SOUTH AFRICAN TRANSPORT SERVICES

CHIEF ELECTRICAL ENGINEER's DEPARTMENT

CODE OF PRACTICE :

EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS

CEE.0177.86

CODE OF PRACTICE : EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS

At all future Electric Light and Power and traction installations, the existing method of earthing by using earth spikes made of galvanised water pipe as depicted on drawing number CEE-E1B-142 and described in circular ENW-10/133 of the 3 September 1952, will be superseded by a deep earthing system as first choice. If, however, a survey indicates that a deep earth is not possible, a trench type earth may be installed. The deep earthing system incorporates the use of copper coated steel electrodes (similar to Copperweld) which are driven into the ground to the depth necessary to give a required earth resistance of 5 ohms or less.

The following procedure for the installation of the earthing system is outlined below for the guidance of System Electrical Engineers, Resident Engineers and other staff concerned.

A. SURVEY

A survey is necessary to determine the type of earthing system to be used and the best possible position of the earthing system within the limits of the site available.

EQUIPMENT REQUIRED FOR SURVEY

(i) A null balance Megger (or other type of resistance measuring instrument with 4 terminals plus a guard terminal and its own current generator). The instrument must be designed to block stray DC currents.

(ii) Five metal rods approximately 450 mm long to be used as test spikes.

(iii) Four lengths of insulated wire to connect the test spikes with the 4 terminals of the instrument. To ensure soil resistivity down to 45 metres, two of the wires should be about 90 metres long and two about 30 metres long. It is most convenient to use wires of different colours on spools mounted on a shaft for rapid unwinding and rewinding.

MEASUREMENT OF THE AVERAGE RESISTIVITY OF THE SOIL

The method described gives results that are accurate enough for all practical purposes wherever the stratification of the subsoil is more or less regular. In cases where the strata are very irregular the results may only approximate and in extreme cases they may be meaningless.

2/..............

The four test spikes A, B, C and D are placed as shown in Annexure A - symmetrically in relation to the point at which the soil is to be measured in a straight line and at equal intervals "a". The fifth spike, G is driven equidistant from B and C and connected to the guard terminal on the instrument and it should be stressed that the accuracy of the distance between spikes is most important. The spikes should not be driven more than about 300 mm into the ground.

The two outer spikes A and D (current spikes) are connected to the current terminals of the test instrument. The two inner spikes B and C (potential spikes) are connected to the potential terminals of the test instrument.

A current generated by turning the crank of the test instrument passes through the two outer spikes and the instrument measures the voltage between the two inner spikes. The relation is given directly on the dial of the test instrument as "r" or resistance in ohms.

The reading "r" must in turn be converted to a figure expressing the average resistivity of the soil : vertically, between the surface and a depth equal to 75 % of interval "a" and horizontally between the two potential spikes. The formula for the conversion is :-

$$p = 2 \quad ra$$

in which p is the soil resistivity value in ohm-metres
r is the instrument reading in ohms
a is the distance between test spikes.

The soil resistivity figure obtained is the average (or apparent) of all the layers of soil between the surface and a certain depth "D". This depth is considered to be 75 % of the distance "a" between the spikes. In other words :-

$$D = 0,75 \ a$$

The resistivity of the soil is measured down to successively greater depths by increasing the distance "a" as shown in the following typical series of measurements :-

Distance (metres) "a"	Depth (metres) "D"	Test reading (ohms) "r"	Resistivity (ohm metres) "p"
2	1,5	90	1 140
4	3	21,5	538
8	6	10	502
12	9	5,5	415
24	18	3	450
40	30	2	502
49,2	37,5	1,5	470

As the soil is rarely uniform to any great depth, the purpose of taking resistivity measurements at successive depths is to determine at what depths, to what extent and in what direction (up or down), the resistivity changes. These measurements indicate which layers of soil are most useful for obtaining a good earth connection.

3/..............

CALCULATION OF RESISTANCE OF EARTH ELECTRODES

The next step is to convert the series of resistivity measurements taken, into a corresponding series of figures showing the resistance "R" which sould be given by a single earth electrode driven to successively greater depths at the same point.

The conversion is made by the formula :-

$$R = 0{,}366 \frac{p}{D} \times \log \frac{(3D)}{d}$$

Where R is the resistance of the electrode in ohms.
P is the resistivity measurement at a particular depth in ohm-metres
D is that depth in metres
d is the diameter of the earth electrode to be used in metres.

For example, in the typical case described above, the resistance of a rod driven 3 metres is calculated as follows :-

$$R = 0{,}366 \times \frac{538}{3} \times \log \frac{(3 \times 3)}{0{,}016} \text{ ohms}$$

$\therefore$ R = 160 ohms (approx.)

IMPORTANT NOTES

Caution should be exercised to ensure that the survey is not executed close to buried conductors, i.e. metallic pipes, electric cables, existing earthing system ; or near the metallic conductors running above ground which are frequently earthed, i.e. fences and overhead transmission lines. The reason for this is that accuracy of the survey depends upon the current generated by the instrument taking its natural path through the soil. If buried conductors are in the close vicinty of the survey array, the current generated by the test set will take the line of least resistance along them and the survey results will be inaccurate. The minimum allowable distance between any of the test spikes and buried conductors should be 15 metres. It is preferable to execute a survey 15 metres or more from buried conductors in the vicinity as it is unlikely that the nature of the soil will change substantially over such a short distance.

Should it be absolutely impossible to avoid a buried conductor, then the survey array should be set to cross the conductor at right angles and never parallel to it.

If the soil in the area to be surveyed appears to be very dry or the initial instrument reading (when the distance "a" is 2 metres) is greater than 100 ohms, the ground in the area of the two outer current spikes must be watered. This is done by hammering the spikes into the ground to a depth of approximately 200 mm, removing them, filling the holes thus created with water and re-inserting the spikes to their full depth of about 300 mm. This procedure is then repeated each time the distance is increased until the survey is completed.

4/...............

SIMPLIFIED CALCULATIONS

The calculations involved in using the formulas given above can be simplified by the use of co-efficients. The formulas are reduced to a series of co-efficients pre-calculated for various depths. These co-efficients are only to be multiplied by the initial instrument reading "r" to give immediately both "p" and "R" for any given depth of electrode.

Attached is Annexure C with a list of resistivity and resistance co-efficients for various depths incorporated. This is a standard form and is to be used to tabulate measurements obtained from the survey.

EXAMPLE : (refer to Annexure C)

The distance between the test spikes is 6 metres, giving a depth D of 4,5 metres, the test instrument reading obtained is 0,50 ohms.

Multiplying 0,50 ohms by co-efficient "K" (37,75 at a depth of 4,5 metres) gives a resistivity (p) of 18,87 ohm metres.

Also multiplying 0,50 ohms by the co-efficient "K1" (8,98 at a depth of 4,5 metres) gives a theoretical resistance (R) for the deep earth electrode of 4,49 ohms.

INTERPRETATION AND PRACTICAL USE OF ABOVE MEASUREMENTS

Let us say that the survey has progressed to the stage where we have a complete list of soil resistivity readings (p) for progressive depths and the corresponding electrode resistance readings (R) and that these readings have been entered on form Annexure C. The tabulated results appear as in Annexure CC. The simplist way to interpret and make use of the measurements is then to plot them on a logarithmic grid, Annexure D. When plotted the results are represented by graphs as on Annexure DD. In general, and within certain limits, as long as the curve showing the calculated resistance values at successive depths drops off at least as sharply as the diagonals on the logarithmic grid it is more advantageous to keep driving a single electrode than to use a number of shorter electrodes connected in parallel. In some cases the soil resistivity does not decrease with depth and if this is so, the trench earthing system (decribed later) and not the deep earth must be installed.

USE OF PARALLEL ELECTRODES

When the resistance curves indicate that it is not advantageous to drive a single set of electrodes beyond a certain depth, or when the subsoil cannot be penetrated beyond a certain depth, the resistance obtained can be reduced by driving two or more electrodes in parallel. As a guide, two electrodes spaced at a distance equal to one and a half times their length and connected in parallel will give ± 60 %, of the resistance of one electrode ; three will give ± 43 % and four electrodes ± 33 1/3 % of the resistance of one electrode.

5/...............

B. APPLICATION OF DEEP EARTHING SYSTEM

EQUIPMENT REQUIRED

(i) Copper coated steel earthing rods approximately 1,2 metres (4 feet) and 16 mm (5/8 of an inch) diameter suitably threaded at each end. The survey will indicate the number of earthing rods required.

The copper coated earthing rods (similar to Copperweld) must conform to the following specifications :-

(a) The earthing rods to be composed of a steel core with a copper covering of not less than 0,38 mm thoroughly moltenwelded thereto so that an interlocking crystalline union exists between the two metals.

(b) The earthing rod when broken by successive bends shall show no seams, pits, slithers, or separation of copper from steel.

(c) The tensile strength of the earthing rods shall be not less than 400 megapascals.

(ii) External sleeve type threaded couplings made of non-zinc bronze for joining the earthing rods together.

(iii) High tensile steel driving bolts.

(iv) Two rod termination clamps for each set of electrodes.

(v) P.V.C. insulated (Anti-electrolysis) cable of not less than 70 mm^2 for connection of electrodes in parallel (if applicable) and for connection to equipment.

DRIVING METHODS

When only shallow electrodes are installed, hand driving with a hammer or weighted pipe as shown in Annexure H provides a simple and convenient method of installation.

When the electrodes are required to be driven to greater depths or through hard subsoil, it will be necessary to use some form of power driver. The actual type of power driver to be used is left to the discretion of the Engineer-in-charge of the installation. As a general guide, however, the petrol driven jack hammer is probably more convenient than the pneumatic or electric hammer as it is selfcontained. As the jack hammer should weigh in the vicinity of 20 to 30 kilograms only, with a cubic capacity of 250 cm^3 or larger, no difficulty should be experienced in manhandling it. Special adaptors for driving should be made from hardened and tempered steel to fit snugly over the driving bolt at the upper end of the electrode to be installed. See Annexure I for a typical type of adaptor in use.

METHOD OF INSTALLATION

The first section of the electrode to be installed should be fitted with a coupling. This coupling should be screwed on to the threaded end of the rod which is opposite the pointed end until all the threads on the rod are just covered. The coupling should then be held and a driving bolt inserted into it. The driving bolt should be screwed very tightly into the coupling so that a strong steel to steel abutment is created between the end of the driving bolt and the steel core of the rod. The rod is then driven vertically into the ground by importing hammer blows to the driving bolt head. The driving bolt is then removed and replaced with another earthing rod and coupling. The pointed end of the second rod is inserted into the coupling remaining on the rod which has previously been installed, ensuring that the threads of both rods are completely covered by the coupling. The first and second rod should then be tightened firmly together. The driving bolt is then screwed into the coupling at the upper end of the second earthing rod section as before, and this section is then driven into the ground.

This procedure is repeated until the electrode has been driven to the required depth and termination clamps fitted to its upper end.

Refer to Annexure B for details of the requirements at this upper end.

RECORDING OF ELECTRODE RESISTANCES DURING INSTALLATION

Readings of actual earth resistances must be taken every 1,2 metres (4 feet) of depth during installation of the deep earth system. These readings are to be recorded as a graph similar to Annexure E. (note that values of XX and YY axis are to be adjusted to suit local readings). Where more than one electrode is installed in order to obtain the required minimum resistance of 5 ohms, a graph should be compiled for each electrode and the overall resistance indicated.

C. APPLICATION OF TRENCH EARTH SYSTEM

In some cases the survey may indicate that the soil resistivity at the site does not decrease with depth, when this condition persists to a depth of approximately 20 metres, a trench earth must be installed.

The trench earth consists of copper conductors of not less than 40 sq. mm cross sectional area buried at least 600 mm below the surface of the soil. The earth may be installed as one of the following two type :-

(1) The radial trench earth as depicted diagrammatically at the bottom of Annexure F. The length of conductor needed to give a resistance of 5 ohms in soil with a resistivity of 100 ohm metres may be read off the chart Annexure F. Since the conductor resistance is proportional to the soil resistivity, the graph may be used for resistivities other than 100 ohm metres by multiplying by the appropriate factor. For practical purposes the soil resistivity indicated at a depth of 1,5 metres on the completed Annexure C chart may be used to calculate the length of trench earthing required.

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Example : A survey shows a soil resistivity of 500 ohm metres at a depth of 1,5 metres and a single wire trench earth is to be installed. What length of earth conductor is required ?

From the chart (Annexure F) the total length of conductor needed to give the required resistance of 5 ohms at a soil resistivity of 100 ohm metres is approximately 45 metres. At a soil resistivity of 500 ohm metres this length must be multiplied by 5 to give a total length of 225 metres.

The above example is for the installation of a single wire system and suitable adjustments can be made for 2, 3, 4 or 6 wire radial earth if required.

(2) The loop trench earth as depicted diagrammatically at the bottom of Annexure G. This type of trench earth may be installed where space is restricted. As with the radial trench earth, the soil resistivity indicated at a depth of 1,5 metres on the completed Annexure G chart may be used to calculate the length of the loop conductor.

Example : A survey indicates a soil resistivity of 100 ohm metres at a depth of 1,5 metres and a loop trench earth is to be installed. What length of conductor is required ?

From the chart Annexure G the total length required to give the required resistance of 5 ohms is 40 metres or, alternatively, the radius of the loop will be approximately 6,5 metres.

D. CONCLUSION

The staff responsible for the installation of an earthing system are required to forward to the Test and Research Engineer (Electrical) for record purposes the following :-

(a) Copies of Annexure D and E when the deep earthing system is installed.

(b) Copy of Annexure D and the final resistance reading when the trench earth system is installed.

Extant instructions covering earthing and applicable to existing installations remain for the time being but such, together with drawing number CEE-E1B-142 (Diagram of Earthing Arrangement) and the Code of Practice for negative circuits will be revised in due course for all changes to existing, and for new, installation.

CHIEF ELECTRICAL ENGINEER'S OFFICE
JOHANNESBURG

REFERENCE : EWPOL 3/0/4
DATE : FEBRUARY 1979

TYPICAL EXAMPLE

SITE : REPUBLIC TRACTION SUBSTATION

EQUIPMENT BEING EARTHED : AC EQUIPMENT IN OUTDOOR YARD

ANNEXURE CC TO CODE OF PRACTICE : EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS

DATE : 6 MARCH 1972

1	2	3	4	5	6	7
Interval "a" (metres)	Depth "D" (metres)	Instrument Reading "r" (ohms)	Resistivity Co-efficient "K"	Resistivity "P" (ohm metres) col 3 x 4	Resistance Co-efficient "K1"	Calculated Resistance "R" col 3 x 6
2	1,5	124	12,58	1 560	7,49	929
4	3	51,4	25,16	1 293	8,44	434
6	4,5	15,6	37,75	589	8,98	140
8	6	8,01	50,20	402	9,36	75
10	7,5	4,27	62,90	269	9,65	41,2
12	9	2,70	75,40	204	9,89	26,7
14	10,5	1,97	88,00	173	10,10	19,9
16	12	1,53	100,60	154	10,30	15,8
18	13,5	1,28	113,50	145	10,45	13,4
20	15	1,14	125,66	143	10,57	12
22	16,5	0,93	138,23	129	10,70	9,95
24	18	0,73	150,80	110	10,80	7,88
26	19,5	0,52	163,50	85	10,90	5,67
28	21	0,38	176,00	66,9	11,00	4,18
30	22,5	0,21	188,50	39,6	11,10	2,33
32	24		201,00		11,20	
34	25,5		213,90		11,30	
36	27		226,00		11,35	
38	28,5		239,00		11,40	
40	30		251,80		11,50	
42	31,5		263,90		11,60	
44	33		276,80		11,65	
46	34,5		289,00		11,70	
48	36		301,40		11,75	
50	37,5		314,10		11,80	
52	39		326,60		11,84	
54	40,5		339,10		11,90	
56	42		351,70		12,00	

SITE : ....

EQUIPMENT BEING EARTHED ....

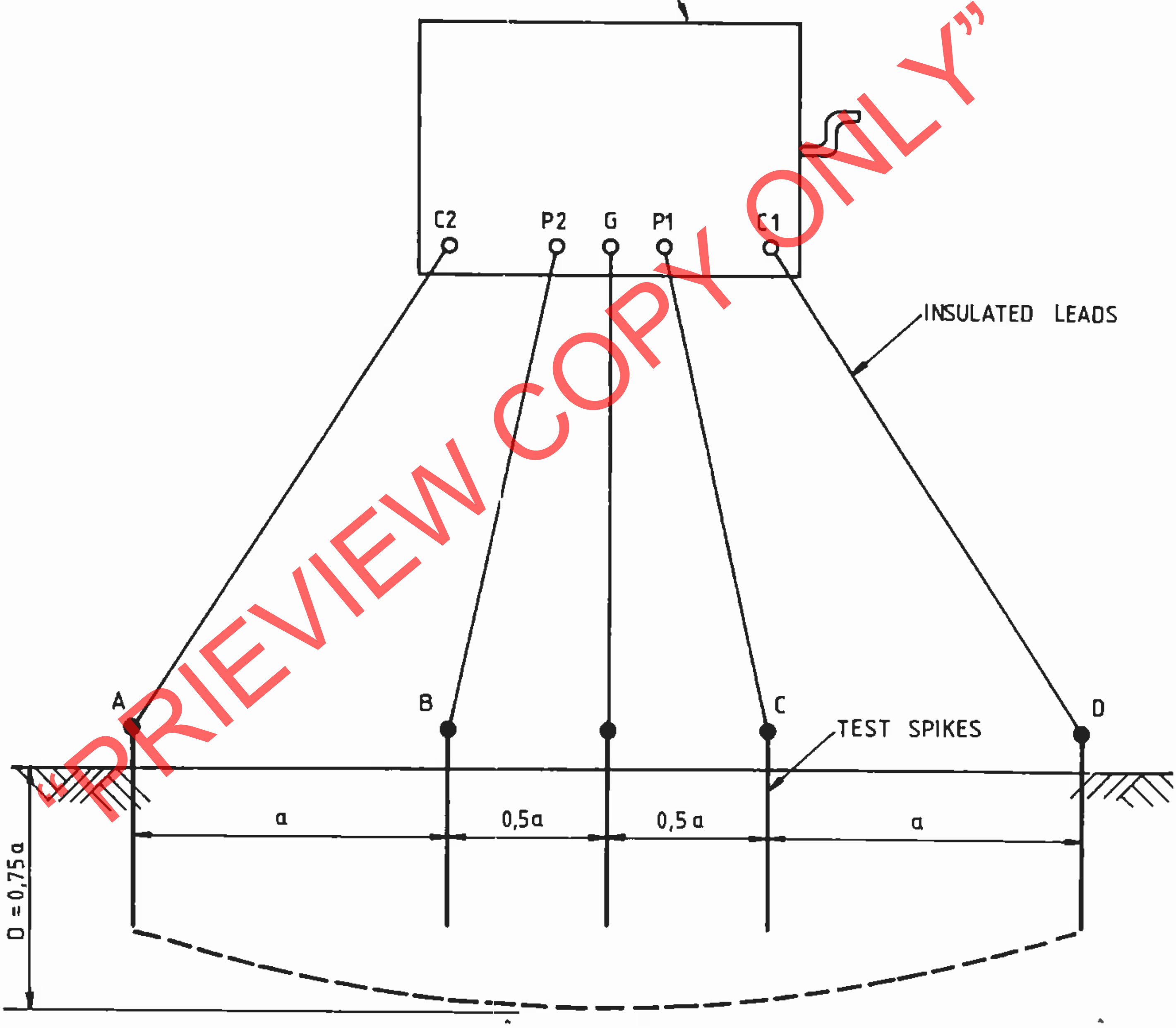
DATE ....

ANNEXURE C TO CODE OF PRACTICE EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS

1	2	3	4	5	6	7
Interval "a" (metres)	Depth "D" (metres)	Instrument Reading "r" (ohms)	Resistivity Co-efficient "K"	Resistivity "P" (ohm metres) col 3 x 4	Resistance Co-efficient "K1"	Calculate Resistanc "R" col 3 x 6
2	1,5		12,58		7,49	
4	3		25,16		8,44	
6	4,5		37,75		8,98	
8	6		50,20		9,36	
10	7,5		62,90		9,65	
12	9		75,40		9,89	
14	10,5		88,00		10,10	
16	12		100,60		10,30	
18	13,5		113,50		10,45	
20	15		125,66		10,57	
22	16,5		138,23		10,70	
24	18		150,80		10,80	
26	19,5		163,50		10,90	
28	21		176,00		11,00	
30	22,5		188,50		11,10	
32	24		201,00		11,20	
34	25,5		213,90		11,30	
36	27		226,00		11,35	
38	28,5		239,00		11,40	
40	30		251,80		11,50	
42	31,5		263,90		11,60	
44	33		276,80		11,65	
46	34,5		289,00		11,70	
48	36		301,40		11,75	
50	37,5		314,10		11,80	
52	39		326,60		11,84	
54	40,5		339,10		11,90	
56	42		351,70		12,00	

ANNEXURE A TO CODE OF PRACTICE
EARTH SYSTEMS FOR EL & P AND
TRACTION INSTALLATION.

NULL BALANCE MEGGER OR OTHER TYPE RESISTANCE MEASURING INSTRUMENT WITH 4 TERMINALS PLUS A GUARD TERMINAL AND ITS OWN CURRENT GENERATOR.

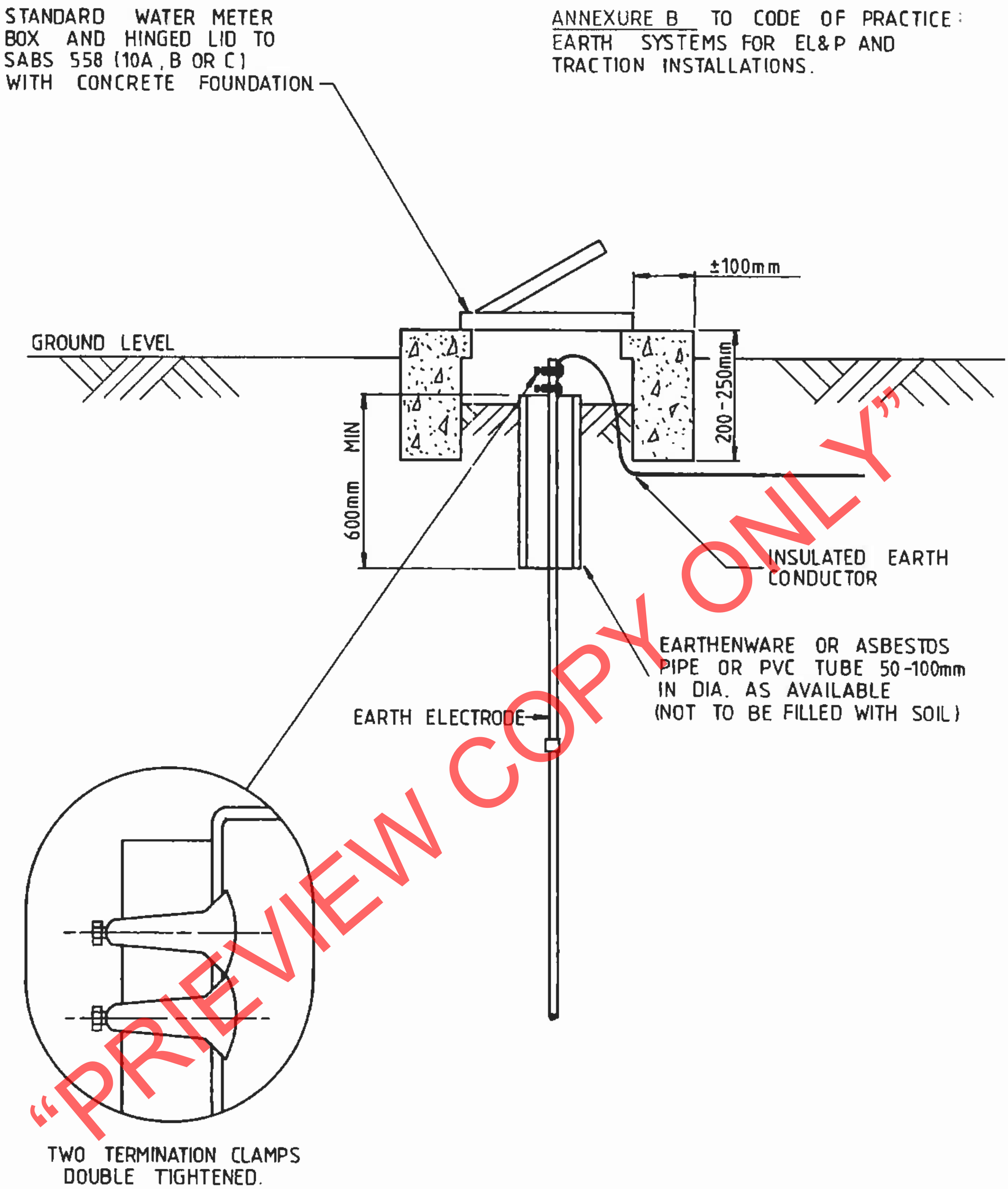


REQUIREMENTS FOR TESTING AVERAGE SOIL RESISTIVITY.

MENDMENT

DRG. No. CEE-MR-6 Sht 1

ANNEXURE B TO CODE OF PRACTICE:
EARTH SYSTEMS FOR EL&P AND
TRACTION INSTALLATIONS.



ARRANGEMENT FOR TERMINATION
OF EARTH ELECTRODE.

ANNEXURE B TO CODE OF PRACTICE: EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS

LOCALITY. ______________________________

EQUIPMENT BEING EARTHED. ______________________

DATE. ____________

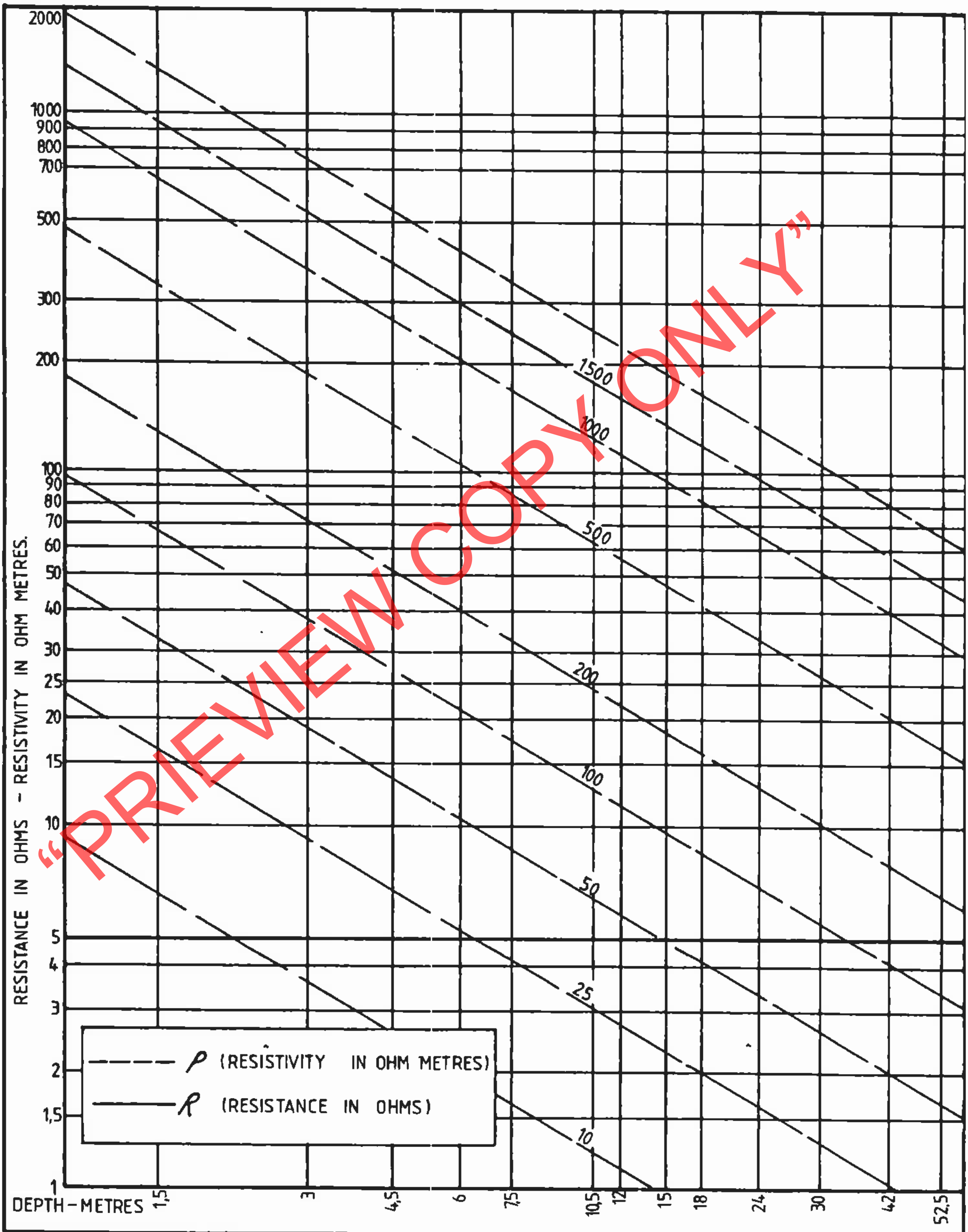


CHART TO RECORD (a) MEASUREMENTS OF SOIL RESISTIVITY

(b) CALCULATED RESISTANCE OF EARTH ELECTRODES

DRAWING TEKENING No CEE-MB-6 SHT 2

AMENDMENT

OF PRACTICE: EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS.

LOCALITY. REPUBLIC TRACTION SUBSTATION.

EQUIPMENT BEING EARTHED. AC. EQUIPMENT IN OUTDOOR YARD.

DATE. 6 th MARCH 1972.

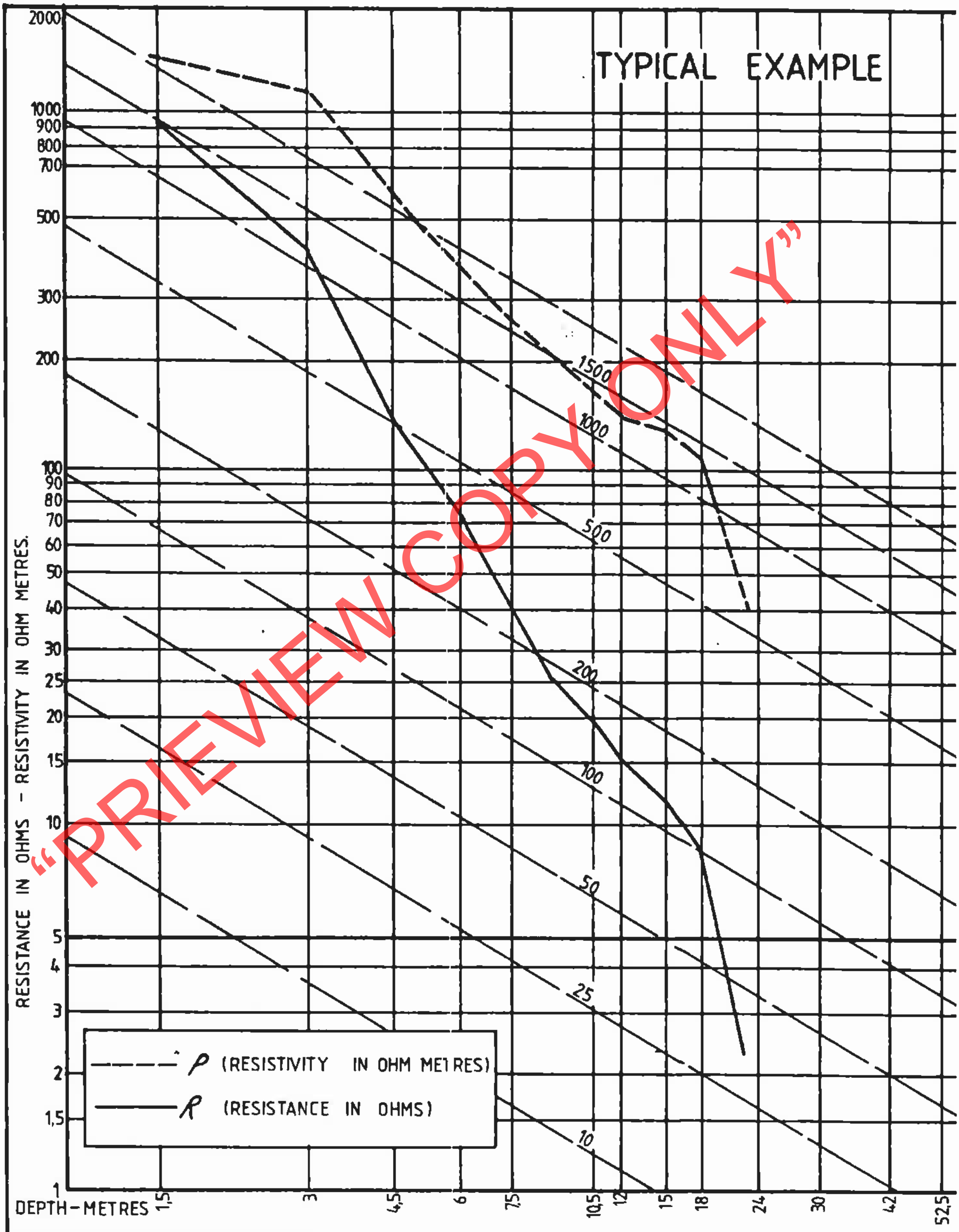


CHART TO RECORD (a) MEASUREMENTS OF SOIL RESISTIVITY.

(b) CALCULATED RESISTANCE OF EARTH ELECTRODES.

DRAWING No / TEKENING No CEE-MB-6 SHT 4

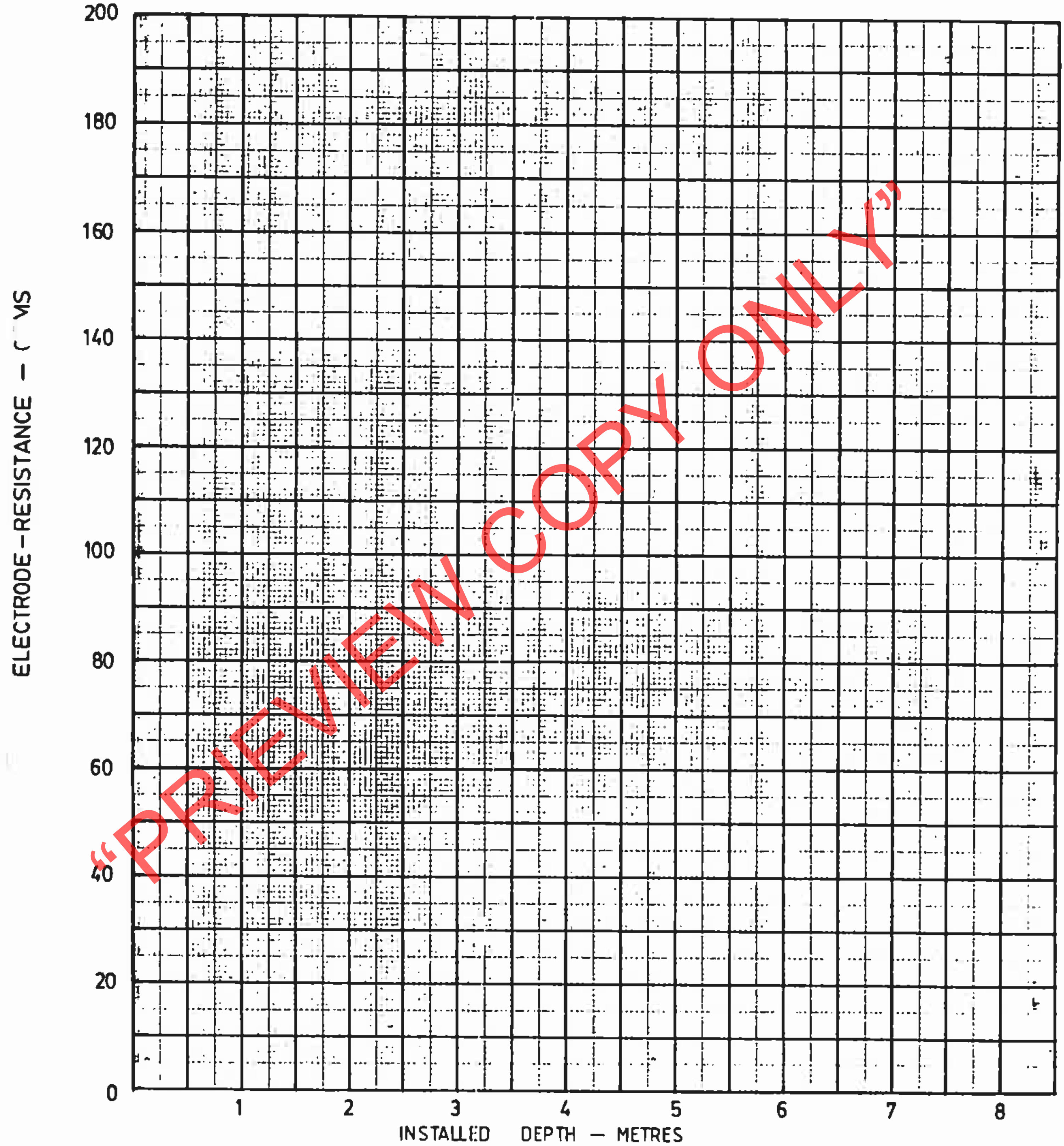
AMENDMENT

ANNEXURE E TO CODE OF PRACTICE : EARTH SYSTEMS FOR EL & P AND TRACTION INSTALLATIONS

LOCALITY ___________

EQUIPMENT BEING EARTHED___________

DATE________



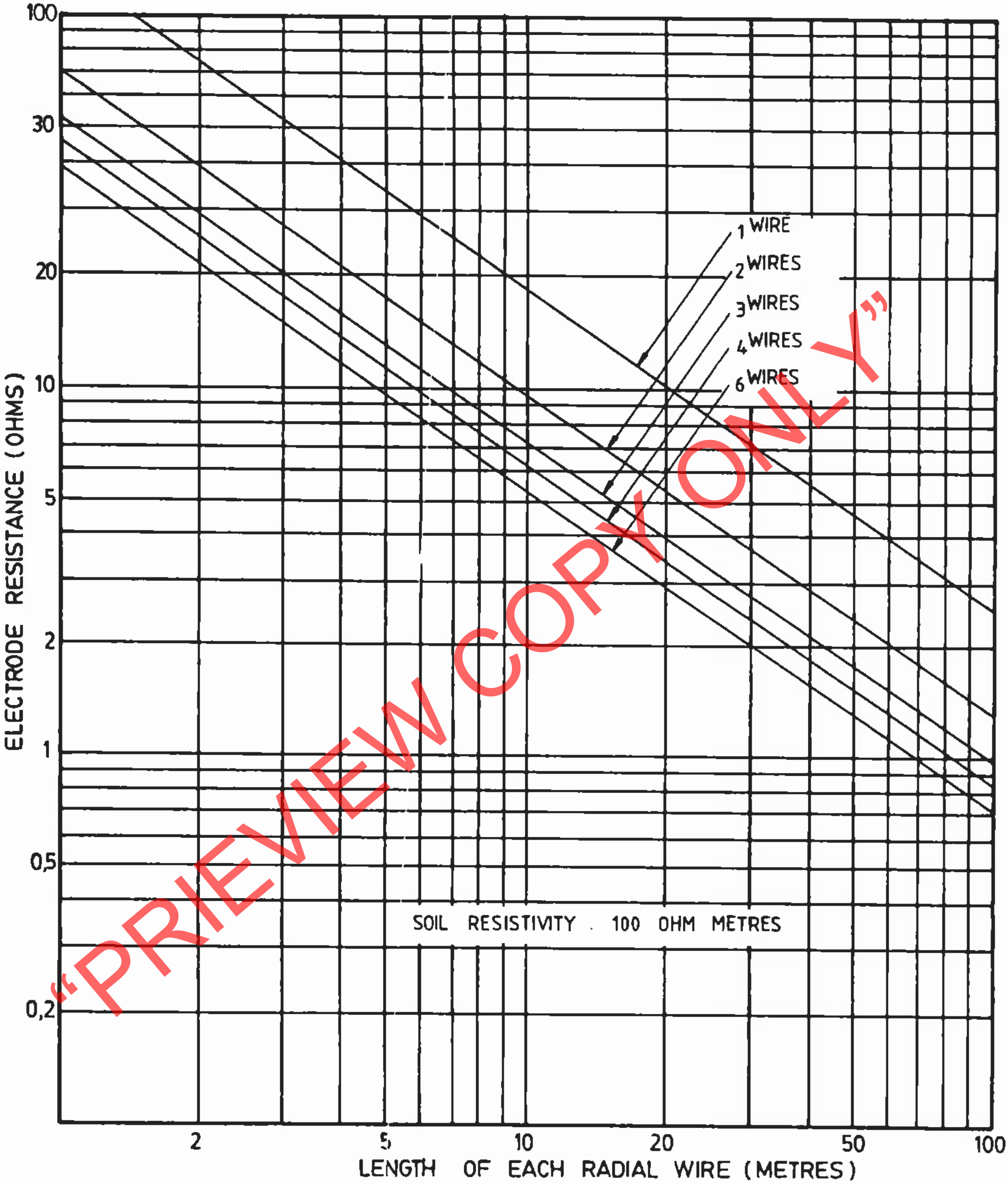
ELECTRODE RESISTANCES RECORDED.
DURING INSTALLATION.

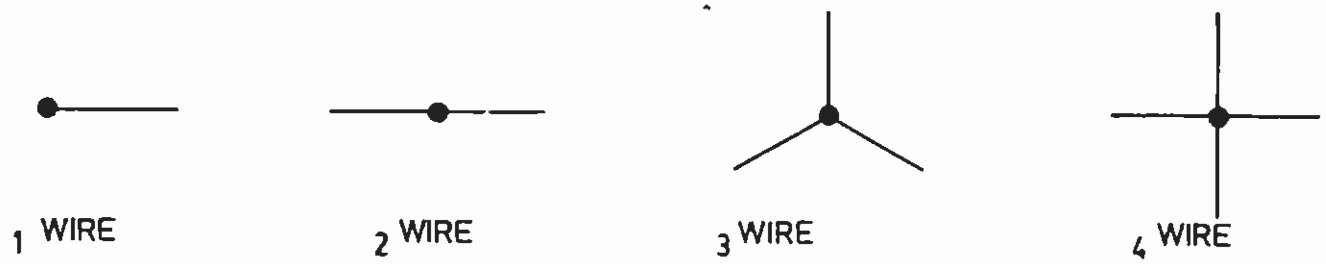
AMENDMENT

DRG ... STH

RESISTANCE (IN OHMS) OF A RADIAL EARTH ELECTRODE IN RELATION TO A SOIL RESISTIVITY OF 100 OHM METRES.

ANNEXURE F TO CODE OF PRACTICE : EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS





AMENDMENT

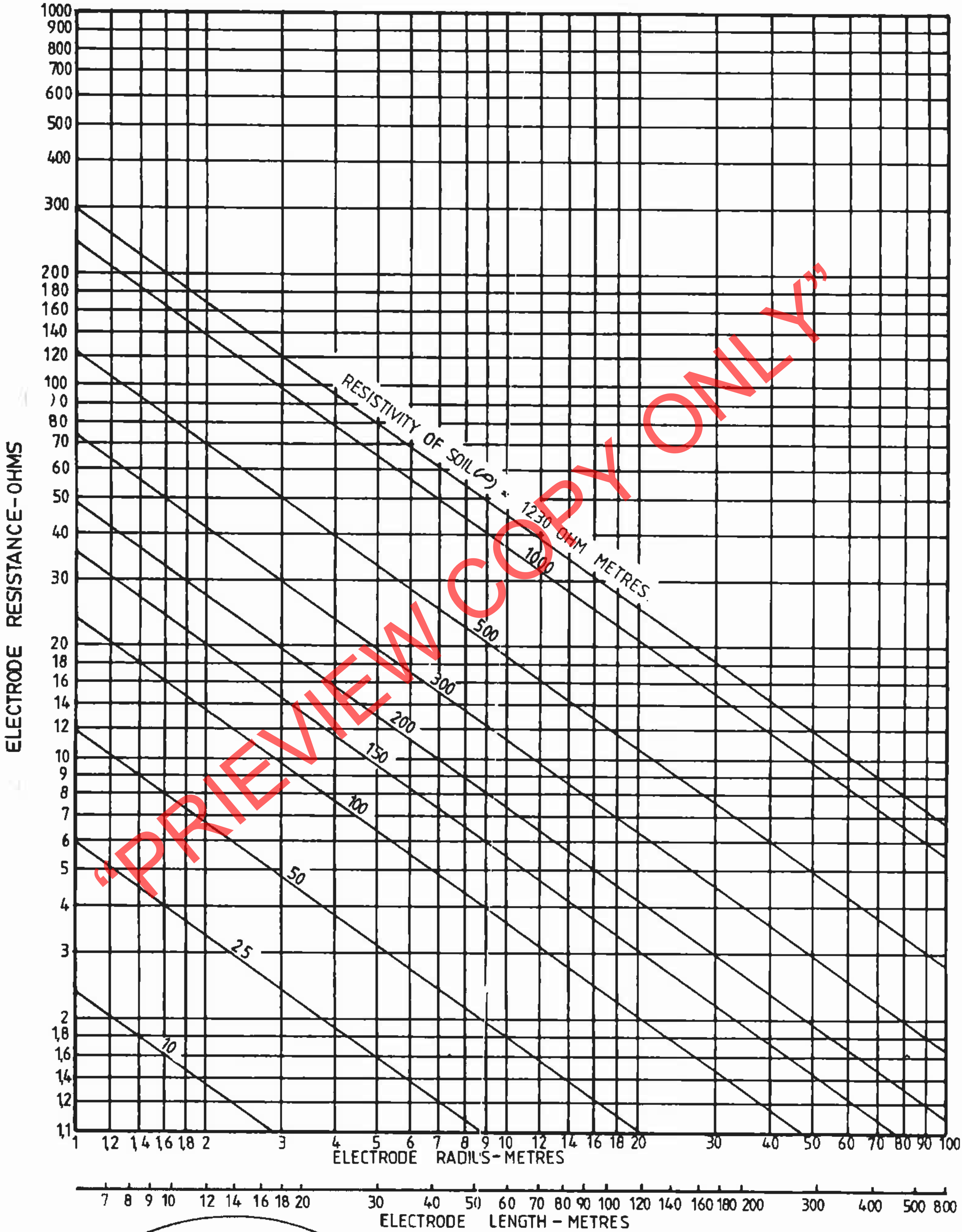
TRENCH EARTHING (RADIAL)

DRAWING TEKENING NO. CEE-

SHT

ANNEXURE G TO CODE OF PRACTICE: EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS

RESISTANCE (IN OHMS) OF AN EARTH CONDUCTOR BURIED IN THE FORM OF A LOOP IN RELATION TO THE RESISTIVITY ρ OF THE SOIL IN OHM METRES

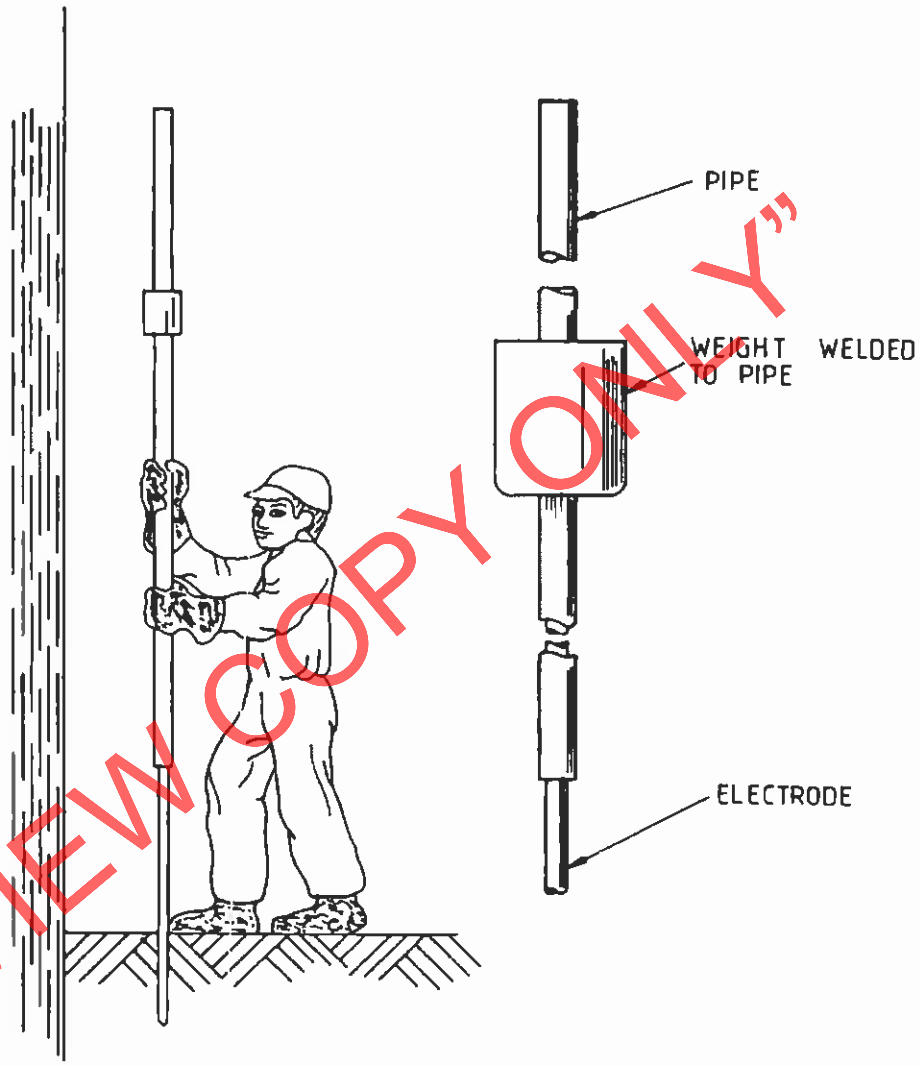


LEGEND.

LOOP

TRENCH EARTHING (LOOP)	DRAWING TEKENING No	CEE-

ANNEXURE H TO CODE OF PRACTICE:
EARTH SYSTEMS FOR EL&P AND TRACTION INSTALLATIONS

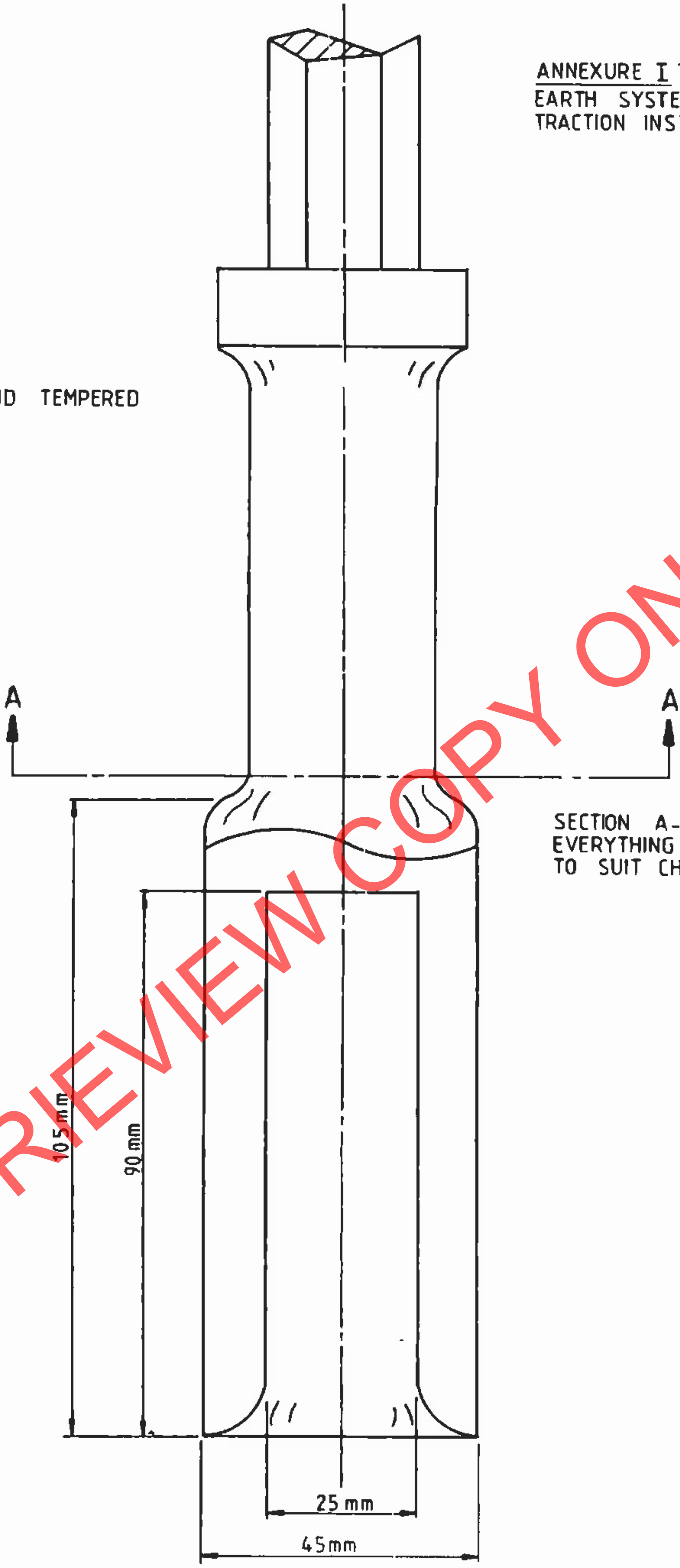


METHOD OF INSTALLING ELECTRODE BY MEANS OF A WEIGHTED PIPE.

AMENDMENT

ANNEXURE I TO CODE OF PRACTICE: EARTH SYSTEMS FOR EL & P AND TRACTION INSTALLATIONS.

MATERIAL
HARDENED AND TEMPERED STEEL.



SECTION A-A
EVERYTHING ABOVE THIS LINE TO SUIT CHUCK OF HAMMER

TYPICAL ADAPTOR FOR USE IN JACK HAMMER TO INSTALL EARTH ELECTRODES.

AMENDMENT

SOUTH AFRICAN TRANSPORT SERVICES

CHIEF ELECTRICAL ENGINEER's DEPARTMENT

CODE OF PRACTICE :

EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS

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a is the distance between test spikes.

The soil resistivity figure obtained is the average (or apparent) of all the layers of soil between the surface and a certain depth "D". This depth is considered to be 75 % of the distance "a" between the spikes. In other words :-

$$D = 0{,}75 \ a$$

The resistivity of the soil is measured down to successively greater depths by increasing the distance "a" as shown in the following typical series of measurements :-

Distance (metres) "a"	Depth (metres) "D"	Test reading (ohms) "r"	Resistivity (ohm metres) "p"
2	1,5	90	1 140
4	3	21,5	538
8	6	10	502
12	9	5,5	415
24	18	3	450
40	30	2	502
49,2	37,5	1,5	470

As the soil is rarely uniform to any great depth, the purpose of taking resistivity measurements at successive depths is to determine at what depths, to what extent and in what direction (up or down), the resistivity changes. These measurements indicate which layers of soil are most useful for obtaining a good earth connection.

3/..............

CALCULATION OF RESISTANCE OF EARTH ELECTRODES

The next step is to convert the series of resistivity measurements taken, into a corresponding series of figures showing the resistance "R" which sould be given by a single earth electrode driven to successively greater depths at the same point.

The conversion is made by the formula :-

$$R = 0{,}366 \frac{p}{D} \times \log \frac{(3D)}{d}$$

Where R is the resistance of the electrode in ohms.
P is the resistivity measurement at a particular depth in ohm-metres
D is that depth in metres
d is the diameter of the earth electrode to be used in metres.

For example, in the typical case described above, the resistance of a rod driven 3 metres is calculated as follows :-

$$R = 0{,}366 \times \frac{538}{3} \times \log \frac{(3 \times 3)}{0{,}016} \text{ ohms}$$

$\therefore$ R = 160 ohms (approx.)

IMPORTANT NOTES

Caution should be exercised to ensure that the survey is not executed close to buried conductors, i.e. metallic pipes, electric cables, existing earthing system ; or near the metallic conductors running above ground which are frequently earthed, i.e. fences and overhead transmission lines. The reason for this is that accuracy of the survey depends upon the current generated by the instrument taking its natural path through the soil. If buried conductors are in the close vicinty of the survey array, the current generated by the test set will take the line of least resistance along them and the survey results will be inaccurate. The minimum allowable distance between any of the test spikes and buried conductors should be 15 metres. It is preferable to execute a survey 15 metres or more from buried conductors in the vicinity as it is unlikely that the nature of the soil will change substantially over such a short distance.

Should it be absolutely impossible to avoid a buried conductor, then the survey array should be set to cross the conductor at right angles and never parallel to it.

If the soil in the area to be surveyed appears to be very dry or the initial instrument reading (when the distance "a" is 2 metres) is greater than 100 ohms, the ground in the area of the two outer current spikes must be watered. This is done by hammering the spikes into the ground to a depth of approximately 200 mm, removing them, filling the holes thus created with water and re-inserting the spikes to their full depth of about 300 mm. This procedure is then repeated each time the distance is increased until the survey is completed.

4/................

SIMPLIFIED CALCULATIONS

The calculations involved in using the formulas given above can be simplified by the use of co-efficients. The formulas are reduced to a series of co-efficients pre-calculated for various depths. These co-efficients are only to be multiplied by the initial instrument reading "r" to give immediately both "p" and "R" for any given depth of electrode.

Attached is Annexure C with a list of resistivity and resistance co-efficients for various depths incorporated. This is a standard form and is to be used to tabulate measurements obtained from the survey.

EXAMPLE : (refer to Annexure C)

The distance between the test spikes is 6 metres, giving a depth D of 4,5 metres, the test instrument reading obtained is 0,50 ohms.

Multiplying 0,50 ohms by co-efficient "K" (37,75 at a depth of 4,5 metres) gives a resistivity (p) of 18,87 ohm metres.

Also multiplying 0,50 ohms by the co-efficient "K1" (8,98 at a depth of 4,5 metres) gives a theoretical resistance (R) for the deep earth electrode of 4,49 ohms.

INTERPRETATION AND PRACTICAL USE OF ABOVE MEASUREMENTS

Let us say that the survey has progressed to the stage where we have a complete list of soil resistivity readings (p) for progressive depths and the corresponding electrode resistance readings (R) and that these readings have been entered on form Annexure C. The tabulated results appear as in Annexure CC. The simplist way to interpret and make use of the measurements is then to plot them on a logarithmic grid, Annexure D. When plotted the results are represented by graphs as on Annexure DD. In general, and within certain limits, as long as the curve showing the calculated resistance values at successive depths drops off at least as sharply as the diagonals on the logarithmic grid it is more advantageous to keep driving a single electrode than to use a number of shorter electrodes connected in parallel. In some cases the soil resistivity does not decrease with depth and if this is so, the trench earthing system (decribed later) and not the deep earth must be installed.

USE OF PARALLEL ELECTRODES

When the resistance curves indicate that it is not advantageous to drive a single set of electrodes beyond a certain depth, or when the subsoil cannot be penetrated beyond a certain depth, the resistance obtained can be reduced by driving two or more electrodes in parallel. As a guide, two electrodes spaced at a distance equal to one and a half times their length and connected in parallel will give ± 60 %, of the resistance of one electrode ; three will give ± 43 % and four electrodes ± 33 1/3 % of the resistance of one electrode.

5/...............

B. APPLICATION OF DEEP EARTHING SYSTEM

EQUIPMENT REQUIRED

(i) Copper coated steel earthing rods approximately 1,2 metres (4 feet) and 16 mm (5/8 of an inch) diameter suitably threaded at each end. The survey will indicate the number of earthing rods required.

The copper coated earthing rods (similar to Copperweld) must conform to the following specifications :-

(a) The earthing rods to be composed of a steel core with a copper covering of not less than 0,38 mm thoroughly moltenwelded thereto so that an interlocking crystalline union exists between the two metals.

(b) The earthing rod when broken by successive bends shall show no seams, pits, slithers, or separation of copper from steel.

(c) The tensile strength of the earthing rods shall be not less than 400 megapascals.

(ii) External sleeve type threaded couplings made of non-zinc bronze for joining the earthing rods together.

(iii) High tensile steel driving bolts.

(iv) Two rod termination clamps for each set of electrodes.

(v) P.V.C. insulated (Anti-electrolysis) cable of not less than 70 mm^2 for connection of electrodes in parallel (if applicable) and for connection to equipment.

DRIVING METHODS

When only shallow electrodes are installed, hand driving with a hammer or weighted pipe as shown in Annexure H provides a simple and convenient method of installation.

When the electrodes are required to be driven to greater depths or through hard subsoil, it will be necessary to use some form of power driver. The actual type of power driver to be used is left to the discretion of the Engineer-in-charge of the installation. As a general guide, however, the petrol driven jack hammer is probably more convenient than the pneumatic or electric hammer as it is selfcontained. As the jack hammer should weigh in the vicinity of 20 to 30 kilograms only, with a cubic capacity of 250 cm^3 or larger, no difficulty should be experienced in manhandling it. Special adaptors for driving should be made from hardened and tempered steel to fit snugly over the driving bolt at the upper end of the electrode to be installed. See Annexure I for a typical type of adaptor in use.

METHOD OF INSTALLATION

The first section of the electrode to be installed should be fitted with a coupling. This coupling should be screwed on to the threaded end of the rod which is opposite the pointed end until all the threads on the rod are just covered. The coupling should then be held and a driving bolt inserted into it. The driving bolt should be screwed very tightly into the coupling so that a strong steel to steel abutment is created. between the end of the driving bolt and the steel core of the rod. The rod is then driven vertically into the ground by importing hammer blows to the driving bolt head. The driving bolt is then removed and replaced with another earthing rod and coupling. The pointed end of the second rod is inserted into the coupling remaining on the rod which has previously been installed, ensuring that the threads of both rods are completely covered by the coupling. The first and second rod should then be tightened firmly together. The driving bolt is then screwed into the coupling at the upper end of the second earthing rod. section as before, and this section is then driven into the ground.

This procedure is repeated until the electrode has been driven to the required depth and termination clamps fitted to its upper end.

Refer to Annexure B for details of the requirements at this upper end.

RECORDING OF ELECTRODE RESISTANCES DURING INSTALLATION

Readings of actual earth resistances must be taken every 1,2 metres (4 feet) of depth during installation of the deep earth system. These readings are to be recorded as a graph similar to Annexure E. (note that values of XX and YY axis are to be adjusted to suit local readings). Where more than one electrode is installed in order to obtain the required minimum resistance of 5 ohms, a graph should be compiled for each electrode and the overall resistance indicated.

C. APPLICATION OF TRENCH EARTH SYSTEM

In some cases the survey may indicate that the soil resistivity at the site does not decrease with depth, when this condition persists to a depth of approximately 20 metres, a trench earth must be installed.

The trench earth consists of copper conductors of not less than 40 sq. mm cross sectional area buried at least 600 mm below the surface of the soil. The earth may be installed as one of the following two type :-

(1) The radial trench earth as depicted diagrammatically at the bottom of Annexure F. The length of conductor needed to give a resistance of 5 ohms in soil with a resistivity of 100 ohm metres may be read off the chart Annexure F. Since the conductor resistance is proportional to the soil resistivity, the graph may be used for resistivities other than 100 ohm metres by multiplying by the appropriate factor. For practical purposes the soil resistivity indicated at a depth of 1,5 metres on the completed Annexure C chart may be used to calculate the length of trench earthing required.

7/................

Example : A survey shows a soil resistivity of 500 ohm metres at a depth of 1,5 metres and a single wire trench earth is to be installed. What length of earth conductor is required ?

From the chart (Annexure F) the total length of conductor needed to give the required resistance of 5 ohms at a soil resistivity of 100 ohm metres is approximately 45 metres. At a soil resistivity of 500 ohm metres this length must be multiplied by 5 to give a total length of 225 metres.

The above example is for the installation of a single wire system and suitable adjustments can be made for 2, 3, 4 or 6 wire radial earth if required.

(2) The loop trench earth as depicted diagrammatically at the bottom of Annexure G. This type of trench earth may be installed where space is restricted. As with the radial trench earth, the soil resistivity indicated at a depth of 1,5 metres on the completed Annexure G chart may be used to calculate the length of the loop conductor.

Example : A survey indicates a soil resistivity of 100 ohm metres at a depth of 1,5 metres and a loop trench earth is to be installed. What length of conductor is required ?

From the chart Annexure G the total length required to give the required resistance of 5 ohms is 40 metres or, alternatively, the radius of the loop will be approximately 6,5 metres.

D. CONCLUSION

The staff responsible for the installation of an earthing system are required to forward to the Test and Research Engineer (Electrical) for record purposes the following :-

(a) Copies of Annexure D and E when the deep earthing system is installed.

(b) Copy of Annexure D and the final resistance reading when the trench earth system is installed.

Extant instructions covering earthing and applicable to existing installations remain for the time being but such, together with drawing number CEE-E1B-142 (Diagram of Earthing Arrangement) and the Code of Practice for negative circuits will be revised in due course for all changes to existing, and for new, installation.

CHIEF ELECTRICAL ENGINEER'S OFFICE
JOHANNESBURG

REFERENCE : EWPOL 3/0/4
DATE : FEBRUARY 1979

TYPICAL EXAMPLE

SITE : REPUBLIC TRACTION SUBSTATION

EQUIPMENT BEING EARTHED : AC EQUIPMENT IN OUTDOOR YARD

ANNEXURE CC TO CODE OF PRACTICE : EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS

DATE : 6 MARCH 1972

1	2	3	4	5	6	7
Interval "a" (metres)	Depth "D" (metres)	Instrument Reading "r" (ohms)	Resistivity Co-efficient "K"	Resistivity "P" (ohm metres) col 3 x 4	Resistance Co-efficient "K1"	Calculated Resistance "R" col 3 x 6
2	1,5	124	12,58	1 560	7,49	929
4	3	51,4	25,16	1 293	8,44	434
6	4,5	15,6	37,75	589	8,98	140
8	6	8,01	50,20	402	9,36	75
10	7,5	4,27	62,90	269	9,65	41,2
12	9	2,70	75,40	204	9,89	26,7
14	10,5	1,97	88,00	173	10,10	19,9
16	12	1,53	100,60	154	10,30	15,8
18	13,5	1,28	113,50	145	10,45	13,4
20	15	1,14	125,66	143	10,57	12
22	16,5	0,93	138,23	129	10,70	9,95
24	18	0,73	150,80	110	10,80	7,88
26	19,5	0,52	163,50	85	10,90	5,67
28	21	0,38	176,00	66,9	11,00	4,18
30	22,5	0,21	188,50	39,6	11,10	2,33
32	24		201,00		11,20	
34	25,5		213,90		11,30	
36	27		226,00		11,35	
38	28,5		239,00		11,40	
40	30		251,80		11,50	
42	31,5		263,90		11,60	
44	33		276,80		11,65	
46	34,5		289,00		11,70	
48	36		301,40		11,75	
50	37,5		314,10		11,80	
52	39		326,60		11,84	
54	40,5		339,10		11,90	
56	42		351,70		12,00	

SITE : ....

EQUIPMENT BEING EARTHED ....

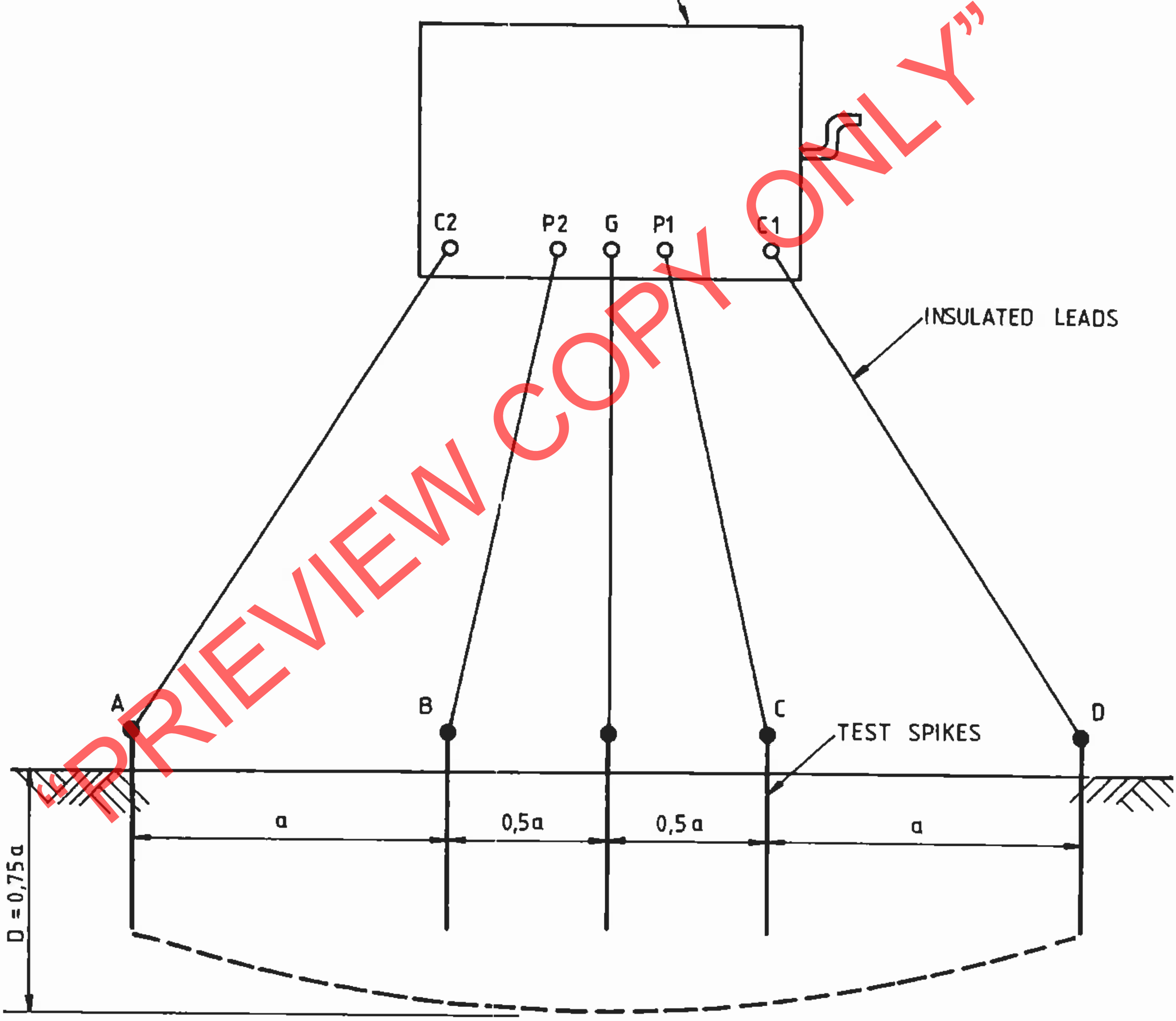
DATE ....

ANNEXURE C TO CODE OF PRACTICE EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS

1	2	3	4	5	6	7
Interval "a" (metres)	Depth "D" (metres)	Instrument Reading "r" (ohms)	Resistivity Co-efficient "K"	Resistivity "P" (ohm metres) col 3 x 4	Resistance Co-efficient "K1"	Calculate Resistanc "R" col 3 x 6
2	1,5		12,58		7,49	
4	3		25,16		8,44	
6	4,5		37,75		8,98	
8	6		50,20		9,36	
10	7,5		62,90		9,65	
12	9		75,40		9,89	
14	10,5		88,00		10,10	
16	12		100,60		10,30	
18	13,5		113,50		10,45	
20	15		125,66		10,57	
22	16,5		138,23		10,70	
24	18		150,80		10,80	
26	19,5		163,50		10,90	
28	21		176,00		11,00	
30	22,5		188,50		11,10	
32	24		201,00		11,20	
34	25,5		213,90		11,30	
36	27		226,00		11,35	
38	28,5		239,00		11,40	
40	30		251,80		11,50	
42	31,5		263,90		11,60	
44	33		276,80		11,65	
46	34,5		289,00		11,70	
48	36		301,40		11,75	
50	37,5		314,10		11,80	
52	39		326,60		11,84	
54	40,5		339,10		11,90	
56	42		351,70		12,00	

ANNEXURE A TO CODE OF PRACTICE EARTH SYSTEMS FOR EL & P AND TRACTION INSTALLATION.

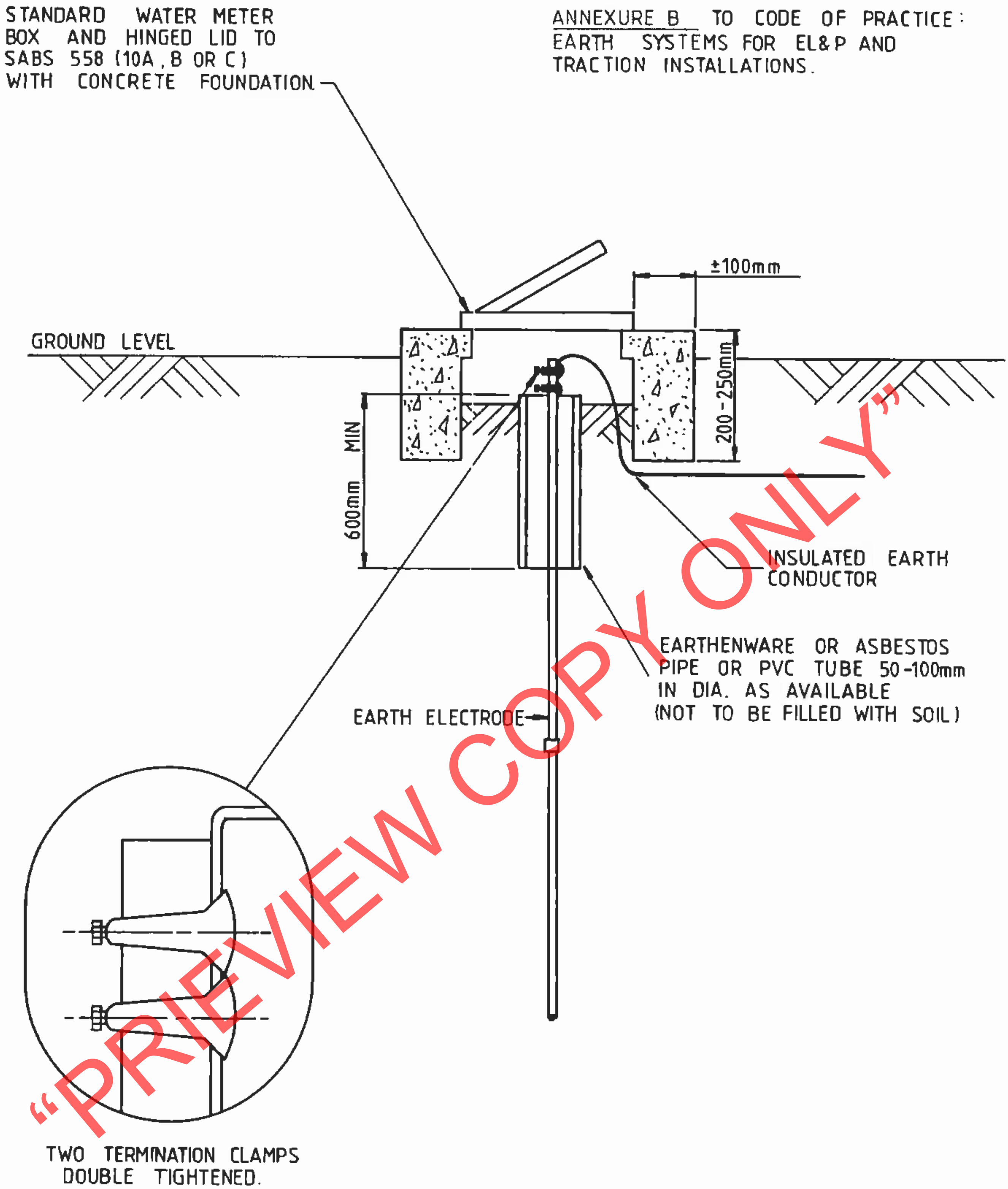
NULL BALANCE MEGGER OR OTHER TYPE RESISTANCE MEASURING INSTRUMENT WITH 4 TERMINALS PLUS A GUARD TERMINAL AND ITS OWN CURRENT GENERATOR.



REQUIREMENTS FOR TESTING AVERAGE SOIL RESISTIVITY.

MENDMENT

DRG. No CEE MP 6 Sht



ARRANGEMENT FOR TERMINATION OF EARTH ELECTRODE.

LOCALITY. ____________________

EQUIPMENT BEING EARTHED. ____________________

DATE. __________

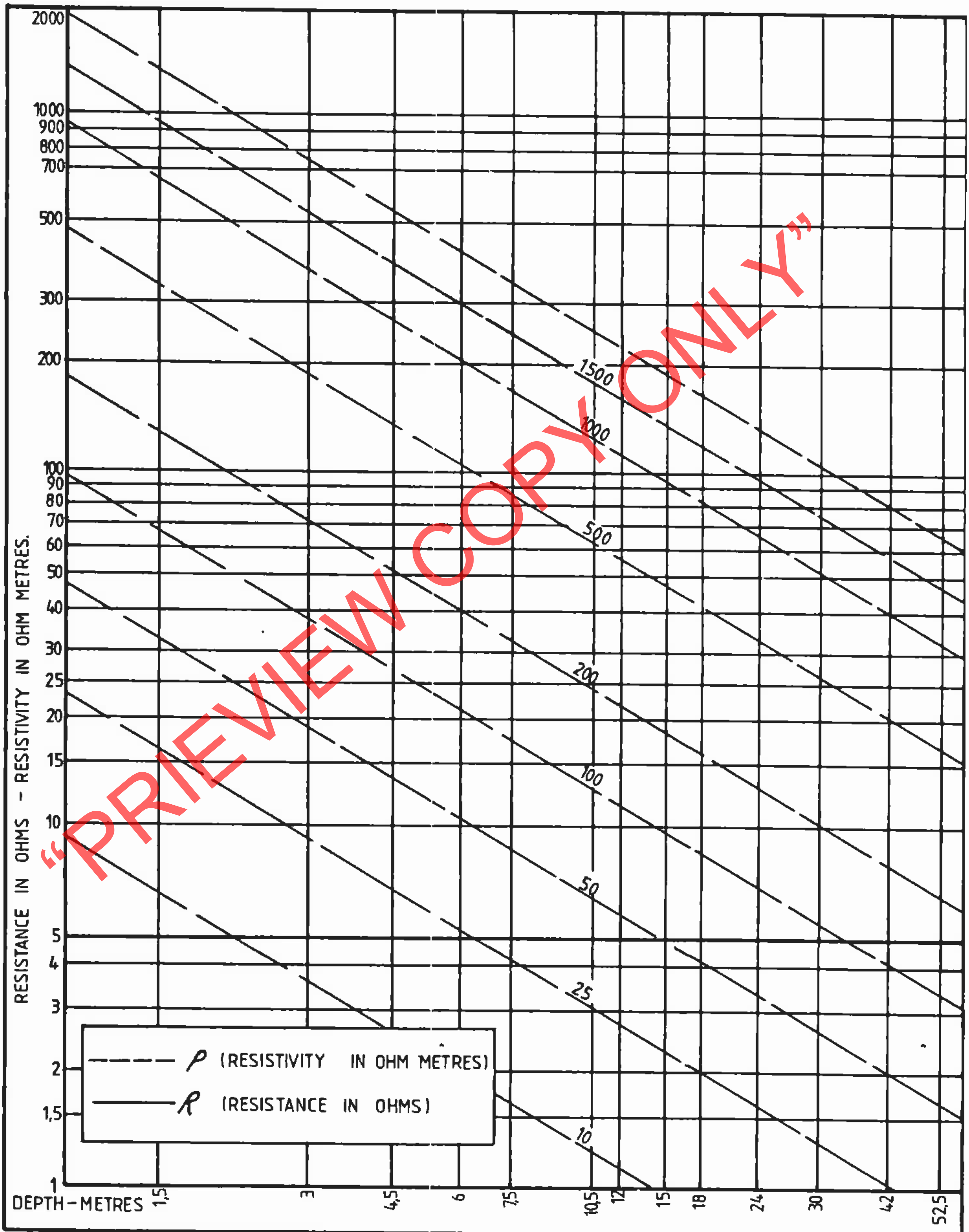


CHART TO RECORD (a) MEASUREMENTS OF SOIL RESISTIVITY

(b) CALCULATED RESISTANCE OF EARTH ELECTRODES

AMENDMENT

DRAWING TEKENING No CEE-MR-6 SHT 2

LOCALITY. REPUBLIC TRACTION SUBSTATION.

EQUIPMENT BEING EARTHED. AC. EQUIPMENT IN OUTDOOR YARD.

DATE. 6 th MARCH 1972.

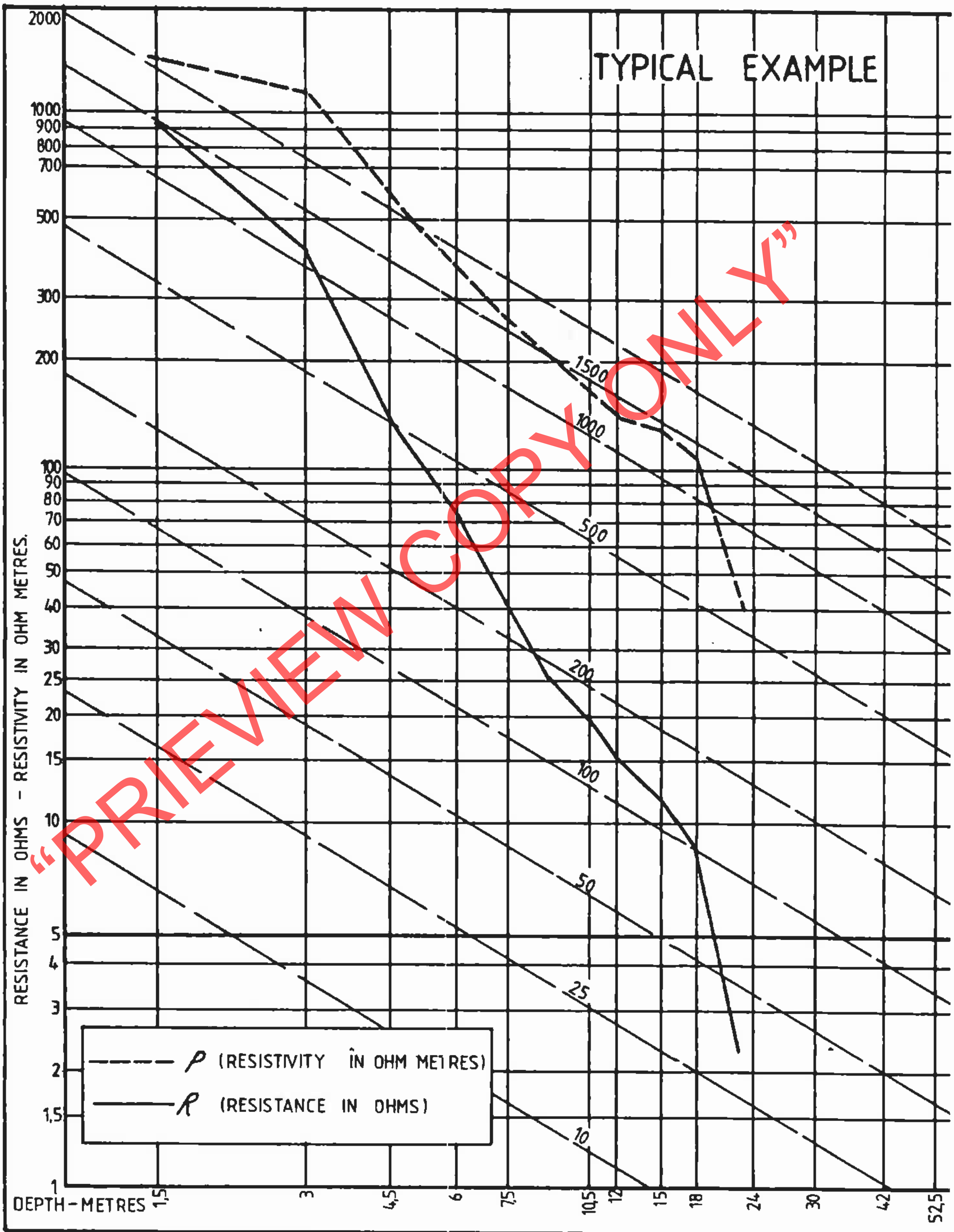


CHART TO RECORD (a) MEASUREMENTS OF SOIL RESISTIVITY.

(b) CALCULATED RESISTANCE OF EARTH ELECTRODES.

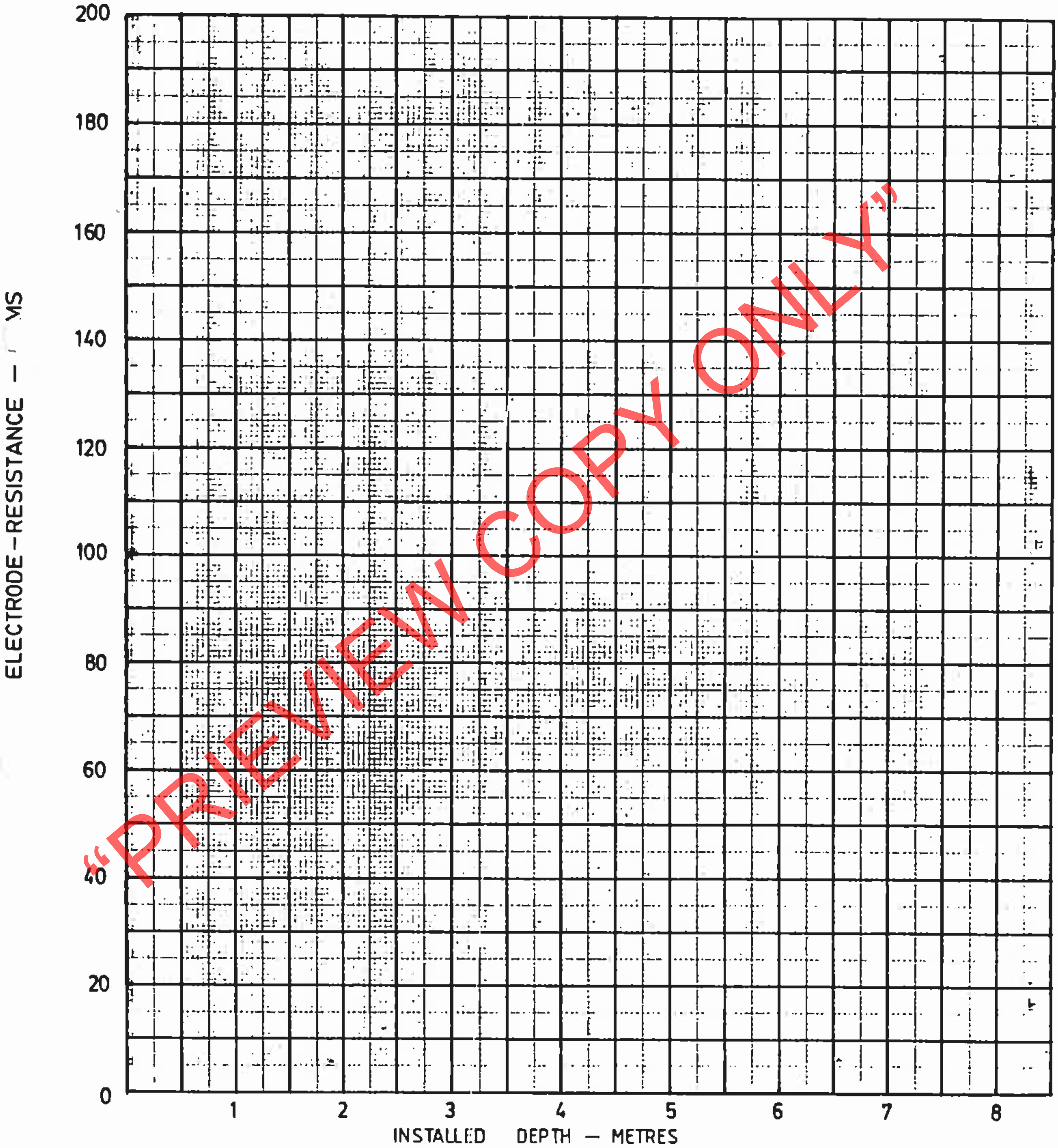
AMENDMENT

ANNEXURE E TO CODE OF PRACTICE : EARTH SYSTEMS FOR EL & P AND TRACTION INSTALLATIONS

LOCALITY ___________

EQUIPMENT BEING EARTHED___________

DATE________

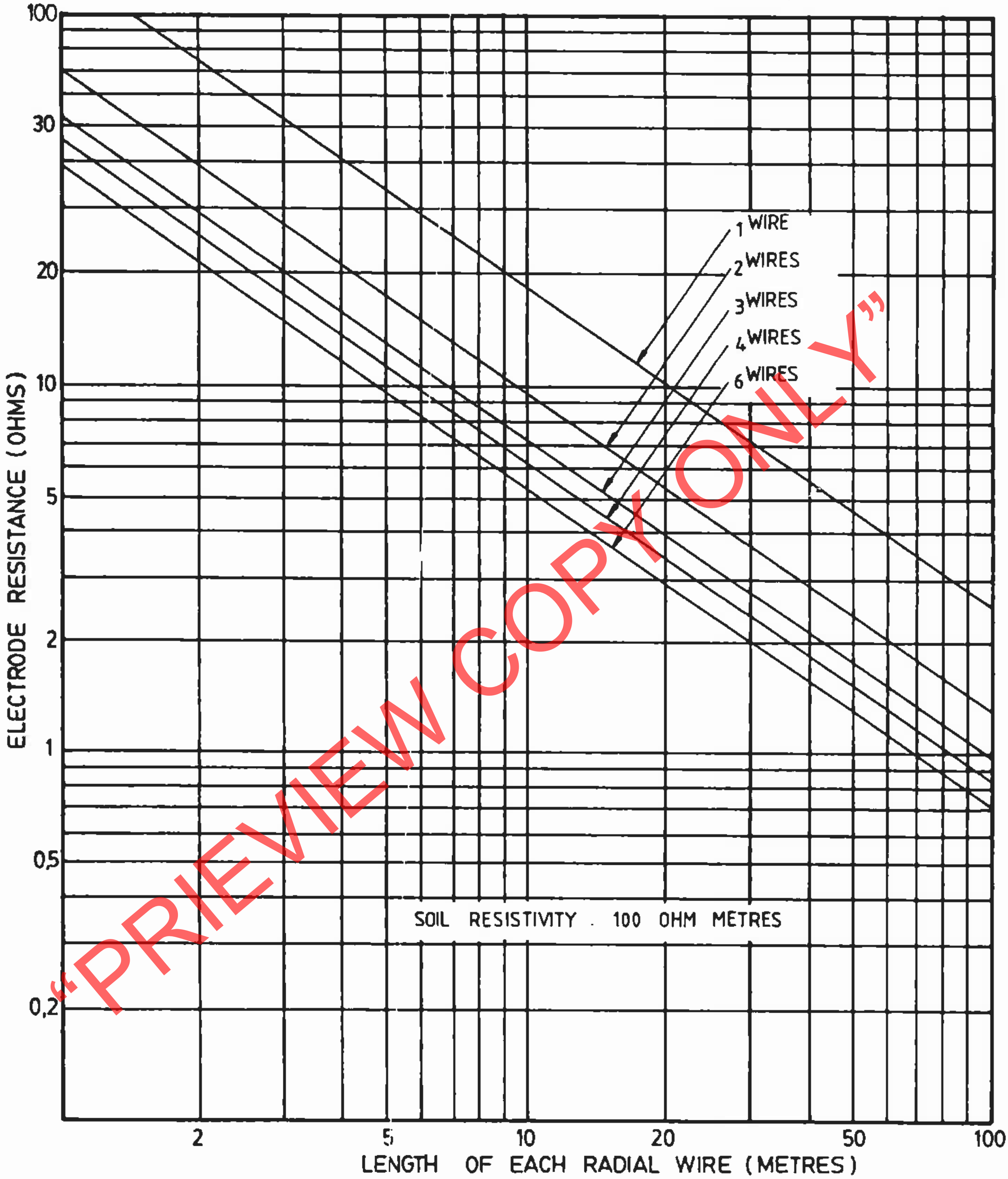


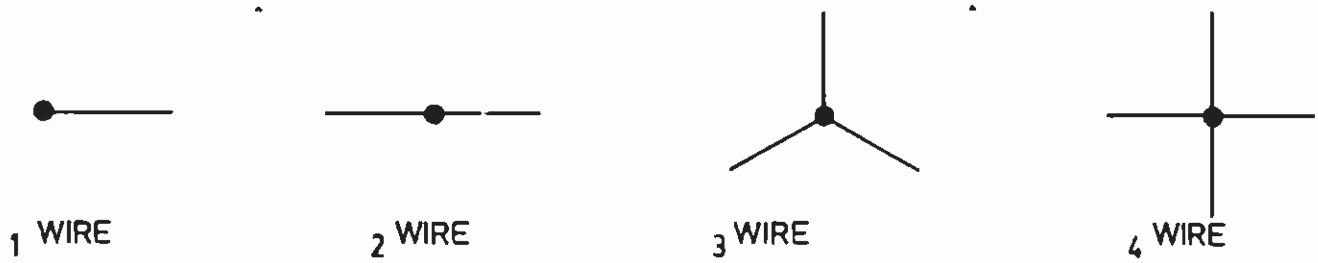
ELECTRODE RESISTANCES RECORDED.
DURING INSTALLATION.

AMENDMENT

RESISTANCE (IN OHMS) OF A RADIAL EARTH ELECTRODE IN RELATION TO A SOIL RESISTIVITY OF 100 OHM METRES.

ANNEXURE F TO CODE OF PRACTICE : EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS





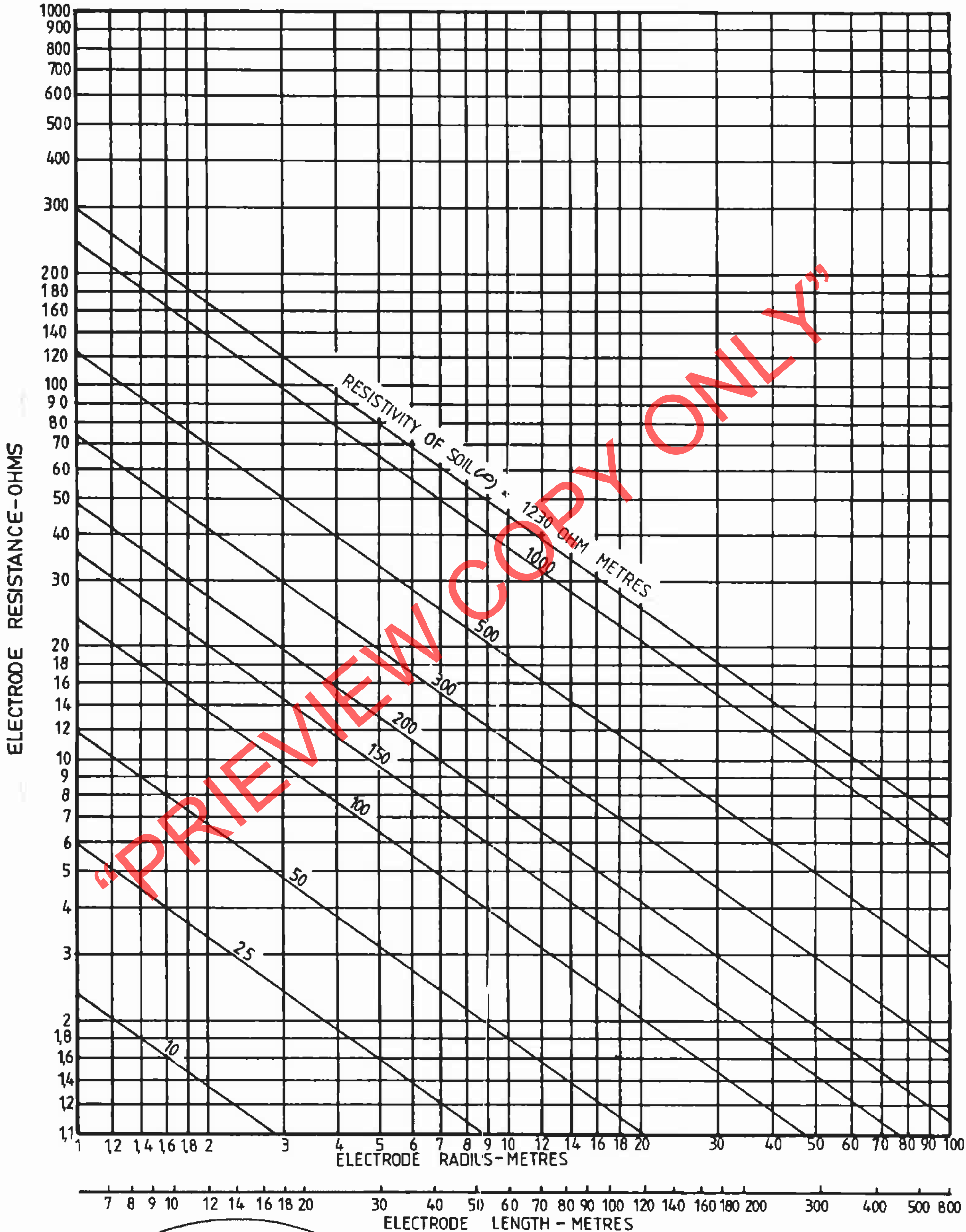
AMENDMENT

TRENCH EARTHING (RADIAL)

DRAWING TEKENING NO. CEE - MP – 4 SHT 4

ANNEXURE G TO CODE OF PRACTICE : EARTH SYSTEMS FOR ELECTRIC LIGHT AND POWER AND TRACTION INSTALLATIONS

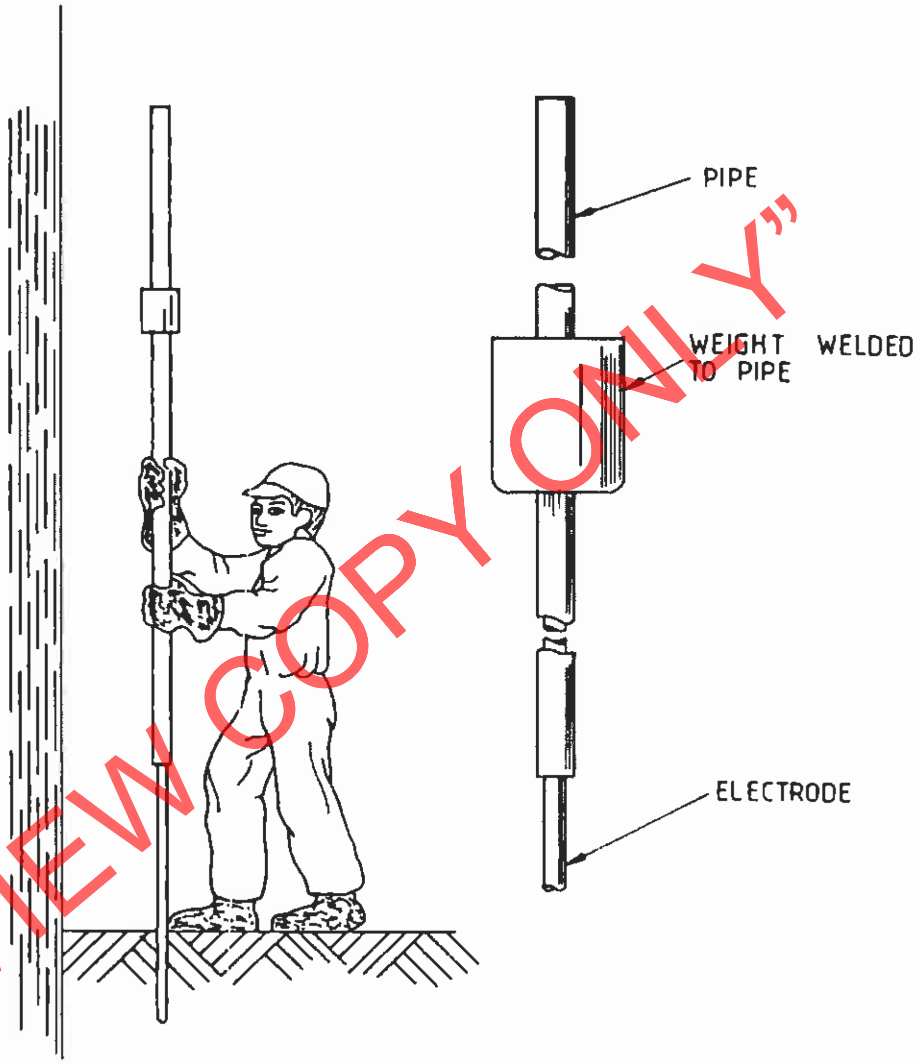
RESISTANCE (IN OHMS) OF AN EARTH CONDUCTOR BURIED IN THE FORM OF A LOOP IN RELATION TO THE RESISTIVITY ρ OF THE SOIL IN OHM METRES



LEND.

LOOP

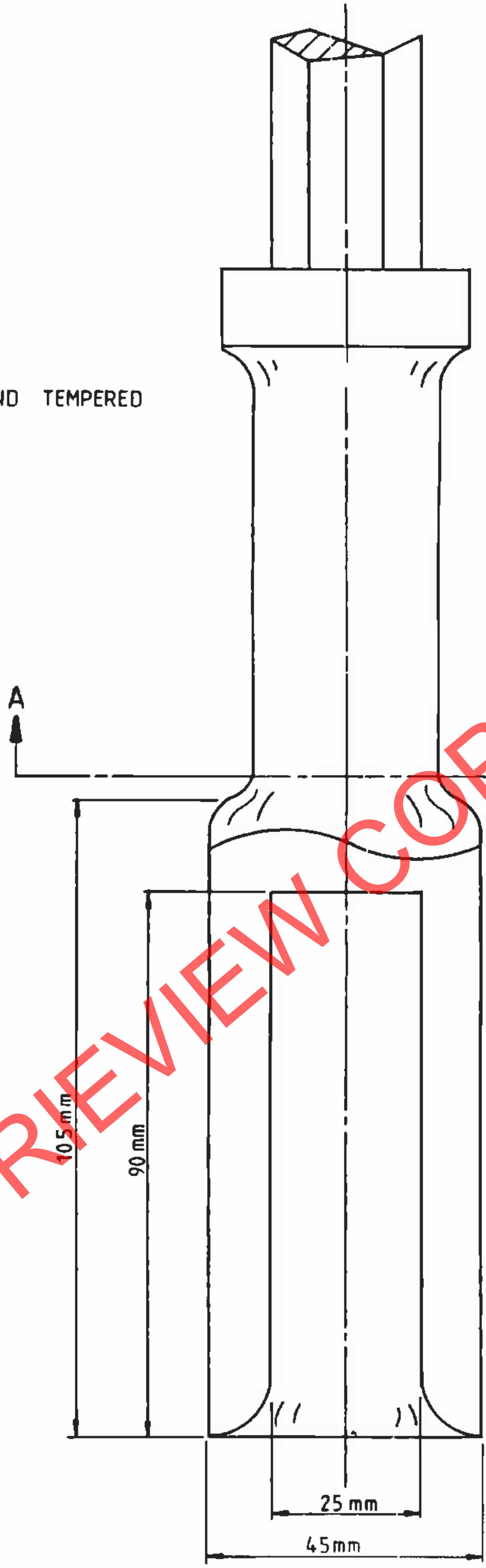
TRENCH EARTHING (LOOP)	DRAWING TEKENING No	CEE-



METHOD OF INSTALLING ELECTRODE BY MEANS OF A WEIGHTED PIPE.

ANNEXURE I TO CODE OF PRACTICE: EARTH SYSTEMS FOR EL & P AND TRACTION INSTALLATIONS

MATERIAL
HARDENED AND TEMPERED STEEL.



SECTION A-A
EVERYTHING ABOVE THIS LINE TO SUIT CHUCK OF HAMMER

TYPICAL ADAPTOR FOR USE IN JACK HAMMER TO INSTALL EARTH ELECTRODES.

AMENDMENT

SPOORNET

A division of Transnet limited

TECHNICAL

CONFIGURATION MANAGEMENT

SPECIFICATION CONTROL PAGE

DRAWINGS, CATALOGUES, INSTRUCTION MANUALS AND SPARES LISTS FOR ELECTRICAL EQUIPMENT SUPPLIED UNDER CONTRACT

Statement of authorisation:
There is no SABS specification available for similar material / equipment and as far as can be ascertained no other specification / standard suitably covers Spoornet requirements. The specification has been compiled in a manner which shall favour / encourage local manufacture of material / equipment to a maximum degree.

Author:	Chief Engineering Technician *Documentation management*	J C van Tonder
Approved:	Senior Engineer Railway Engineering	L O Borchard
Authorised:	Senior Technologist Configuration Management	J H Hancock

Date: January 2002

This page is for control purposes only and shall not be issued with the specification.

SPOORNET

A division of Transnet limited

TECHNICAL

CONFIGURATION MANAGEMENT

SPECIFICATION

DRAWINGS, CATALOGUES, INSTRUCTION MANUALS AND SPARES LISTS FOR ELECTRICAL EQUIPMENT SUPPLIED UNDER CONTRACT

Circulation restricted to:

Technical

INDEX

1.0 SCOPE

This specification covers Spoornet's requirements for drawings, catalogues, and instruction manuals and spares lists of electrical equipment supplied under contract.

2.0 DEFINITIONS

2.1 "Design drawings for approval" defines those drawings, which have to be submitted to Spoornet for approval prior to manufacture of equipment.

2.2 "Installation drawings" defines those drawings, which are required for the installation of the equipment.

2.3 "As Built drawings" defines those drawings, which reflect all the various approved designs, layouts, etc., of the actual final accepted state of the equipment.

3.0 STANDARDS AND SPECIFICATIONS

3.1 The following standards and specifications are referred to:

CEE.0012: Method of Tendering

SABS 0111: Engineering Drawings.

BS 308: Engineering Drawing Practice.

NRS 002: Graphical Symbols for Electrical Diagrams.

IEC 617: Graphical Symbols for Diagrams.

ASHRAE: American Society of Heating Refrigeration Air-conditioning Engineers Standard.

3.1.1 The following Spoornet standard (Electrical) symbol drawings are listed for reference:

CEE-PA-19: Symbols for Electrical Installations.

CEE-PA-42: Symbols for Distribution and Transmission Layout.

CEE-PA-101: Symbols for Air-conditioning installations.

CEE-TA-62: Standard Electrification Symbols.

3.2 Tenderers and contractors shall ensure that they work to the latest issues and amendments of the above standards and specifications.

4.0 APPENDIX

The following appendix forms an integral part of this specification:

Appendix 1:SCHEDULE OF REQUIREMENTS

This appendix calls for specific requirements applicable to the contract.

5.0 METHOD OF TENDERING

5.1 Tendering shall be in accordance with Spoornet (Electrical) specification CEE.0012.

5.2 Tenderers shall indicate clause by clause compliance or non-compliance with the specification. This shall take the form of a separate document listing all the specification clause numbers indicating the individual statement of compliance or non-compliance.

5.3 The Schedule of Requirements, Quantities and Prices, Appendix 1 to this specification shall be fully completed by Tenderers. Failure to submit a fully completed sheet may preclude a tender from further consideration.

6.0 LANGUAGE AND UNITS OF MEASURE

Drawings and documents shall be prepared in English and the ISO unit of measure. Other offers will be considered on merit.

7.0 DRAWINGS

7.1 Drawings shall be generated in either Microstation or any CAD format, which can be read by Microstation, but offers on other media will be considered on merit.

7.2 Drawings shall be prepared in such a manner that they fully comply with the requirements of SABS 0111 and/or BS 308.

7.3 Symbols, with their explanations used on the drawings but not covered by the NRS 002, IEC 617, ASHRAE or Spoornet's symbol drawings shall be furnished i.e. then included on the drawing or supplied on a separate symbol list which is to be cross referenced to the drawing.

7.4 Where the publications referred to in clause 3.1 are at variance, the practice detailed in SABS 0111 shall take preference.

7.5 Drawings shall be prepared for ISO; "A" series size sheets and shall not be greater than A1 size except as detailed below.

7.5.1 Where under exceptional circumstances the nature of the work is such that a size A1 is impractical, then the AO size may be used.

7.5.2 Long drawings, where necessary for wiring/circuit diagrams, cable run diagrams, track layouts, etc., shall be prepared with widths equal to the widths of the "A" series sheets as required, but preferably not exceeding the length of an A0 sheet.

7.6 All interrelated drawings shall be clearly and adequately cross-referenced.

7.7 The Contractor hereby grants to Transnet a non-exclusive licence, in accordance with the provisions of section 22 of the Copyright Act, 1978;

7.7.1 to copy any plan, diagram, drawing, specification, bill of quantities, design calculation or other similar document made by the Contractor, other than under the direction or control of Transnet, in connection with the extent of work;

7.7.2 to make free and unrestricted use thereof for its own purposes;

7.7.3 to provide copies thereof to consultants to Transnet to be used by them for the purpose of such consultations and consulting services and-

7.7.4 to provide other parties with copies thereof for the purpose of tenders invited by Transnet.

7.7.5 Such non-exclusive licence shall apply *mutatis mutandis* to any plan, diagram, drawing, specification, bill and/or schedule of quantities, design calculation or other similar document made, other than under the direction or control of Transnet, by any principal or sub-contractor of the Contractor. The provisions of this clause shall not apply to documents made, in the case of plant or equipment to be supplied, for the manufacturing process of such equipment, but only to the equipment supplied itself.

7.7.6 Transnet shall make no separate or extra payment in respect of any non-exclusive licence granted in terms hereof.

8.0 INFORMATION REQUIRED ON DRAWINGS

8.1 A title block shall be provided in the lower right hand corner of each drawing, indicating:

8.1.1 Descriptive title.

8.1.2 Contractor's drawing number.

8.1.3 Space for Spoornet's drawing number (as requested in clause 7.7).

8.1.4 Place of installation.

8.1.5 Contract / Order number.

8.1.6 Contractor's name.

8.1.7 Signature or name of approving officer (as requested in clause 8.0).

8.1.8 Approval date.

8.1.9 Issue number.

8.1.10 Projection symbol for multi-view drawings, if required.

8.2 Successful Tenderers can obtain a copy of Spoornet's standard title block (Microstation or DXF formats) free of charge by contacting the Documentation Management section.

8.3 On wiring and circuit diagrams, the following shall be specified:

8.3.1 Cable and wire sizes.

8.3.2 Values of resistance.

8.3.3 Breaking capacity of switches.

8.3.4 Ratings of equipment.

8.4 On each assembly or sub-assembly drawing, the following shall be given:

8.4.1 Description of item.

8.4.2 Quantity required for assembly depicted.

8.4.3 Material manufactured from.

8.4.4 The classification of the material according to the relevant SABS specification or other specifications referred to herein.

8.4.5 The class or process of finish and/or coating.

8.4.6 Where special parts are specified, the name of the manufacturer, the size, capacity and the name or catalogue number of each part shall be furnished.

8.4.7 The mass of finished item depicted on the drawing.

8.4.8 Dimensions from a proper reference surface.

8.4.9 Dimension tolerances.

8.5 *On electrification drawings, the following shall be specified:*

8.5.1 Kilometre distances.

8.5.1.1 Kilometre distances of all new and existing masts measured from the preceding kilometre post.

8.5.2 Civil

8.5.2.1 The following civil information shall be shown:

8.5.2.1.1 Bridges.

8.5.2.1.2 Tunnels.

8.5.2.1.3 Pipes.

8.5.2.1.4 Culverts.

8.5.2.1.5 Subways.

8.5.2.1.6 Manholes.

8.5.2.1.7 Off track platforms.

8.5.2.1.8 Water-furrows along track.

8.5.2.1.9 Service roads that may influence electrification.

8.5.2.1.10 Level crossings.

8.5.2.1.11 All banks and cuttings.

8.5.2.1.12 Retaining walls.

8.5.2.1.13 Gradient markers and gradients.

8.5.2.1.14 Boundary fences (where relevant).

8.5.2.1.15 The beginning and ending of transition and circular curves and the radius.

8.5.2.3 On all station plans the beginning and ending of the platforms to be indicated, as well as all buildings and structures on the platform which may effect electrification. All secondary platforms/structures/obstacles, which may effect electrification, must also be shown.

8.5.2.4 All points with stock rail joints, intersection of centre lines and all ends of point positions to be shown, as well as the type of point, e.g. 1:9 LH (left hand.

8.5.3 Electrical

8.5.3.1 The following electrical information shall be shown:

8.5.3.1.1 New and existing masts and structures with appropriate sizes.

8.5.3.1.2 Span lengths.

8.5.3.1.3 Tension lengths.

8.5.3.1.4 Mast to track centres.

8.5.3.1.5 Tension type (spring or weight).

8.5.3.1.6 Transmission lines, Transnet and Eskom (Showing crossing heights above rail level).

8.5.3.1.7 Telkom lines.

8.5.3.1.8 Height gauges.

8.5.3.1.9 Power and Lighting kiosks.

8.5.3.1.10 Electrical cables nearer than 3,2m from track centre, as well as cables crossing the track.

8.5.3.2 Wire profiles showing clearances/wire heights for all transmission and telecommunication lines that cross the tracks shall be shown on the drawing at the point of crossing, in either tabular or graphic format.

8.5.3.3 Wire profile for all bridges and tunnels shall be shown on separate drawings.

8.5.3.4 Important information that shall be noted are:

8.5.3.4.1 Basic span.

8.5.3.4.2 Ruling contact wire height.

8.5.3.4.3 Reference to bonding drawings.

8.5.3.4.4 Wire sizes.

8.5.3.4.5 Types of structures and foundations.

8.5.3.4.6 Tables for traction and transmission line (Showing wire heights).

8.5.3.4.7 Dropper chart.

8.5.3.4.8 Overlaps.

8.5.3.4.9 Jumpers.

8.5.3.4.10 Staggering.

8.5.3.4.11 References to switching diagram drawings.

8.5.3.4.12 Any other relevant information.

8.5.4 Signal.

8.5.4.1 The following signal information shall be shown:

8.5.4.1.1 Signal gantries (showing direction of aim).

8.5.4.1.2 Independent signals (showing direction of aim).

8.5.4.1.3 Signal kiosks.

8.5.4.1.4 Telephones.

8.5.4.1.5 Signal relay rooms.

8.5.4.1.6 Radio repeater rooms.

8.5.4.1.7 Signal cables nearer than 3,2m from track centre, as well as cables crossing the track.

8.5.5 Electrification information must be clearly indicated on drawings (see also drg no CEE-TA-62 for Standard Electrification Symbols).

8.7 The successful tenderer shall obtain Spoornet's drawing numbers from the Documentation Management section of Spoornet well in advance in writing, wherein details of all relevant drawings, i.e. titles and makers numbers are quoted. Against this information Spoornet will allocate its own numbers for inclusion by the Contractor on the original drawings.

9.0 CERTIFICATION OF DRAWINGS

The contractor against a date to certify that the drawing has been checked and is correct in all respects shall approve each drawing. This also includes changes.

10.0 CHANGES TO DRAWINGS

Any drawing returned to the Contractor for changes shall be re-submitted to Spoornet within 21 days with the appropriate changes endorsed thereon.

11.0 SUBMISSION OF TENDER DRAWINGS

The Tenderer shall submit drawings of all major items of equipment with the tender. The drawings shall be sufficiently detailed (e.g. safety factors) to enable suitability of the design to be judged and to enable Spoornet to prepare a reasonably accurate estimate of the cost of maintenance.

12.0 DRAWINGS TO BE SUPPLIED BY SUCCESSFUL TENDERER

12.1 Two prints of each design drawing for approval to be submitted prior to commencement of work or manufacture of any equipment to Spoornet. This includes drawings of general layouts, cable routes, schematic diagrams, foundations, equipment etc.

12.2 Two prints of each installation and/or erection drawing to be submitted to Spoornet. This includes drawings of modular steel buildings, structures etc. and shall be delivered at the same time the delivery of the equipment commences.

12.3 The successful tenderer shall supply one complete set of approved (signed) "As Built" working drawings as well as the electronic files thereof. Drawings shall be fully dimensioned, fully detailed, clear and neat. The set shall comprise all electrical and mechanical drawings considered necessary by Spoornet and shall include drawings of all renewable parts or items. "As Built" drawings of all enclosures, structures and foundations shall also be supplied.

12.4 All relevant "As Built" drawings required shall be delivered to Spoornet within 90 days of completion of the installation and delivery of equipment.

12.5 Until all relevant drawings called for in the contract are delivered, the contract will be considered incomplete.

13.0 CATALOGUES

13.1 Tenderers shall submit a separate quotation for the supply of the itemised part catalogues when specified in the Schedule of Requirements. The size shall be A4 (297 mm x 210 mm). Consideration shall be given on merit of the supply of these catalogues electronically (PDF format).

13.2 The information contained in the catalogues shall be classified into convenient sectors and be indexed. Thumb tabs shall be provided for quick reference to sections. All apparatus shall be illustrated by means of photographs or detailed sketches on which both the parts and the catalogue numbers of the parts are clearly shown. Catalogues shall have exploded views of components for clarity where needed.

13.3 The following information shall be given in tabular form:

13.3.1 Designation of apparatus or item of equipment.

13.3.2 Description of part including information such as dimensions, sizes, resistance values, stranding, material, current ratings, etc.

13.3.3 Catalogue number.

13.3.4 Manufacturer's name.

13.3.5 "As Built" drawing and item number where applicable.

13.3.6 Quantity of parts required for each piece of apparatus.

13.3.7 Illustrating photographs or sketch number.

13.3.8 Nato registration where applicable.

13.4 In a suitable section of the catalogue the following information shall be given:

13.4.1 Index to "As Built" Drawings.

13.4.1.1 "As Built" drawing number.

13.4.1.2 Heading.

13.4.1.3 Parts shown on drawing.

13.4.2 Index to catalogue numbers.

13.4.2.1 Catalogue numbers in numerical order.

13.4.2.2 Catalogue volume number, where applicable.

13.4.2.3 Section in which part is listed.

13.4.2.4 Page number.

13.4.3 Special tools.

13.4.3.1 Designation and description of special tools.

13.4.3.2 Catalogue number.

13.5 Each volume shall be neatly bound in hard serviceable cover on which the contract numbers volume number and titles are printed. All the information in the catalogues shall be given in a clear legible manner. The catalogues shall include all items of equipment to be supplied by the successful tenderer.

13.6 Catalogues shall be delivered before date of completion of the contract.

14.0 INSTRUCTION MANUALS

14.1 Tenderers shall submit a separate quotation for the supply of the number of copies of instruction manuals specified in the Schedule of Requirements. The size shall be A4 (297 mm x 210 mm). Consideration shall be given on merit of the supply of these catalogues electronically (PDF format).

14.2 The successful tenderer shall submit draft instruction manuals for approval prior to final printing/compiling and delivery.

14.3 The approved instruction manuals shall be delivered before commissioning the equipment. If this cannot be met, the successful tenderer shall furnish at least three copies of preliminary instruction manuals, suitable for the use of maintenance staff, until the final instruction manuals are to hand (which shall be before the date of completion of the contract).

14.4 The construction, method of operation and purpose of all items of equipment shall be fully explained by means of descriptions and photographs, sketches, drawings or circuit diagrams showing all details.

14.5 The information contained in the instruction manuals shall be classified into convenient sections and indexed. Where multiple models are produced each model shall be described in a separate section in such a manner that models not applicable can be omitted. Where possible the sections shall be subdivided as follows:

14.5.1 Installation and commissioning.

14.5.2 General description and method of operation.

14.5.3 Maintenance and inspection.

14.5.4 Overhaul and repair of equipment.

14.5.5 Technical and maintenance data.

14.5.6 Test procedure flow charts.

14.5.7 Fault finding and trouble shooting.

14.6 The method of calibrating, setting or adjusting all equipment requiring such attention shall be described and where necessary illustrated. The necessary data shall be given in each case to enable the equipment to be checked by measurement if required.

14.7 Full step-by-step instructions regarding the servicing and repair of the equipment shall be given together with all the necessary data such as dismantling and assembling procedures, working clearances, tolerances, limits, fits, maximum permissible wear, recommended lubricants, use of special tools, insulation and winding data, spring pressures and tensions, brush data, fuse data, etc. Recommended servicing/rework/replacement of parts frequencies shall also be included in the maintenance and inspection section of the instruction manual.

14.8 Any delay in delivery of the complete supply of satisfactory instruction manuals/preliminary manuals as provided for in this clause, will subject the Contractors to a deduction from the contract sum, of a penalty as defined in the tender, counting from the specified delivery time until such time as the said manuals are delivered.

15.0 COMBINED DOCUMENTS

If desired the catalogues and instruction manuals specified in clauses 12.O and 13.O may be combined into single volumes. Tenderers shall state whether or not it is their intention to do so. In this case the delivery shall be as specified in clause 13.3, alternatively the conditions described in clause 13.8 applies.

16.0 SPARES LIST

16.1 To enable Spoornet to catalogue and timeously acquire all spares required, the following information shall be submitted before commissioning of equipment:

16.1.1 An itemised schedule of the spares (with reference to alternatives) which are recommended for normal maintenance purposes.

16.1.2 The quantity recommended to be held against each item on the spares list and where sets are supplied, the types and quantity per type to make up a set.

16.1.3 A full and complete ordering description and number of each individual spare with drawing number if relevant.

16.1.4 Where the ordering description and number differs from that of the original manufacturer's catalogue, description and number, the original manufacturer's name, description, type and ordering number shall be listed as well as all other relevant data available.

16.1.5 The national stock number - Nato - number of each spare where the particular spare was imported from a Nato country and where a national stock number was allocated.

16.2 Initially the spares list containing the above information will suffice, but this list shall not in any way replace or supersede the spare parts catalogue mentioned in clause 12.O.

17.0 PACKING OF DRAWINGS, CATALOGUES, INSTRUCTION MANUALS AND SPARES LISTS

All items shall be packed in such a way that they are received in good condition.

18.0 SUBSTITUTION

This specification replaces specification CEE.0224.94

END

SCHEDULE OF REQUIREMENTS

END