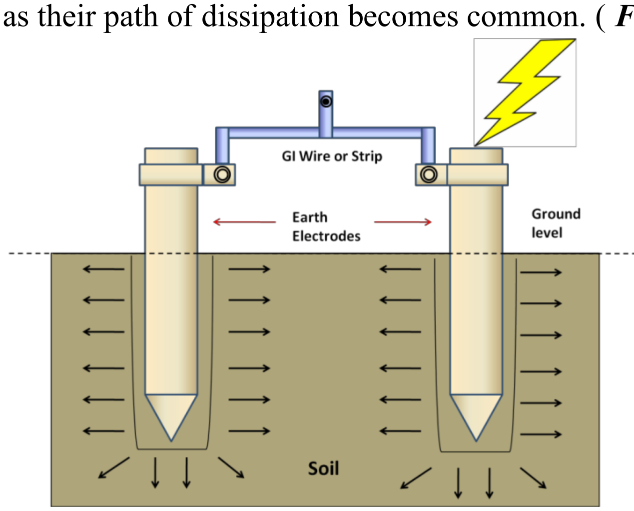

Figure 4 : Current dissipation in two electrodes joined at a terminal

Case 3: Two Electrodes joined with naked buried GI strip

If two earth electrodes are provided and internally joined by buried GI wire or strip then the earth resistance will improve further as the path for dissipation of current is enhanced as compared to the set up in Case 2. (***Figure 5***)

Note:

The GI strip should be naked and buried minimum 6 inches in the earth, then only the current is dissipated properly.

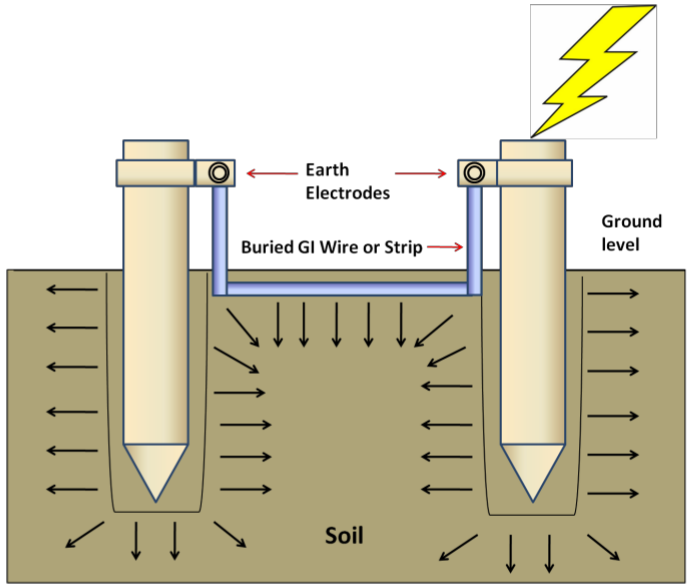

Figure 5 : Current dissipation in two electrodes joined with naked buried GI strip

In this way the earth resistance value can be brought to a very low value which is required for some signalling applications. This forms the basis for ring earth.

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Chapter-2
CONVENTIONAL EARTHING ARRANGEMENT

2.1 Introduction

The conventional earthing arrangement is mainly provided for earthing of Mechanical & Electrical Block Signalling equipments like lever frames in cabins, cable terminal boxes connecting the ends of the cables, metallic sheathing and armouring of cables, lightning and spartk arrestors, signal location boxes, signal screens and block instruments.

The earthing arrangement in this system consists of the following:

• Soil.
• Earth lead wire.
• Earth electrode.
• Connecting wire to extend earth to equipment**.**

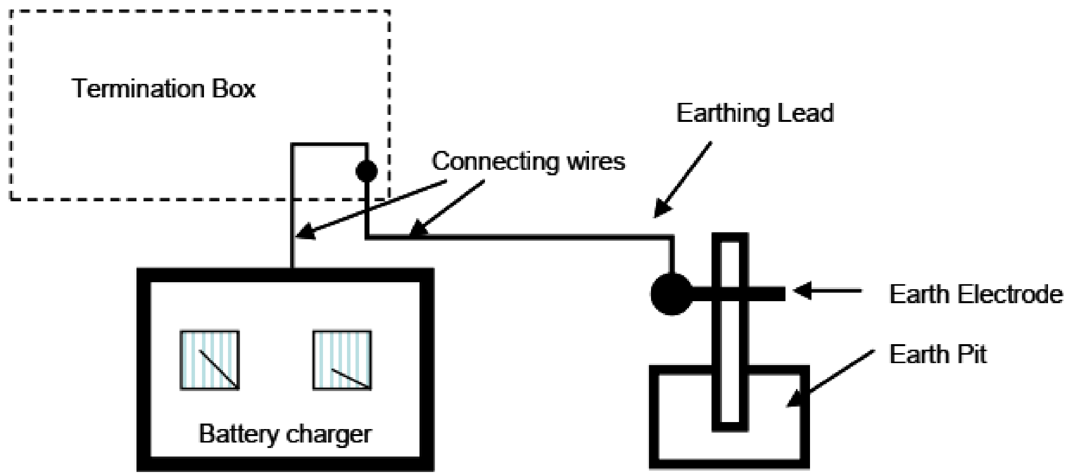

Fig. 2.1: Conventional earthing arrangement for power equipment (Battery Charger)

2.1.1 Soil

The site for earthing should be chosen in the following order:

1. Wet marshy ground and grounds containing refuse such as ashes, cinders.
2. Clay soil or loam mixed with small quantity of sand.
3. Clay mixed with varying properties of sand, gravel and stone.

2.1.2 Treatment of Soil

• The soil is to be prepared to obtain optimum resistivity.
• To reduce the resistivity of soil, some highly conductive substance is required to be dissolved in the moisture normally contained in the soil.
• The most commonly used substances are sodium chloride (common salt), calcium chloride, sodium carbonate, copper sulphate, salt and soft coke and salt and charcoal in suitable proportions.

2.1.3 Earth electrode

It may be a metal plate, pipe or other conductor or an array of conductors electrically connected to the general mass of earth.

Type	Size	
	Length in Mtrs	Dia /Cross section
G.I. Pipe	2.5 to 3.5	above 38 mm (internal)
G.I. Angle	2.5 to 3.5	50 mm x 50 mm x 5mm
Copper Rod	2.5 to 3.5	16 mm

GI pipe shall consist of spike at one end and a lug at the other for connecting the earth lead wire.

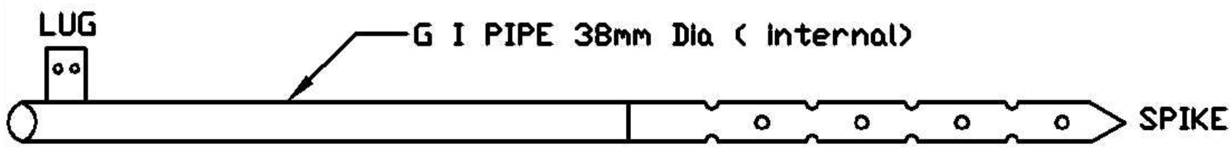

Fig.2.2: Earth electrode (GI pipe)

2.1.4 Lightning conductor or earth lead wire

It is the metallic wire which connects the earth electrode to the equipment/ Installation. Size and metal of the conductor is given below:

Material	Size
G.I. Wire	8 mm Dia
G.I Strip	20mm x 3 mm
Copper wire	29 Sq.mm (19 strand wire of 1.4 mm dia)
ACSR wire	6 / 1 / 2.11 mm

2.2 Procedure of installation

• The hole can be made by manual trenching or by using "Earth auger".
• The top of the electrode shall be 30 cm above the ground.
• The GI pipe is embedded vertically and the rod/angle electrodes are driven vertically in the ground.
• When rocky soil is encountered at a depth of less than 2.0 metres or the length of electrode, the electrode may be buried inclined to the vertical, the inclination being limited to 30º from the vertical.
• After inserting the electrode, the hole shall be filled with earth properly and water should be spread to ensure good contact between electrode and filling.
• In the soils of high resistivity, can be treated with salt and charcoal in appropriate proportion.
• Earth pit of 600 mm dia and 2.5 mtrs depth shall be formed by excavation and the electrode shall be placed at the center.
• The pit shall be filled alternately with layers of common salt and charcoal each layer of about 2.5 cm thick up to a depth of about 200 cm from the ground level.
• The pit shall be filled with several times with water, and then covered with excavated earth and water shall be poured to ensure good electrical contact.

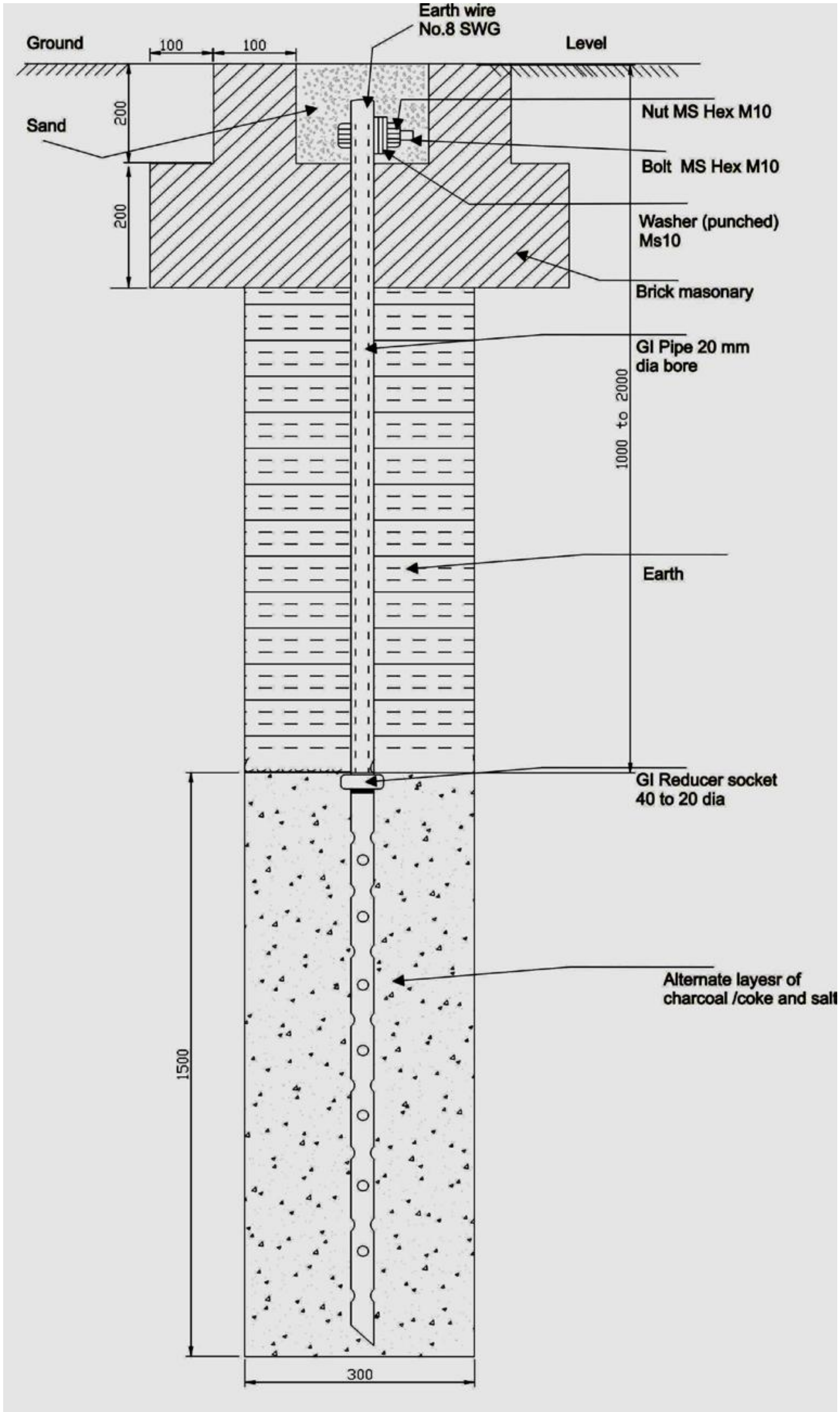

Fig. 2.3: Conventional earthing arrangement {RDSO drawing no. TCA 565(ADV)}

2.3 Inspection and maintenance

• Check earth and its connections periodically at interval of not more than one month, to ensure that all connections are intact and soldered joints are in proper condition.
• Measure the earth resistance once in a year. Enter the value, date of last test and location of earth should be entered in a register.
• Earth resistance, date of last testing should also be printed suitably on the wall of nearby structure or post on a conveniently placed sign board.
• Water to be added every day to the earth electrode in summer and once in two days in other seasons.
• If earth resistance is more than the nominal value either renew the old earth or provide a new earth.

2.4 Precautions

• Earth electrodes shall not be buried in a position likely to cause an obstruction or where it is likely to be damaged.
• Protect the earth lead wire from mechanical damage.
• Apply anti-corrosive paint/ bitumen compound on the portion of wire buried in ground.
• The lead in wire of different earth must be electrically insulated from each other, from metallic structures etc.
• There should not be any possibility of simultaneous human contact with metallic bodies connected to different earthing.
• Whenever it is not possible to provide suitable spacing or partition between various metallic bodies, they must be connected to a common earthing.

2.5 Drawbacks of Conventional Earthing

• The salt poured in pit causes severe corrosion of G.I. pipe and makes the earthing ineffective.
• The earth resistance value depends on "Soil resistivity" which depends on strata so the effect of earthing is dependent on property of soil.
• The earth resistance value is very high, fluctuating & increases heavily with time.

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Chapter-3
MAINTENANCE-FREE EARTHING AND BONDING SYSTEM

3.1 Introduction

•This type of earthing and bonding system is adopted for S&T equipments with solid state components which are more susceptible to damage due to surges, transients and over-voltages being encountered in the system due to lightning, sub-station switching etc. these equipments include Electronic Interlocking, Integrated Power Supply equipment, Digital Axle Counter, Data Logger etc. This system conforms to RDSO Specification no. RDSO/SPN/197 version 1.0 for Code of practice for Earthing & Bonding system for signalling equipments (With effect from: 04.07.2016).

• This type of earthing arrangement requires no maintenance hence it is called as "Maintenance –free earthing.
• This is also called as "Effective Earthing".
• Effective earthing electrode eliminates problems of conventional earthing:
1 By providing highly corrosion resistant Earthing Electrode.
2 By eliminating the corrosion causing elements in the salt.
3 By providing uniform non corrosive, low soil resistivity material around the electrode.

3.1.1 Requirement of low resistance Earthing system

The installation and maintenance of an effective low resistance earthing system is essential due to the following -

(a) Efficiently dissipate heavy fault currents and electrical surges, both in magnitude and duration, to protect equipment being damaged so as to minimize down time, service interruption and replacement cost.

(b) Provide a stable reference for electrical and RF circuits at the installation to minimize noise during normal operation.

(c) Protection of personnel who work within the area from dangerous electric shock caused due to "step potential" or "touch potential".

3.1.2 Characteristics of good Earthing system

(a) Excellent electrical conductivity

(i) Low resistance and electrical impedance.

(ii) Conductors of sufficient dimensions capable of withstanding high fault currents with no evidence of fusing or mechanical deterioration.

(iii) Lower earth resistance ensures that energy is dissipated into the ground in the safest possible manner.

(iv) Lower the earth circuit impedance, the more likely that high frequency lightning impulses will flow through the ground electrode path, in preference to any other path.

(b) High corrosion resistance

The choice of the material for grounding conductors, electrodes and connections is vital as most of the grounding system will be buried in the earth mass for many years. Copper is by far the most common material used. In addition to its inherent high conductivity, copper is usually cathodic with respect to other metals in association with grounding sites, which means that it is less likely to corrode in most environments.

(c) Mechanically robust and reliable

3.1.3 Location for Earthing

a. Low lying areas close to the building or equipment are good for locating Earth Electrodes.
b. The location can be close to any existing water bodies or water points but not naturally well-drained.
c. Dry sand, lime stone, granite and any stony ground should be avoided.
d. Earthing electrode should not be installed on high bank or made-up soil.

3.1.4 Acceptable Earth Resistance value

The acceptable Earth Resistance at earth MEEB busbar shall not be more than 1 ohm. For achieving this value more than one earth pits can be installed if necessary depending upon the soil resistivity.

3.2 Components of Earthing & Bonding system

Following are the components of earthing and bonding system:

- Earth Electrode
- Earth enhancement material
- Earth pit
- Equi-potential earth-busbar
- Connecting cable
- Tape/strip and associated accessories

3.2.1 Earth Electrode

(a) The earth electrode shall be made of high tensile low carbon steel circular rods, molecularly bonded with copper on outer surface to meet the requirements of Underwriters Laboratories (UL) 467-2007 or latest as well as IEC 62561. Such copper bonded steel cored rod is preferred due to its overall combination of strength, corrosion resistance, low resistance path to earth and cost effectiveness.

(b) The earth electrode shall be UL listed and of minimum 17.0mm diameter and minimum 3 Meter long.

(c) In rocky area, a set of 3 electrodes of 1 Meter each of 17.0mm dia in grid form shall be installed in grid form.

(d) The minimum copper bonding thickness shall be of 250 microns of 99.9% electrolyte grade copper.

(e) Marking: UL marking as per UL 467 scheme, Manufacturer‟s name or trade name, length, diameter, catalogue number must be punched on every earth electrode.

(f) Earth electrode can be visually inspected, checked for dimensions and thickness of copper coating using micron gauge. The supplier shall arrange for such inspection at the time of supply, if so desired.

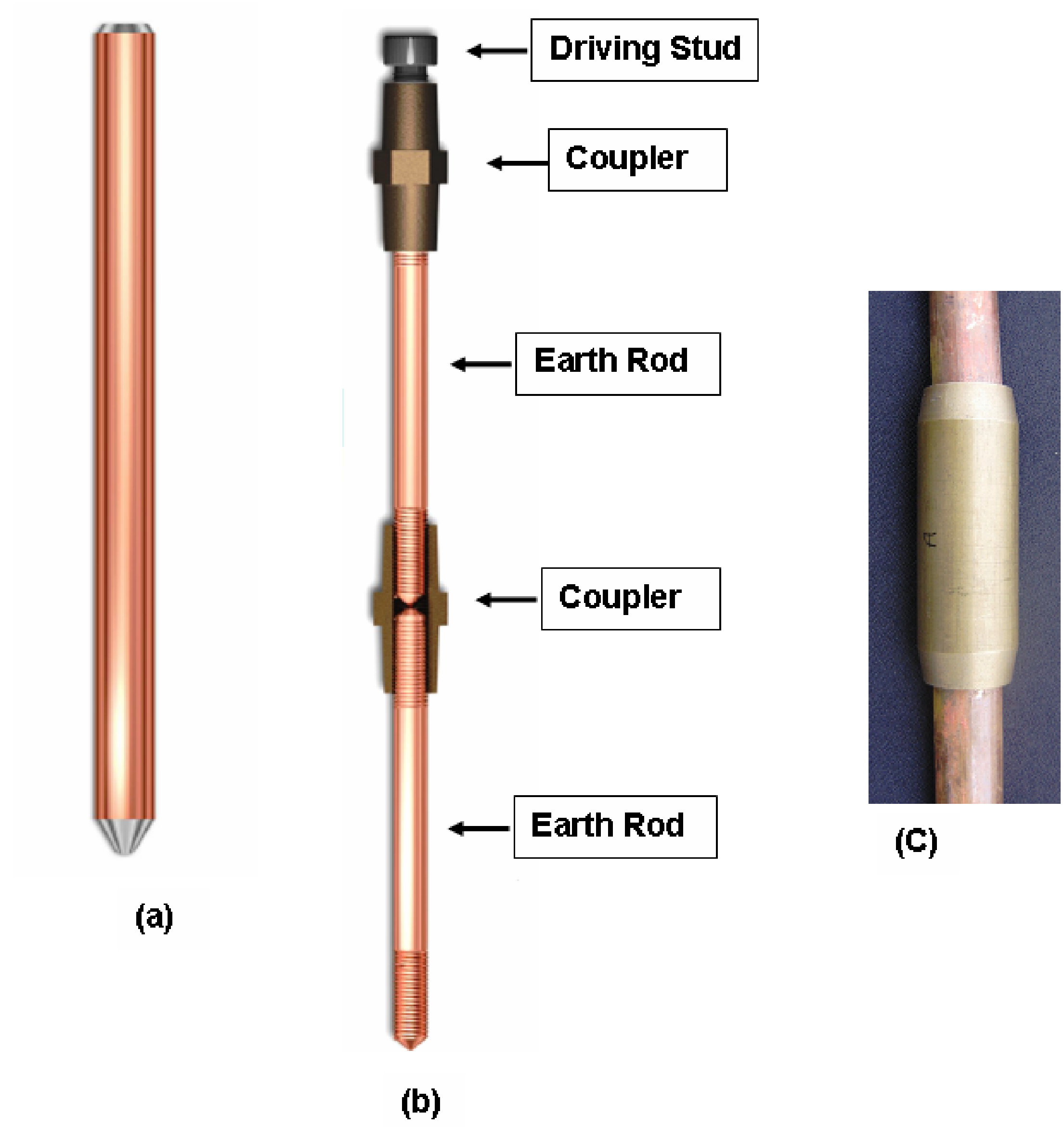


Figure 3.1 : (a) Copper bonded steel earth electrode (b) Electrode with coupler & (c) Enlarged view of coupler

2.7.2 Earth enhancement material

Earth enhancement material is a superior conductive material that improves earthing effectiveness, especially in areas of poor conductivity (rocky ground, areas of moisture variation, sandy soils etc.). It improves conductivity of the earth electrode and ground contact area. It shall be tested and confirm to the requirements of IEC 62561-7 having following characteristics: -

(a). Shall be carbon based with min 95% of fixed carbon content premixed with corrosion resistant cement to have set properties. Cement shall not mix separately & shall not have Bentonite.

(b). Shall have high conductivity, improves earth"s absorbing power and humidity retention capability.

(c). Shall be non-corrosive in nature having low water solubility but highly hygroscopic. (d). Shall have resistivity of less than 0.2 ohms -meter.

(e). Shall be suitable for installation in dry form or in a slurry form.

(f). Shall not depend on the continuous presence of water to maintain its conductivity.

(g). Shall be permanent & maintenance free and in its "set form", maintains constant earth resistance with time.

(h). Shall be thermally stable between -10° C to +60° C ambient temperatures.

(i). Shall not dissolve, decompose or leach out with time.

(j). Shall not require periodic charging treatment nor replacement and maintenance.

(k). Shall be suitable for soils of different resistivity.

(l). Shall not pollute the soil or local water table and meets environmentally friendly requirements for landfill, shall not be explosive &shall not cause burns, irritation to eye, skin etc. In this regard "Safety Data Sheets" shall be submitted by the manufacturers.

(m). Marking: The Earth enhancement material shall be supplied in sealed, moisture proof bags. These bags shall be marked with Manufacturer's name or trade name, quantity etc.

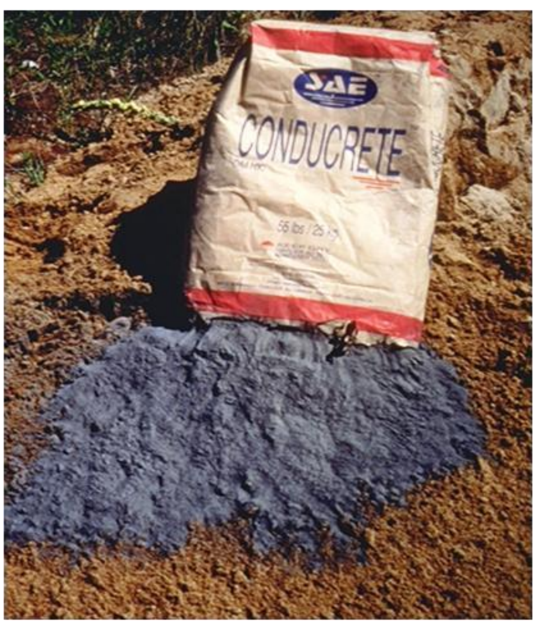


Figure 3.2 : Earth enhancement material before & after setting

3.2.3 Backfill material

- The excavated soil is suitable as a backfill but should be sieved (screened) to remove large stones and place around the electrode taking care to ensure that it is wet and compact.
- Material like sand, salt, coke breeze, cinders and ash shall not be used because of its acidic and corrosive nature.

3.2.4 Earth Pit

Construction of unit earth pit:

Refer ***Figure 3.3*** typical installation drawing no. **SDO/RDSO/E&B/001**.

(a). A hole of 100mm to 125mm dia shall be augured /dug to a depth of about 3.0 meters.

(b). The earth electrode shall be placed into this hole.

(c). It will be penetrated into the soil by gently driving on the top of the rod. Here natural soil is assumed to be available at the bottom of the electrode so that min. 150 mm of the electrode shall be inserted in the natural soil.

(d). Earth enhancement material (minimum approx. 30-35 kg) shall be filled into the augured/dug hole in slurry form and allowed to set. After the material gets set, the diameter of the composite structure (earth electrode + earth enhancement material) shall be of minimum 100mm dia covering entire length of the hole.

(e). Remaining portion of the hole shall be covered by backfill soil, which is taken out during auguring /digging.

(f). A copper strip of 200mmX25mmX6mm shall be exothermically welded to main earth electrode for taking the connection to the main equi-potential earth busbar in the equipment room and to other earth pits, if any.

(g). Exothermic weld material shall be tested as per provisions of IEEE 837 by NABL/ILAC member labs.

(h). The main earth pit shall be located as near to the main equi-potential earth busbar in the equipment room as possible.

Drawing for Typical Installation of Earth

(Ref: RDSO/SPN/197 Ver 1.0- TAN/3006 Ver 3.1)

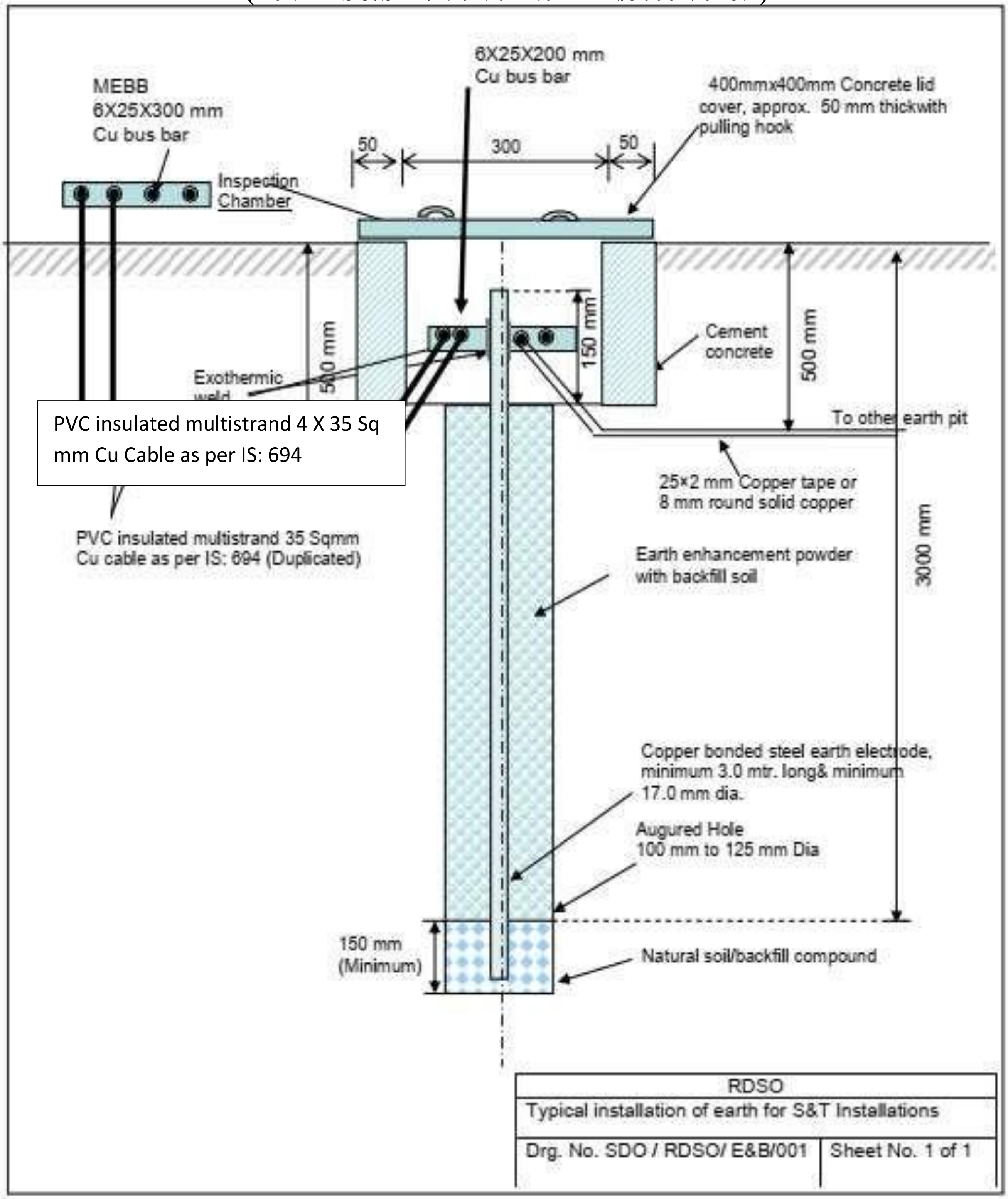


Figure 3.3

3.2.5 Construction of loop Earth by providing multiple earth pits

(a). At certain locations, it may not be possible to achieve earth resistance of ≤1ohm with one earth electrode /pit due to higher soil resistivity. In such cases, provision of loop earth consisting of more than one earth pit shall be done. The number of pits required shall be decided based on the resistance achieved for the earth pits already installed. The procedure mentioned above for one earth pit shall be repeated for other earth pits.

(b). The distance between two successive earth electrodes shall be min. 3mtrs. and max. up to twice the length of the earth electrode i.e. 6 mtrs. approx.

(c). These earth pits shall then be inter linked using 25X2mm. copper tape or 8mm round solid copper conductor to form a loop using exothermic welding technique.

(d). The interconnecting conductor shall be buried at depth not less than 500mm below the ground level. This interconnecting conductor shall also be covered with approximately 30 Kg of earth enhancing compound for each 3 meters length.

Figure 3.4 : Interlinking of earth pits using copper tapes

3.2.6 Inspection Chamber

(a). Inspection chamber should be as per IEC 62561-5 or latest.

(b). The dimension of the chamber will be of 300 x 300 x 300 mm (inside dimension) of RCC with 50mm thick and fine finish.

(c). The marking space should be present an RCC cover.

(d). The date of testing and earth resistance value shall be written on the cover with black base with yellow paint.

C nts

Figure 3.5: Inspection Chamber

3.3 Equi-potential Earth Busbar and its connection to equipments & Surge protection devices in the Equipment room:

(Ref: Bonding& Earthing connections for Signalling Equipments Drg. No. 21-D8 of IRSEM) Figure 3.6

3.3.1 Equi-potential earth busbars

(a). There shall be one equi-potential earth busbar for each of the equipment room i.e. IPS/Battery charger room and EI/Relay room. The equi-potential earth busbars located in individual rooms shall be termed as Sub equi-potential busbars (SEEB)/ Bonding Ring Conductor (BRC)/ Common Bonding Network (CBN) as per TAN3006 Ver.3.1.

(b). The equi-potential earth busbar located in the IPS /Battery charger room and directly connected to Class 'B' SPDs and the main earth pit shall be termed as Main equi-potential earth busbar (MEEB).

(c). The EEBs shall have pre-drilled holes of suitable size for termination of bonding conductors.

(d). The EEBs shall be insulated from the building walls. Each EEB shall be installed on the wall with low voltage insulator spacers of height 60mm.

(e). The insulators used shall have suitable insulating and fire-resistant properties for this application.

(f). The EEBs shall be installed at the height of 0.5m from the room floor surface for ease of installation & maintenance.

(g). All terminations on the EEBs shall be by using tinned copper lugs with spring washers.

3.3.2 Bonding Connections

- To minimize the effect of circulating earth loops and to provide equi-potential bonding, "star type" bonding connection is required.
- As such, each of the SEEBs/ (BRC/CBN as per TAN3006 Ver.3.1) installed in the rooms shall be directly connected to MEEB using bonding conductors. Also, equipment/racks in the room shall be directly connected to its SEEB/ (BRC/CBN as per TAN3006 Ver.3.1).
- The bonding conductors shall be bonded to their respective lugs by exothermic welding.
- All connections i.e routing of bonding conductors from equipments to SEEB/BRC/CBN & from SEEBs/BRC/CBN to MEEB shall be as short and as direct as possible with min. bends and separated from other wiring.
- However, connection from SPD to MEEB shall be as short as possible (not more than 0.5 meter as per TAN 3006 Ver.3.1) and preferably without any bend.

3.3.3 Materials and dimensions

Materials and dimensions of bonding components for connection of individual equipments with equipotential bus bar and earth electrode shall be as given below as per TAN 3006 Ver. 3.1):

SN	Item/ Component	Size	Quantity
1	Earth Electrode	Dia- 17 mm Length- 3 mtr	As per site requirement
2	Earth Enhancement Material	30- 35 Kg	
3	Main equipotential earth busbar (MEEB)	300X25X6 mm (min.)	
4	Bonding Ring Conductor (BRC)	25 X 2 mm	
5	Multi-strand single core PVC insulated copper cable as per IS:694 used to connect individual equipment to BRC	10 Sq mm	
6	Multi-strand single core PVC insulated copper cable as per IS:694 used to connect SPD to MEEB or BRC to CTR	16 Sq mm	
7	Multi-strand single core PVC insulated copper cable as per IS:694 (4 Nos) used to connect MEEB to Main earth electrode	35 Sq mm	
8	Copper tape or solid copper round conductor used to connect Main earth pit to other earth pit in case of loop earth and Copper tape for connecting MEEB to Main earth electrode	25 X 2 mm or 8 mm dia and 25 X 2 mm (2nos.)	
9	GI tape used to connect Main earth pit to other earth pit in case of loop earth (For theft prone areas)	50 X 6 mm	
10	Copper strip to be exothermically welded to earth electrode	200X25X6 mm (min.)	
11	Exothermic Weld Material & Mould	-	

3.4 Warranty

The OEM shall be responsible for complete supply, installation & commissioning of the earthing & bonding system. The warranty of such system shall be 60 months from date of commissioning. During this period, any failure of earthing system due to improper materials & bad workmanship shall be attended free of cost by the OEM.

3.5 Drawing of earthing & bonding system

The complete layout with dimensions of the earthing & bonding system shall be submitted by the supplier after commissioning.

3.6 Maintenance of Earthing & Bonding system

The maintenance schedule should cover verification of earthing system conductors and components, verification of electrical continuity, measurement of earth resistance, re-fastening of components and conductors etc.

3.7 Precautions to be followed for execution of earthing work

3.7.1 All the material supplied for the earthing work should be inspected by RDSO.

3.7.2 Site location for earthing:

3.7.2.1 Low line areas close to the building are good for locating earth electrode.

3.7.2.2 Dry sand, lime stone, granite and any stony ground should be avoided.

3.7.2.3 Earth electrode should not be installed on high bank or made-up soil.

3.7.3 The copper coating on earth electrode should not be cracked due to damage during storage /transport and should be free of corrosion.

3.7.4 The packing bags of earth enhancement compound should be in sealed condition.

3.7.5 For the earth pit, a hole of 100mm-125mm dia should be augured to a depth of approx. 3m and the earth electrode is placed in the hole with about 150mm of bottom part inserted in the natural soil.

3.7.6 Earth enhancement material (minimum 30-35Kg) shall be filled into the augured hole in a slurry form such that it spreads evenly around the electrode covering entire length of the hole.

3.7.7 In order to achieve earth resistance of less than or equal to 1 ohm, multiple earth pits should be provided depending upon soil resistivity if required.

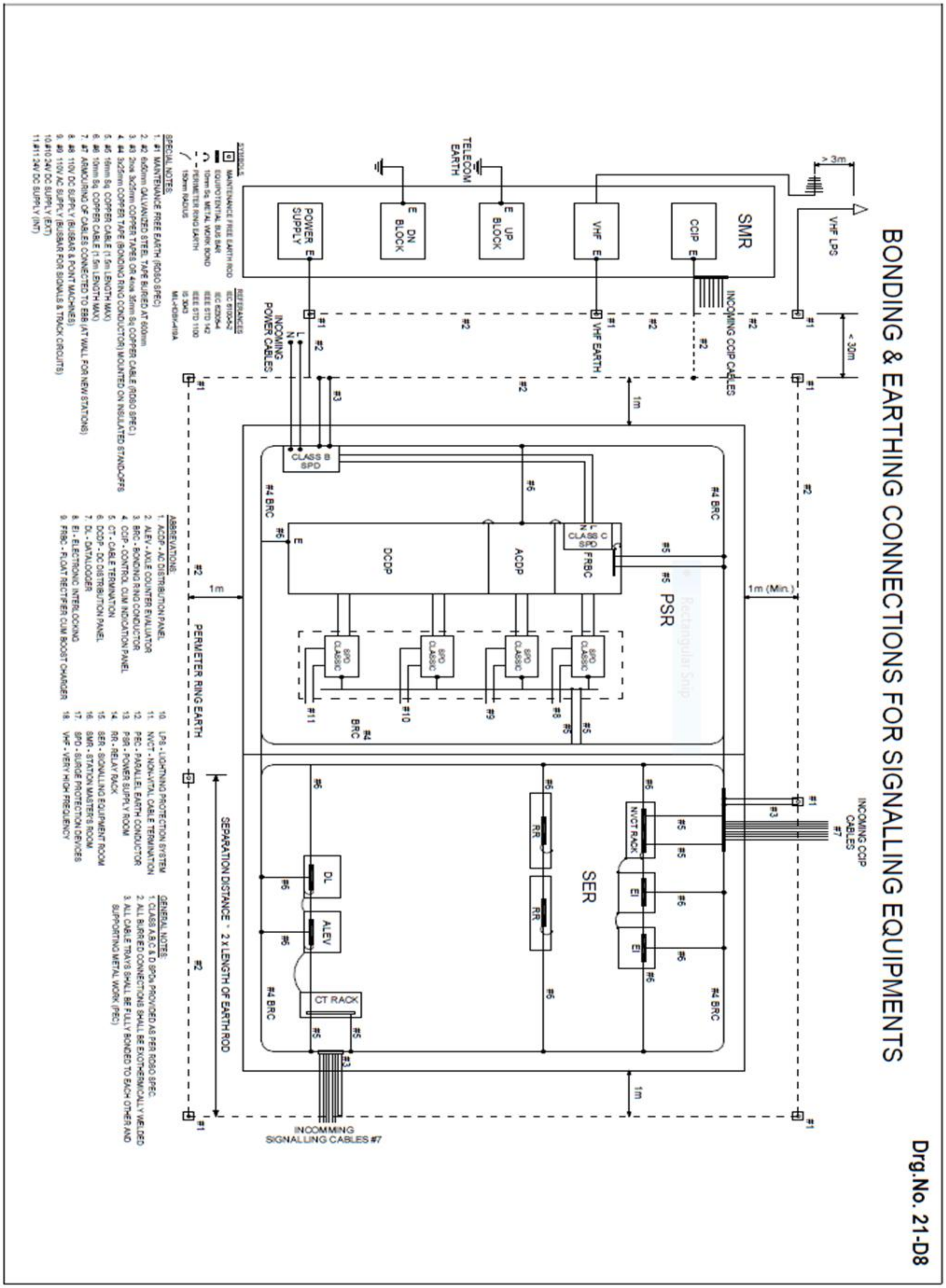
3.7.8 The distance between two earth electrodes shall be minimum 3m and maximum upto 6m (approx.).

3.7.9 The 25 x 2copper strip or 8mm round solid copper interconnecting the earth electrode shall be buried at a depth not less than 500mm below ground level and this copper strip should also be covered with earth enhancement compound.

3.7.10 Proper size of cable should be used for connection of equipments to equi-potential busbar, SPDs to equi-potential busbar, equi-potential busbar to earth electrode as indicated in the specification.

3.7.11 The length of cable connection between SPDs and equi-potential busbar and between equipment and equi-potential busbar should be as short and as direct as possible and preferably without/ minimum bends.

3.7.12 Authorized representative of the RDSO approved OEM should supervise each installation and certify that the installation is complying the requirements of the specification.



Ref: IRSEM Drg No 21-D8
Figure 3.6

Chapter-4
Measurement of Earth resistance

4.1 Measurement of Earth resistance

The earth resistance shall be measured at the Main Equi-potential Earth Busbar (MEEB) with all the earth pits interconnected using Fall of Potential method. The typical connection diagram used for measurement of earth resistance is as per ***Figure 4.1*** (RDSO Drawing no. SDO/RDSO/E&B/003)**.** It consists of an earth tester which is provided with four terminals C1, C2, P1, and P2. The terminals C1 and C2 are the current terminals while terminals P1 and P2 are known as potential terminals.

The basic procedure of fall of potential method using four terminal equipments is as under: -

(a). The electrode under test i.e., earth electrode E is connected to the terminals C1 and P1 by shortening them. Connect the C1 & P1 on the test set to the earth electrode as per ***Figure 4.1*** (RDSO drawing no. SDO/RDSO/E&B/ 003)**.**

(b). Drive a probe into the earth 30 to 60 meters from the centre of the electrode and connect to terminal C2. This probe should be driven to a depth of 15 to 30 cms.

(c). Drive another probe into the earth midway between the electrodes and probe C2 and connect to terminal P2. This probe should be driven to a depth of 6 to 12 inches.

(d). The tester injects a known current through the current electrode and measures the voltage between the potential electrode and the existing earth electrode under test. The earth resistance is calculated using Ohm's law:

$$R=V/I$$

Where R is the earth resistance, V is the measured voltage, and I is the injected current.

(e). Measure the resistance.

(f). Move the potential probe 3 meters farther away from the electrode and make the second measurement.

(g). Move the potential probe 3 meters closure to the electrode and make the third measurement.

(h). All the three measurements shall be within a few percent of their average. The average of the three measurements may be used as the electrode/earth resistance.

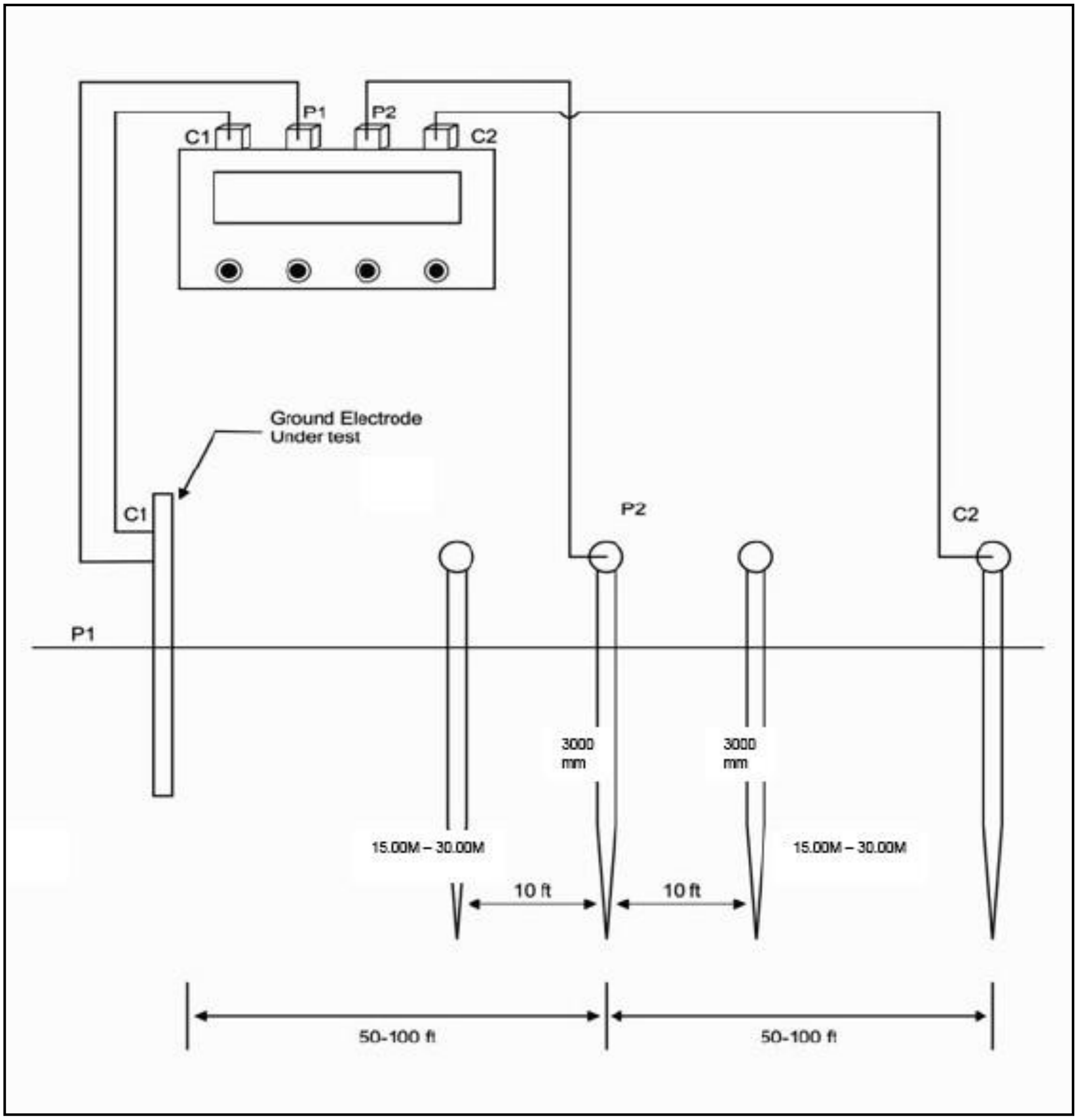


Figure 4.1: Typical arrangement of earth resistance measurement

(RDSO Drawing No. SDO/RDSO/E&B/003)

4.2 Precautions during measurement of earth resistance: -

The earth resistance is normally measured using fall of potential method. While measuring earth resistance, sometimes the location of measurement is not selected properly**.** As a result the earth resistance measurements go wrong. To understand the same two cases are explained below:

Case I: Measurement at Single Earth Electrode

When measuring with fall of potential method, the current is injected at the test electrode through a megger and it reaches current probe and becomes zero after decay as shown in ***Figure 4.2*** below.

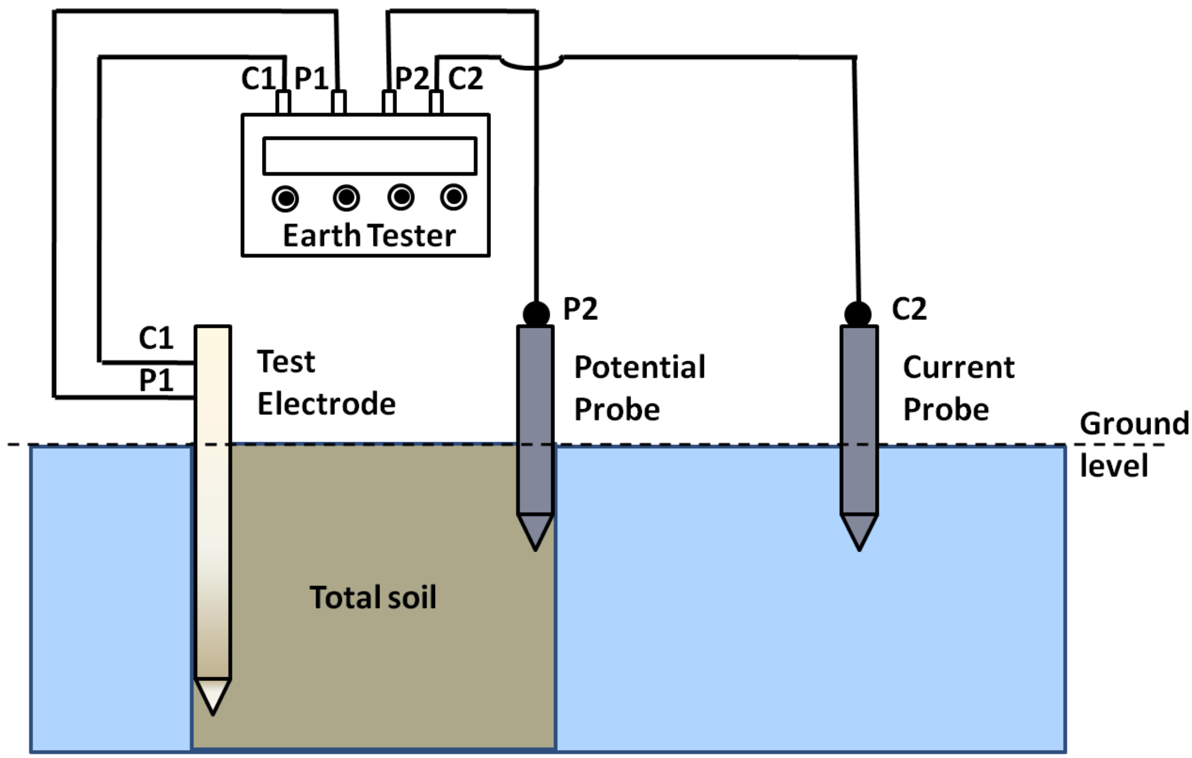


Figure 4.2: Measurement of Earth Resistance at Single Earth Electrode

The value of each resistance of test electrode depends upon the voltage generated at potential probe. Hence the area between test electrode and potential probe should be total soil. There should be no extraneous metalwork like buried rods, pipes etc. in this area. Otherwise, the measurements will not be correct.

As per BS 7430:2011 standard: ***For accurate results, the current flowing between probe and the earth system being measured should return through the soil, not through any extraneous metalwork.***

Case II: Measurement in a Ring Earth System

Generally, for earth resistance measurement in ring system, the test probe is connected to the entry point of earth (say relay room).

If potential probe is placed parallel to the metal (copper) strip of ring earth system as shown in ***Figure 4.3.*** the current injected through the test probe will flow through the copper strip upto its end instead of dissipating through the soil. As a result, there will be no significant voltage drop along the copper strip upto its end which is parallel to the potential probe. The voltage will drop beyond the copper strip end but the measured value of voltage will be less than the value if parallel metal path was not available. The earth tester will show less resistance value than the actual resistance value. Hence it is advised to always measure ring earth resistance by placing probes at 90 degrees as shown in ***Figure 4.4.*** If placed parallel then the test probe to be connected to the point which is at the end of the ring earth system.

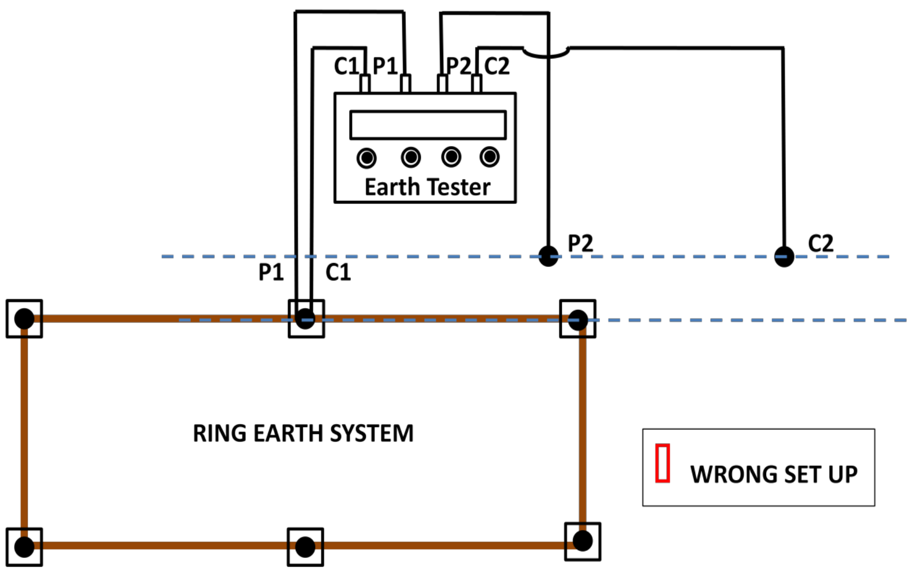


Figure 4.3: Measurement of Earth Resistance in a Ring Earth System-Wrong set up

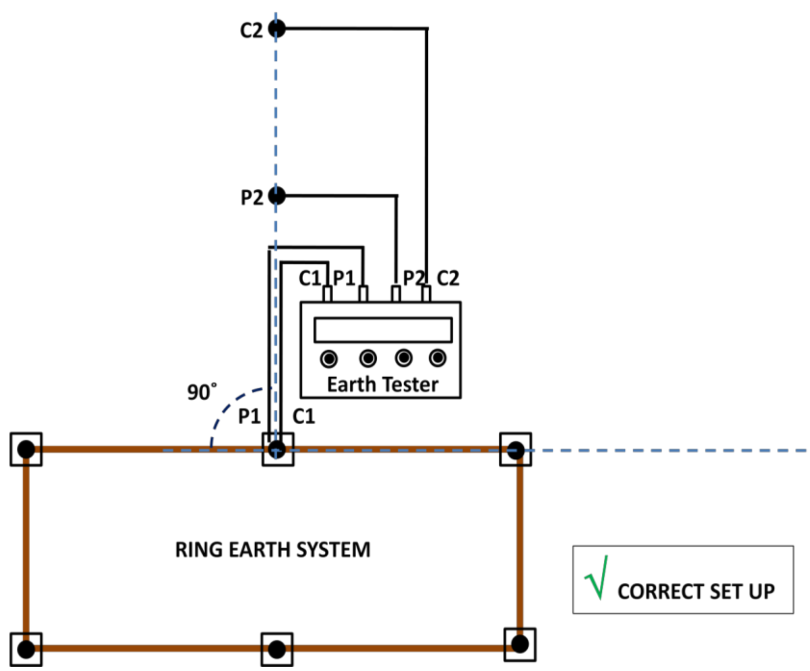


Figure 4.4: Measurement of Earth Resistance in a Ring Earth System - Correct set up

Chapter 5
Earthing for Outdoor Signalling Equipment

Ref:IRSEM,Chapter-19, Section-11

5.1 Types of Earths

(a) Earths are of two types

(i) Functional Earth: The earth return used for block instruments is a functional earth which is used to conduct the current through earth during normal operation/function of equipment.

(ii) Protective Earth: This earth for dissipating surges, which comes in contact with equipment's connections through Surge Protection Devices (SPD) during Lightning or surges so as to protect the equipment.

(b) Perimeter Ring Earth (PRE) shall be provided around building housing signalling equipment. Chasis of all S&T equipment shall be bonded to BRC (Bonding Ring Conductor) provided inside the Power Equipment Room or Signal Equipment Room. BRC is to be connected to MEEB in Power room and from there to PRE as per extant guidelines. In case, no BRC exists, chassis of the equipment shall be connected directly to MEEB (Main Equi- potential Earth Busbar).

(c) Earthing shall be provided as per approved specifications, drawings and code of practice issued by RDSO.

(d) The maximum earth resistance shall be specified as per OEM & RDSO recommendations.

5.2 Purpose of Earthing

Earthing of cables, equipment, buildings and structures is done for one or more of the following purposes:-

(a) Lightning & surge protection of equipment.

(b) Earthing of metal screens of telecommunications cables and equipment for reducing Electromagnetic interference.

(c) Human safety.

5.3 Earthing to be provided at

(a) The lever frame and other metallic frames of the cabin shall be earthed.

(b) The earthing shall be provided at every location box where cables terminate.

(c) The earthing shall be provided at each signal.

(d) Wherever possible, the common earthing system to be provided for closely located location boxes, signal posts, etc. Separate earth is required for equipment requiring functional earth only.

(e) Sheath & Armour of Main cables to be earthed. Armour of OFC shall be earthed at both ends. It is not necessary to earth the armouring of unscreened cables when they are used as a tail cables except in special cases where the length of the tail cable exceeds normal prescribed limits.

(f) In case of signals falling within 2 meters from the electrified track, the protection screen shall be connected to an earth.

(g) There shall not be any possibility of simultaneous human contact with metallic bodies connected to different earths, where it is not possible to provide suitable spacing or partition between various metallic objects referred to above, they shall be connected to a common earth.

(h) Common/Equi-potential earth for modern electronic equipment such as EI, DAC, Datalogger etc. to be used in Relay room. Earth value shall not be more than one ohm and shall be measured annually during dry season.

(i) Earthing wires from subsystems to earth terminal shall be of distinctive color. Green or Green Yellow (GNYE) color is recommended for quick identification of a loose or disconnected earth wire.

(j) All earth wires shall be as straight as possible and shall never be coiled. Earth wires should be of adequate current carrying capacity and should not be less than 4 Square mm copper cross-section or its equivalent.

(k) Earth resistance up to 10 ohm is normally permissible for protective earth except when specified otherwise. For electronic equipment, Earth resistance shall not be more than one ohm.

(l) Earthing of approved type shall be provided for each block instruments and other signalling equipment at a station. Dedicated earthing arrangement to be provided for earth return circuits individually if any.

(m) The resistance of earth for signalling circuits shall not exceed 10 ohm or as prescribed by OEM/RDSO. If the resistance is more than the required value, steps to reduce the earth resistance shall be taken. If it is still not possible to reduce the value below the required value, even with the adoption of these methods, additional earths may be provided in parallel.

(n) Where more than one earth electrode is used, the distance between two earthing electrodes shall be as per approved design.

5.4 Earthing Leads

(a) Earth wires shall be protected against mechanical damage and possibility of corrosion particularly at the point of connection of earth electrode.

(b) The earthing lead shall be mild steel flat of size 40 mm x 6 mm or as per the approved earthing practice/drawing.

(c) The earthing lead shall be soldered or crimped on a lug, which shall be bolted to the earth electrode or preferably exothermically welded. The nut & bolt to be painted with anti-corrosive paint.

5.5 Selecting Site for Earthing

(a) The site for earthing shall be chosen in the following order of preference:

(i) Wet marshy ground and grounds containing refuse, such as ashes, cinders and brine waste.

(ii) Clay soil or loam mixed with small quantities of sand.

(iii) Clay and loam mixed with varying proportions of sand, gravel and stone; and

(iv) Damp and wet sand and peat.

(b) A site which is naturally well drained shall be chosen. A water-logged situation, however, is not essential unless the soil be sand or gravel. Perennial wells may also be used as sites for earth electrodes with advantage where the bottom of the earth is rocky.

(c) Electrodes shall preferably be situated in a soil which has a fine texture and which is packed by watering and ramming as tightly as possible. Where practicable, the soil shall be sifted and all lumps broken up and stones removed in the immediate vicinity of the electrodes.

(d) Where soil conductivity is poor, the chemical treatment may be resorted to improve the same. Common salt together with charcoal in alternate layers is generally used for this purpose and the addition of less than one part by weight of salt to 200 parts of soil mass may reduce the resistivity by 80% but there is little advantage in increasing the salt content above 3%. Calcium chloride and sodium carbonate are also beneficial.

(e) Use should be made where possible of natural salts in soil produced by bacteriological action on decaying plants. The resistivity of the soil on which plants are growing will be less than that of a similar soil in the absence of plants.

(f) As far as possible, the earthing arrangement shall be located in the natural soil. The made-up soil which has not consolidated or is likely to be eroded by weather, shall be avoided.

(g) The minimum clearance of equipment earths from system earths (e.g. earthing of AT/Transformer etc.) provided by the Electrical Department either of the Railways or of the other Administrations shall be 20 meter.

(h) Asphalt or concrete cover of about 50 mm thickness around the Earth for a radius of 1 meter to retain the soil moisture is desirable.

5.6 Earth Resistance

Earth Resistance of an 'earth' is the sum of three separate resistances, viz.,

(a) the resistance of the conductor joining the earth electrode to the installation.

(b) The contact resistance between the surface of the earth electrode and the soil, and the resistance of the body of soil surrounding the earth electrodes.

(c) Normally the first two resistances are negligibly small compared with the third; so, the resistance of an 'earth' is primarily determined by the nature of the soil and not by the electrode itself.

(d) The material used for a standard electrode system should be corrosion resistant. Under ordinary soil conditions, use of galvanized iron or mild steel electrode is recommended. In cases where soil corrosion is likely to be excessive, it is preferable to use either copper or copper clad electrode. The electrodes shall be free from paint, enamel or grease.

(e) Earth tester normally used for measurement of earth resistivity comprises of the current source and meters in a single instrument and directly read the resistance value.

5.7 Maintenance of outdoor earths

(a) Watering:

Conventional Earths shall be regularly watered. Earth enhancement material should be periodically added to Maintenance free earth to improve the earth resistance. Earth pit to be regularly cleaned.

(b) Earth Connections:

All Earth connections shall be carefully examined and kept intact and joints soldered. The wire between each earth and the connected equipment shall be electrically isolated. The exothermic welding termination on maintenance free earth rod shall be checked and cleaned.

5.8 Regular Checks/Upkeep of Earths

(a) Block earths and their connections shall be examined at intervals of not more than one month by JE (Signals) and not more than three months by Sectional SSE(Signal)/Incharge.

(b) Block earths shall be tested for resistance at intervals of not more than 12 months by Sectional JE/SSE (Signal). Where the resistance exceeds 10 ohms, action shall be taken to reduce the resistance by providing additional earths in parallel.

(f) If routine testing indicates that existing earth electrode system is not satisfactory, a new earth electrode system (or part of a system to supplement the existing system) shall be provided.

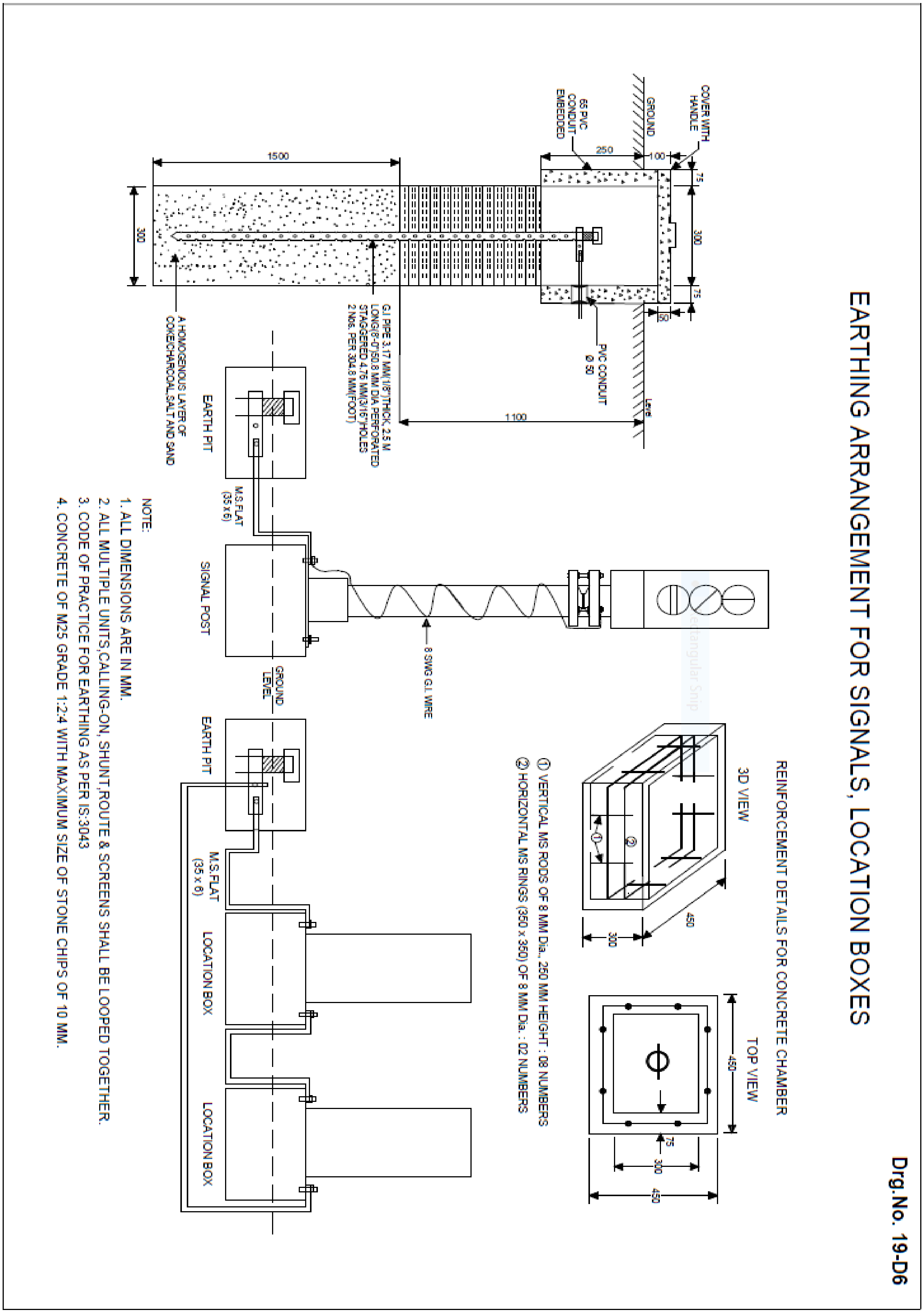


Figure5.1 *(Ref: IRSEM Drg No 19-D6)*

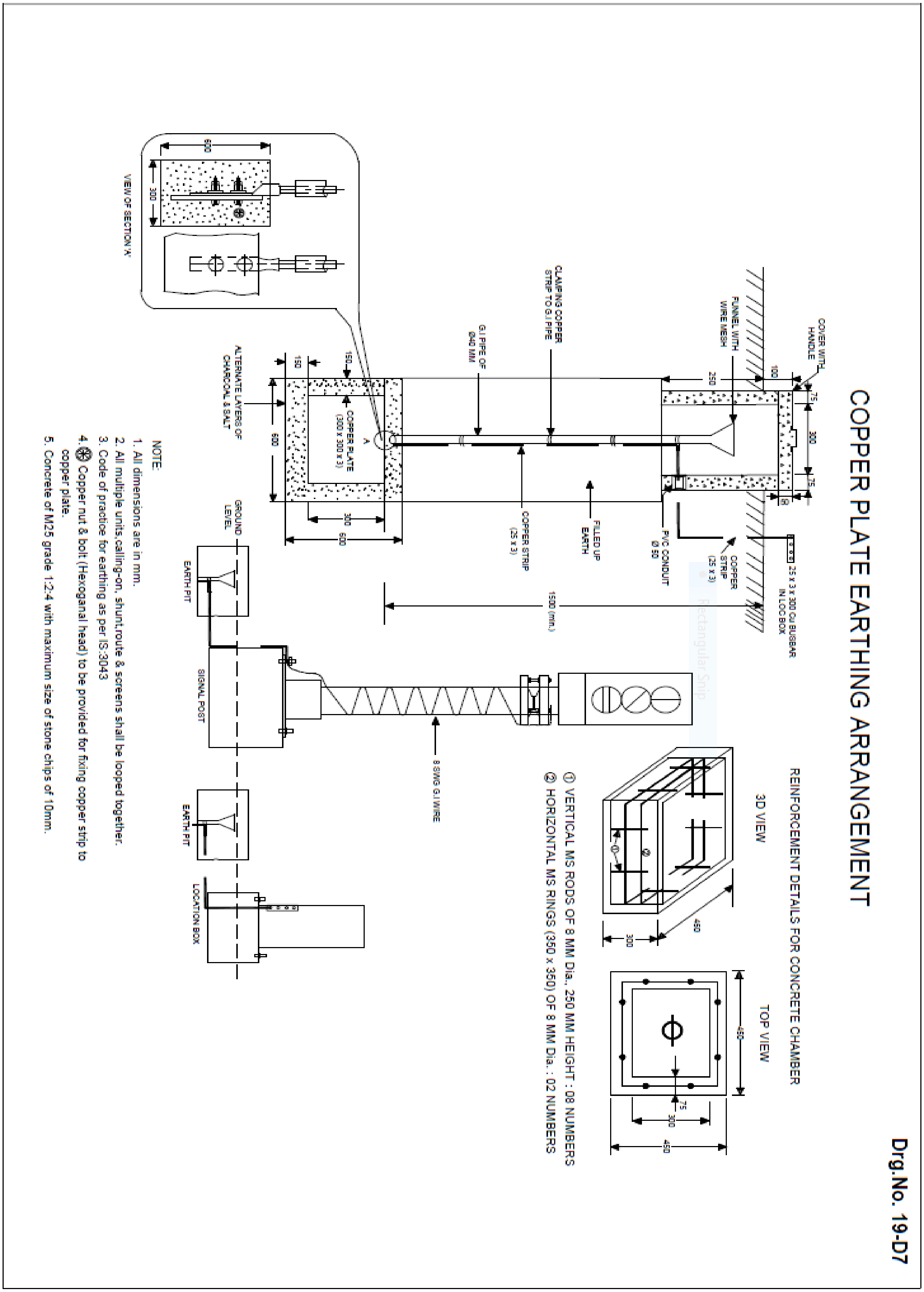


Figure 5.2 *(Ref: IRSEM Drg No 19-D7)*

Chapter-6
Maintenance Schedule of Earthing (Conventional & Maintenance Free) and Lightning Protection

Periodicity	Schedule Code
Monthly	E1
Quarterly	E1
Half Yearly	E1, E2
Yearly	E2, E3

	Schedule Code: E1 *Periodicity: Technician (Signal): Monthly* *Sectional SSE/JE(Signal): Quarterly* *SSE(Signal)/ Incharge: Half-yearly*
S. No.	Check the following:
1.	All earth connections of block earth, Axle counter, MUX and other equipment earth
2.	Earth wire lead is not corroded and is well protected.
3.	Nut connecting earth wires to electrode are not corroded.
4.	SPD (B & C type at 230 V entry stage) indications are OK.
5.	Connections to SPD are intact.
	Schedule Code: E2 *Periodicity: Sectional SSE/JE(Signal): Half-yearly* *SSE(Signal)/Incharge: Yearly*
S. No.	Check the following:
1.	SPD (C type at the output side of DC supply) indications are OK. Before onset of monsoon and after every lightning it has to be verified.
2.	Connections to SPD are intact.
	Schedule Code: E3 *Periodicity:* Sectional SSE/JE: Yearly SSE(Signal)/Incharge: Yearly *(Note: They shall do in alternate Six months)*
S. No.	Check the following:
1.	Proper rating and type of SPD used.
2.	Available potential free contacts are wired.
3.	Separate earth exists for each block.
4.	Different earthing conductors are insulated from each other.
5.	Measuring the value of earth resistance of the earthing provided for signaling circuit, improving earth resistance if found more than beyond specified limit of installed equipment, take steps to reduce it further.
6.	Keeping records of the earth resistance measurement and painting its value on earth enclosures/nearest wall.

Note: There should not be any other earth or system earth of electrical, placed less than 20 meters away from the equipment earth.

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