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NEWSLETTER FOR MANUFACTURING COMMUNITY

Word for the day: **Grounding Practices**

Often, we are advised by our seniors, parents and teachers not to ignore "ground" realities when making a decision. Philosophers assert that people who have their foot firm on "ground" are the ones who become successful in life. It is no magical co-incidence that any electrical or electronic equipment that is not grounded will not work properly and can pose electrical hazard to the users. Be it simple hair dryer in our wardrobe or a complex process line running in a set-up, they must be grounded. Modern electronic equipments does not work without proper grounding.

What is grounding?

Grounding, also called earthing, is a method of providing return path for an electrical potential from an equipment that might otherwise be left floating. If some other component or person touches such ungrounded equipment, the floating potential will immediately find a return path and damage the equipment. Not to mention the electrical shock it imposes on the person touching it.

With 12,753 kilometers (7926 miles) as its diameter and weighing 6 x 10^{24} kilograms (6 x 10^{21} or 6000000000000000000000 tons !!), earth provides huge storage facility to absorb all the floating voltages from different equipments, installed all over its surface.

Grounding is a vast subject and some of the concepts will be exclusive to the type of system to be grounded. The grounding requirement for a railway line can be completely different from the grounding requirement for a coal mine. In this newsletter, we intend to explore the very basics of grounding in a typical manufacturing set up.

The grounding must be separate for body (equipment) and neutral in a typical electrical system. They are generally called NEUTRAL EARTH (NE) and BODY EARTH (BE). Body grounding protects personnel against any electrical signals passing thru the "non-electrical" parts of any equipment like machine frames, bearings and panels. Neutral earthing protects against any insulation failure or floating voltage occurring in neutral line.

The lightning arrestor, a spear like metal rod installed above highest point of any building is also a grounding circuit. It is protecting the building and all the components inside, against extremely high voltage (more than 25,000 volts) generated by lightning. Grounding circuit for this must be separate from other ground systems in the set-up.

Apart from exposing personnel to electrical hazard, poor grounding also produce errors in various instruments, measuring devices and communication equipments. Grounding also eliminates effect from any static charges generated in the electrical system, thus preventing damage of expensive equipments.

Grounding is accomplished by inserting highly conductive metal conductor, called GROUNDING ELECTRODE, deep into the earth. The electrode, in different shapes, will be usually made from high-quality steel or copper or copper-clad steel.

The number of ground electrodes to be fixed will be generally decided after measuring one important attribute, called GROUND RESISTANCE. It is similar to resistance of any electrical component but varies and hence is difficult to calculate. It can be measured by using GROUND or EARTH RESISTANCE METERS. General purpose multi-meters and meggers should not be used for measuring this resistance value. But, multi-meters can be used for checking the continuity among various ground points.

Ground resistance will be affected by quality and length of grounding electrode used, its contact area with the soil, surrounding soil condition and number of electrodes in a particular location. The condition of soil plays a vital role in reducing ground resistance, and attributes of other components can be externally controlled. Soil with high moisture content will have LESS ground resistance than dry soil. Following is a list of different types of soil in the increasing order of its resistance (Item 1 will have least resistance compared to item 6).

1. Wet marshy lands, or lands containing ashes, cinders or brine waste
2. Clay, loamy soil, arable land clay
3. Clay & loam mixed with varying proportion of gravel & sand
4. Damp & wet sands
5. Dry sand
6. Gravel & Stones

The quantity and electrical quality of soil surrounding electrodes determines its ability to discharge the ground current, as quickly as possible. This property of soil to provide least resistance and quick discharge of ground current is measured by its RESISTIVITY. Referring again to the list above, item 1 has less resistivity compared to item 6. A comprehensive resistivity table is provided on page 6 for ready reference.

RESISTIVITY is amount of resistance conductor offers over its length. From the fundamentals of Ohm's law, resistivity is directly proportional to conductor's cross-sectional area and inversely proportional to its length. For instance, a conductor with same RESISTANCE value will have MORE resistivity if its cross-sectional area is more. The same material will have LESS resistivity if the length is more. Motors, transformers and all similar equipments have LONGER but THINNER copper wires wound multiple times for the same reason. Otherwise, it would have been easier to complete few windings with larger diameter copper wire. The same reason is applicable in power transmission wires and standard cables. A cable with multiple smaller diameter conductor (multi-strand) offers LESS resistance than a cable with a large diameter conductor. If large diameter cable is used over long distances, it will induce severe voltage drop, causing what is known as transmission losses. RESISTIVITY is measured in Ohm-Centimeter, Ohm-Millimeter, Ohm-Meter or Ohm-Kilometer based on the distance involved.

$$R = \frac{\rho \, x \, L}{A} \quad \text{Therefore,} \quad \rho = \frac{R \, X \, A}{L}$$

Where R = Resistance, in Ohms L = Length of the conductor A = Conductor's cross-sectional area $\rho = Resistivity$

REMEMBER: To reduce resistivity and hence ground resistance, longer electrode or multiple electrodes must be selected instead of increasing the diameter alone. For non-circular electrodes, it is suggested to install thinner sheets or wires than thick ones.

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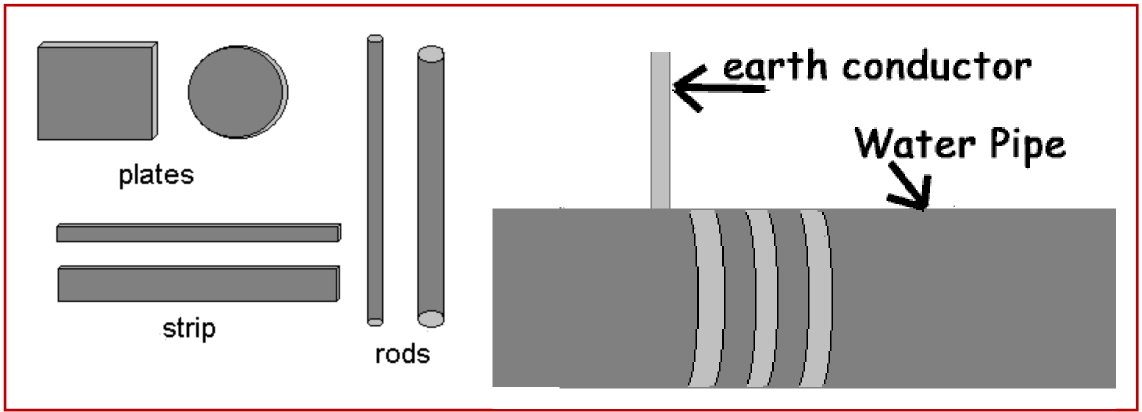
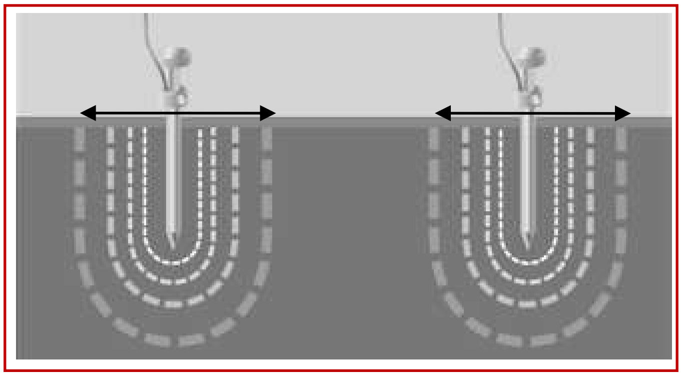
The grounding electrodes can be made in different shapes, although round ones are very popular. One of the most important requirement of the ground electrode should be to INCREASE contact area with surrounding soil and REDUCE resistance. Therefore, the electrodes must be free of paint, coatings and other insulating materials. Following shapes are generally used for electrodes:

- Round rods or pipes – Most commonly used in factories, commercial establishments
- Horizontal wires – Most commonly used in receiving stations, distribution stations and transformer yards
- Four Pointed stars – Most commonly used in RF tower stations (mobile towers for example)
- Conductive Plates – Can be used effectively as an alternative to round rods or pipes – Increases contact area
- Water pipes – One of the most common medium for grounding in residential townships and layouts. If they run close to low tension cables (either underground or overhead), they will be used as common grounding electrode.



Water pipes which run in almost all townships and residential layouts are more suitable for AC voltage sources. If DC circuits are grounded, any ground current can cause severe electrolysis which result in scale formation inside the pipes, thus blocking water flow.

The resistance offered by soil surrounding a grounding electrode has its influence within certain region, generally called "Circle or Sphere of Influence." The diameter of this circle of influence will be usually equal to twice the length of grounding electrode. So, if more than one electrode is being installed, distance between them should be equal to or greater than twice the electrode length. If the grounding electrode is non-circular, the spacing should be equal to or greater than the electrode's width. Normally round rod (or pipe) and square plate electrodes are commonly used, if electrodes are fitted inside.



It is quite difficult to get ideal soil condition in all locations for maintaining minimum ground resistance. Under such circumstances, by addition of certain chemicals, almost ideal condition can be obtained. The most commonly used material for reducing ground resistance are:

1. Charcoal or Coke power
2. Common Salt (Sodium Chloride, NaCl) or Calcium Chloride (CaCl) or Sodium Nitrate ($NaNO_3$)or Magnesium Sulphate ($MgSO_4$)
3. Construction grade sand

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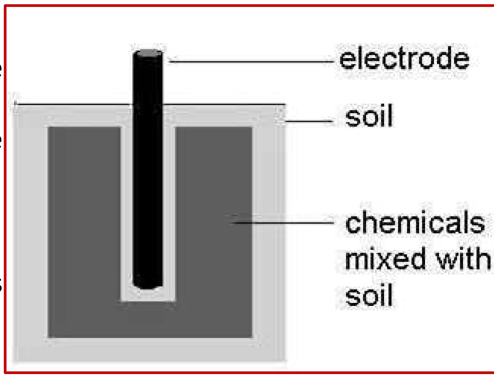
Items 1 and 2 are usually laid in layer form around the grounding electrode. Electrode will be firmly retained inside the sand. The sand retains moisture level for long time thus keeping ground resistance always low. The installation pictures at end of this article explain civil work involved in creating the "EARTH PIT" for circular and flat plate electrodes. When locating the spot for earth pits, pay close attention to following points:



- There are no underground cables or pipe lines – These might be damaged when excavating
- There is no huge stagnation of water – Too much water will dilute the salt content, which increases ground resistance
- The location is easily accessible for regular inspection and maintenance
- No future construction work is planned in the earth pit area
- Prevent growth of marsh around the earth pit – Otherwise, it becomes difficult – after few months – even to locate the earth pit

Generally, galvanized iron or MS (Mild Steel) pipes are used as grounding electrodes in many places to reduce initial cost. But apart from high ground resistance, they are also prone to corrosion from the chemical treatment provided. If the set-up has critical and expensive machines, it is always suggested to install copper based electrodes for proper grounding and safety of equipments.

Some merits and demerits of copper / steel electrodes are listed below:

- Steel electrode should be 5 to 6 times more than copper in terms of size to achieve same ground resistance (Example: If copper electrode is one meter, steel electrode should be between 5 to 6 meters)

- If copper electrodes are installed, they must be kept away from any underground steel pipes. Otherwise, they create a "cathodic" reaction cell which will corrode the steel pipes.

- Steel is mechanically stronger than copper and hence needs less support in an earth pit.

Some stands for Grounding

IS 3043 (Indian Standards)

OSHA (Occupational Safety & Health Administration

ANSI / ISA (American National Standards Institute / Instrument Society of America)

IEC (International Electro technical Commission)

CENELEC (European Committee for Electro technical Standardization)

IEEE (Institute of Electrical & Electronics Engineers)

REMEMBER: Earth-pits are NOT FILL & FORGET type. Their regular inspection should be a part of preventive maintenance and inspection procedure. If earth pits are located in dry area, pour water to maintain sufficient moisture level. For a 3-meter deep earth pit, three to four buckets (15 to 20 liters) of water once in a month is sufficient.

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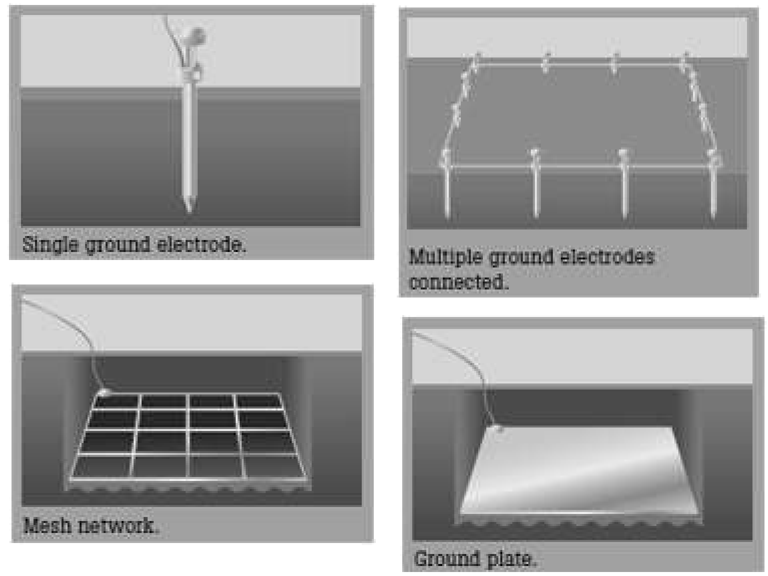
Types of Grounding installations:

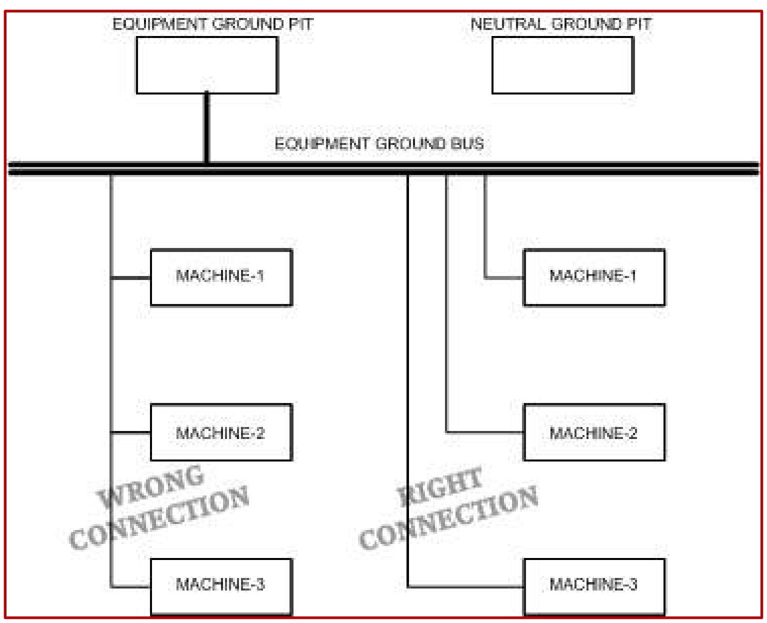


Single ground electrode.
Multiple ground electrodes connected.
Mesh network.
Ground plate.

Based on the soil condition and type of installation to be grounded, different methods of grounding set-up are practiced. Adjacent pictures show some of the common methods of grounding practices. Independent of the type of design used, increasing the contact area of ground electrode with surrounding soil should be one of the primary objectives.

Once the grounding electrodes are installed, they must be connected properly to the equipments in the facility. It is a common practice to use continuous strip of galvanized iron or mild steel plate on the walls, closer to which machines and equipments are installed.

Copper strips are generally used inside distribution panels for easier installation.



Then, each equipment should be separately connected using another strip or multi-strand copper cable or GI wire to this ground bus. Even if a machine is located slightly away from the nearest ground bus, it must not be connected to another machine which is closer. Each grounding must be separately connected. This will prevent ground fault current of one machine affecting the other. Also, resistance of individual ground circuit adds thus increasing total ground resistance of last equipment.

Neutral from each machine will not be usually grounded, although it is suggested for special purpose and expensive machines. But, grounding must be done for neutral point (star point) of the alternator. Grounding of neutral from main isolation step-down transformer must also be done, in the transformer yard itself. It is also advisable to create a neutral ground pit at the main distribution panel as well.

Once the earth pits are fixed, it is important to introduce the process of measuring earth resistance into predictive maintenance schedule. Disconnect the strip or cable from main plant and isolate earth pit. Using a reference probe, fixed at a particular distance from the ground electrode, measure the resistance value (in ohms). Record the value at

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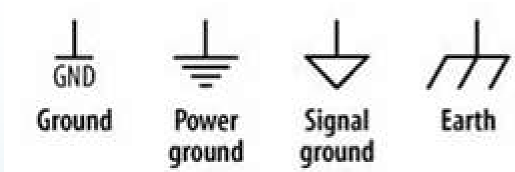
different times of day and calculate average resistance value. Repeat the exercise once or twice a year and monitor deviations. Proper corrective actions must be taken if values are found above acceptable limit.

Soil Resistivity & Earth Resistance Table (Approximate Values)

Type of Soil	Soil Resistivity OHM-METER	Earthing Resistance (OHMS)					
		Ground Electrode Depth (meters)			Earthing Strip (meters)		
		3	6	10	5	10	20
Very moist soil (swamp like)	30	10	5	3	12	6	3
Farming soil and clay soil	100	33	17	10	40	20	10
Sandy clay soil	150	50	25	15	60	30	15
Moist sandy soil	300	66	33	20	80	40	20
Concrete	400	-	-	-	160	80	40
Moist gravel	500	160	80	48	200	100	50
Dry sandy soil	1000	330	165	100	400	200	100
Dry gravel	1000	330	165	100	400	200	100
Stoney oil	30000	1000	500	300	1200	600	300
Rock	107	-	-	-	-	-	-

Grounding Symbols – Adjacent picture show three of the commonly used symbols for grounding. It is important to differentiate between types for proper grounding design. None of these circuits should be combined when connecting to a grounding electrode.



Power Ground – The 0V line of any type of power supply. More commonly seen in DC circuits. But can also symbolize neutral connection of AC system.

Signal Ground – Commonly used for symbolizing communication equipments.

Earth – The equipment or body earth. Symbolizes non-power grounding system.

How grounding electrode size will be determined?

One of the most important functions of a grounding electrode is to withstand sudden inrush current which could occur due to short-circuit or overloading in an equipment. Therefore, the electrode must be able to withstand this short-circuit current. Of all the equipments installed in the set-up, consider highest short-circuit current (usually printed on the circuit breakers or on machine name plate or in the installation manuals). For size calculation you can follow a thumb rule. Steel can withstand 0.124 kA (124 amperes) per square millimeter of conductor area and Copper can withstand 0.282 kA (282 amperes) per square millimeter.

Despite having a good grounding system, it is important to install

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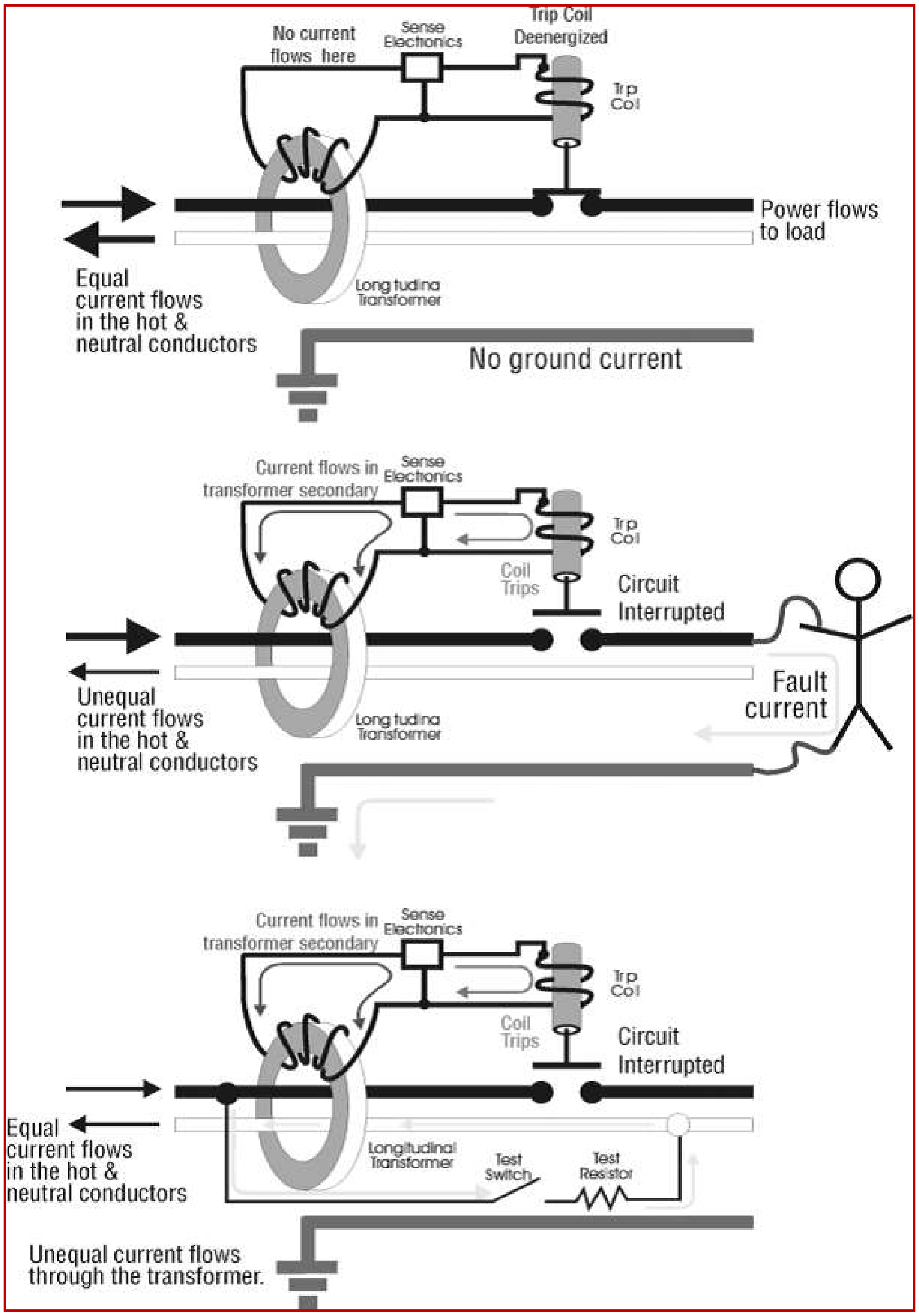
ground circuit sensing and protection devices that will isolate power at the next highest upstream level to prevent further damage and accident. Earth Leakage Relay (ELR) is the most commonly used safety sensing device fitted in the incoming panel of a 3-phase 4-wire system. A CBCT (**Core Balanced Current Transformer**) fitted around the 4-wire system checks the imbalanced current flow in neutral or return line and if it exceeds a present value for a present time, it will close a contact. This auxiliary contact will in turn usually trip the incoming ACB or MCCB or any other circuit breaker.



Remember: If ELR trips, do not immediately increase the trip current or time limit. Reset the breaker and re-check. If ELR trips again, check all the downstream equipments before increasing the limits. ELR is a very sensitive device and does not trip without reason.

In a single-phase system, RCCB (Residual Current Circuit Breaker) must be fitted to prevent electrical hazard to the personnel. This will be especially important in domestic areas where people of all age groups could be dealing with one or other type of electrical equipment. The equipment we "assume" to be most safest can become a electrical hazard without proper protection devices. Also, it is not advisable to use any equipment – computers, electric heaters, ovens, etc – with two pin socket system. This will completely isolate the grounding protection posing great danger to the users.

NOTE: Even while constructing a house, it is highly recommended to follow the grounding rules and build a small earth pit, similar to manufacturing set-up. This will greatly help in isolating all ground faults to maximum extent. Drawing a simple GI wire into ground alone is not sufficient.

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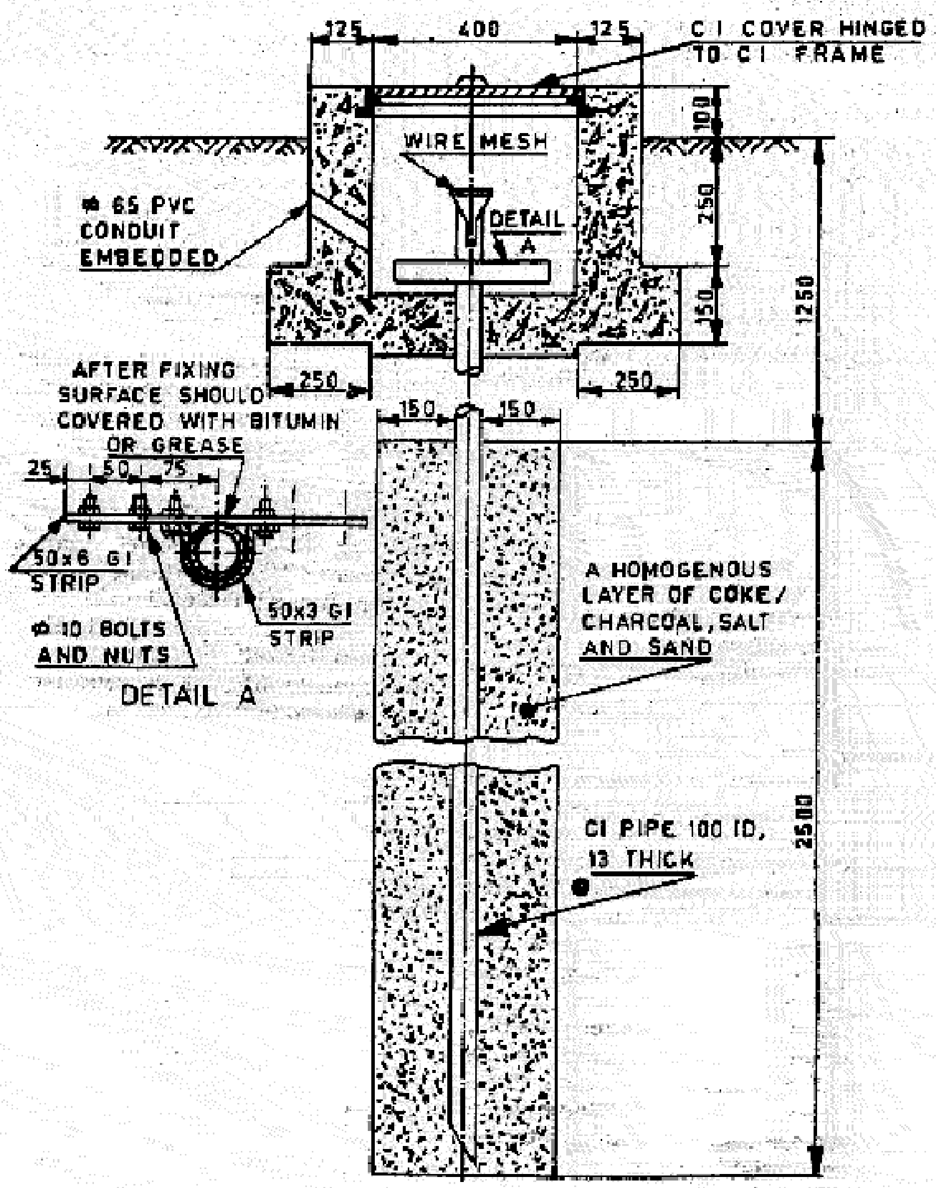
Standard Pipe Earth Pit System Description



NOTE — After laying the earth from the earth bus to the electrode through the PVC conduits at the pit ʼy conduits should be sealed with bitumin compound.

All dimensions in millimetres.

TYPICAL ARRANGEMENT OF PIPE ELECTRODE

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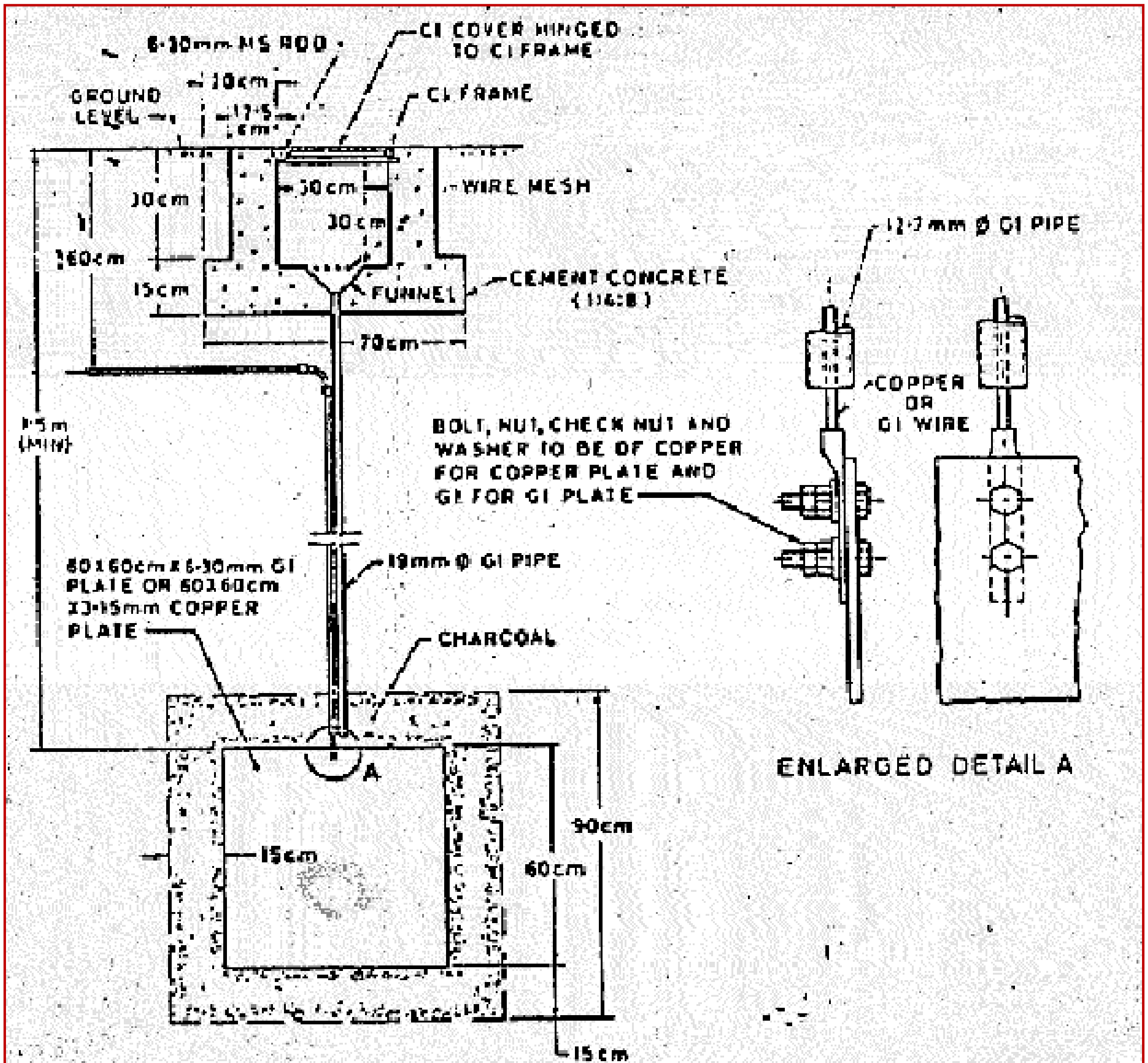
Plate Type Earth Pit System Description



NOTE — Three or four buckets of water to be poured into sump every few days to keep the soil surrounding the earth plate or pipe permanently moist.