# MEGGER® Digital Earth Testers DET3 & DET5

Operating Instructions

MEGGER®

## SAFETY WARNING

- ★ *The earth spikes, test leads and their terminations must not be touched if an installation earth-fault can arise, unless adequate precautions are taken.*
- ★ *When working near high tension systems rubber gloves and shoes should be worn.*
- ★ *Special precautions are necessary when "live" earths may be encountered, and isolation switches and fuses are needed in this situation.*
- ★ *The terminals of the DET5 must be disconnected from any external circuit while its battery cells are being charged.*
- ★ *Before charging the DET5 battery ensure that the correct supply fuse is fitted and the voltage selector is set correctly.*

*Refer also to page 14 for further explanations and other precautions.*

*The warnings and precautions must be read and understood before the instrument is used. They must be observed during use.*

### NOTE

*The instrument is only to be used by a suitably trained and competent person.*



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## GENERAL DESCRIPTION

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## GENERAL DESCRIPTION

The DET3 and DET5 MEGGER® Digital Earth Testers are compact instruments designed to measure earth electrode resistance, earth continuity etc. They may also make earth resistance tests which lead to the measurement of soil resistivity. The DET3 is powered by a hand cranked generator whereas the DET5 has an internal rechargeable battery, with an integral charger unit.

### TEST METHOD

Each instrument uses the well known four-terminal method of measurement in which the resistance of the current circuit test leads does not affect the result. In the DET3 and DET5 the resistance of the potential circuit test leads can also be ignored because a buffer stage is incorporated to prevent the measuring circuit from loading the earth resistance under test.

A reversing d.c. test current, generated electronically from a "floating" constant current source within the instrument, is passed via the 'C1' and 'C2' terminals through the earth being tested. The potential developed across the earth is compared with the current and, after filtering and phase sensitive detection, the resistance is given directly on the digital display.

The test frequency is 128 Hz and in the interests of safety the maximum test voltage at the terminals is limited to 30 V (peak) with respect to earth. Short circuit current is either 10 mA, 1 mA or 100 $\mu$A depending on the range in use.

### INSTRUMENT DESIGN

The instruments are very robust and have tough cases moulded in ABS plastic. Each case is fitted with a fold-down carrying handle and four right-angled adaptors are supplied to connect the test leads to the instrument terminals. Test leads are not supplied with an instrument but form part of an earth testing field accessory kit which is available as an additional option. This kit also includes test spikes (electrodes), a hammer and spike extractors.

Both instruments have simple controls; mounted on the front panel is a rotary range selector and a push-button switch for checking the potential circuit resistance prior to a measurement being made. The instrument's 3½ digit liquid crystal display shows the test result and also indicates a high current circuit resistance, a high potential circuit resistance, (both usually caused by a high test spike resistance), a "noisy" environment within the earth making up the test sample, and a low battery voltage in the case of the DET5, or low generator cranking speed in the case of the DET3. As these factors can influence the measurement being made, noise and the current circuit resistance are continuously monitored during a test, while a check of the potential circuit resistance can be made at any time. The display shows all measurements directly in ohms with the decimal point automatically positioned. It also gives an over-range indication to instruct the user to change to a higher range, and a negative sign to show that the current and potential test leads are reversed.

These testers have been designed to comply with the performance specifications of both the CP 1013 (1965) specification (from BSI) and the VDE 0413 Part 7 (1982) German specification. For this reason each terminal is marked in a dual way i.e.:—

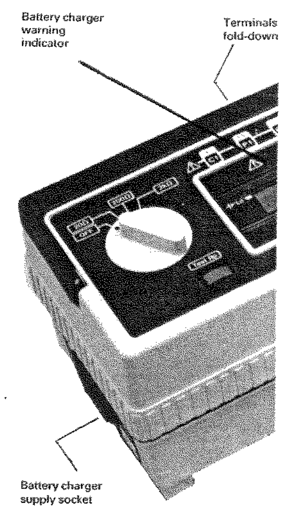
| | | | |
|---|---|---|---|
| C1 | P1 | P2 | C2 |
| E | ES | S | H |

The terminal C1(E) is for the current connection to the earth electrode to be tested.

The terminal P1(ES) is for the potential connection to the earth electrode to be tested.
The terminal P2(S) is for the connection to the remote potential test spike.
The terminal C2(H) is for the connection to the remote current test spike.

In terms of safety the instruments meet, in general, the requirements of BS 4743 (1979), IEC 348 (1978) and VDE 0411 (1981).





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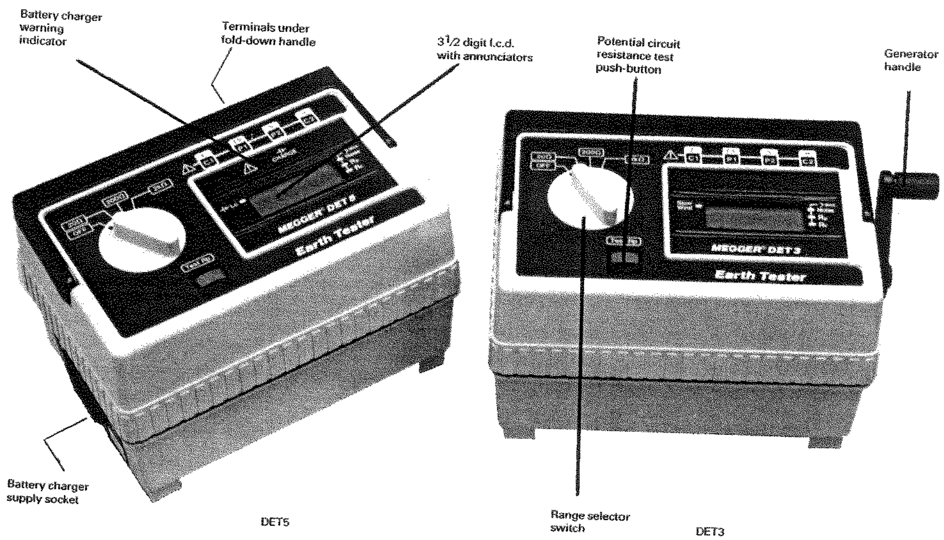


DET5

DET3

## APPLICATIONS

The installation of satisfactory earthing systems is an essential part of electricity supply, wiring safety and installation economics. It is also of great importance in many communications systems.

The primary application of the DET3 and DET5 is in the testing of earth electrodes, whether these take the form of a single electrode, multiple electrodes, mesh systems, earth plates or earth strips. All earthing arrangements should be tested immediately after installation and at periodic intervals thereafter.

### CHOICE OF ELECTRODE SITE

For an earth electrode or system to perform satisfactorily it must always have a low total resistance to earth. This value will be influenced by the specific resistance of the surrounding soil. This in turn depends on the nature of the soil and its moisture content. Before sinking an electrode or electrode system therefore, it is often helpful to survey the surrounding area before choosing the final position for the electrode. It is possible with these instruments to obtain the resistivity of the soil over an area and at different levels beneath the surface of the ground. These resistivity surveys may show whether any advantage is to be gained by driving electrodes to a greater depth, rather than increasing the cost by having to add further electrodes and associated cables, in order to obtain a specified total earth system resistance.



### EARTHING SYSTEM MAINTENANCE

After installation, checks may be made on an earthing system to see if there is any significant change in the resistance over a period of time or under different soil moisture conditions, (e.g. brought about by changing weather conditions or different seasons of the year). Such checks will indicate when there is a need for maintenance of the installation because the required resistance to earth has been exceeded by changing conditions or the ageing of the system.

### OTHER APPLICATIONS

For archaeological and geological purposes, an investigation of soil structure and building remains can be carried out at varying measured depths, by the resistivity survey technique.

In all cases the accuracy of the instrument readings may be taken to be higher than the changes caused by natural variables in soil characteristics.

A further application is in continuity testing, e.g. checking the resistance of conductors used in an earthing circuit.

Resistances between 0,01 Ω and 1999 Ω can be measured with an accuracy of ±2% of reading ±2 digits (nominal). Individual test spike resistances of up to 1 kΩ (total for either current loop or potential loop = 2 kΩ), can be tolerated on the lowest range and on the higher ranges greater values can exist.

## SPECIFICATION

**Earth Resistance Range**

**Accuracy** (23 °C ± 2 °C)

**Comply With Standard**

**Test Frequency**

**Test Current**

**Interference**

**Max. Current Spike Res**

**Max. Potential Spike Re**

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# SPECIFICATION

| | |
|---|---|
| **Earth Resistance Ranges** | 0,01 Ω to 19,99 Ω<br>0,1 Ω to 199,9 Ω<br>1,0 Ω to 1999 Ω |
| **Accuracy** (23 °C ± 2 °C) | ±2% of reading ±1 digit<br>Total service error ±5% of reading ±1 digit. |
| **Comply With Standards** | BS CP1013 (1965)<br>VDE 0413 Part 7 (1982) |
| **Test Frequency** | 128 Hz |
| **Test Current** | 20 Ω range 10 mA a.c. r.m.s.<br>200 Ω range 1 mA a.c. r.m.s.<br>2 kΩ range 100 μA a.c. r.m.s.<br>Test current (= short circuit current) is constant throughout the range. |
| **Interference** | Interference voltages of 5 V a.c. r.m.s. 50 Hz/60 Hz in the potential circuit will have a max. effect of ±0,5% on the reading obtained. |
| **Max. Current Spike Resistance** | The typical limit of resistance of the external current circuit is:—<br>20 Ω range 2 kΩ<br>200 Ω range 5 kΩ<br>2 kΩ range 48 kΩ |
| **Max. Potential Spike Resistance** | The typical limit of resistance of the external potential circuit is:—<br>20 Ω range 2,2 kΩ<br>200 Ω range 22 kΩ<br>2 kΩ range 53 kΩ |

## SPECIFICATION

| | | |
|---|---|---|
| **Max. Output Voltage** | | 30 V |
| **Display** | | 3½ digit l.c.d. maximum reading 1999 |
| **Temperature Effect** | | < ±0,02%/°C over the temperature range −15 °C to +55 °C |
| **Temperature Range** | operating | −15 °C to +55 °C |
| | storage | −40 °C to +70 °C |
| **Humidity** | operating | 95% RH max. at 40 °C |
| | storage | 93% RH max. at 55 °C |
| **Flash Test** | | 3 kV a.c. |
| **Voltage Withstand** | | In the event of a system fault the instrument will withstand 240 V a.c. applied between any two terminals. |
| **Fuses** | DET3 and DET5 | 100 mA ceramic HBC 20 mm x 5 mm IEC 127/1 (for current source protection)<br>Internal 100 mA ceramic HBC 20 mm x 5 mm IEC 127/1 (for potential circuit protection) |
| | DET5 | 50 mA ceramic HBC 20 mm x 5 mm IEC 127/1 for 240 V a.c. supply, 100 mA ceramic HBC 20 mm x 5 mm IEC 127/1 for 120 V a.c. supply (for circuit protection during battery charging).<br>Internal 500 mA ceramic HBC 20 mm x 5 mm IEC 127/1 (for battery protection) |
| **Power Supply** | DET3 | Internal hand-cranked a.c. generator (Minimum cranking speed 120 r.p.m.) |
| | DET5 | Internal rechargeable sealed lead acid cells 12 V, 0,8 Ah capacity. Battery voltage range over which basic accuracy is maintained, 10,0 V to 13,5 V. Battery life, 1750 x 10 s tests (4½ hours continuous use).<br>Battery charging time, 10 hours max. (from completely exhausted). Charging supply required, 200 V to 255 V a.c. or 100 V to 130 V a.c. 50 Hz/60 Hz. |



**Safety**

**Dimensions**

**Weight**

The VDE 0413 part 7 specification st
these instructions should contain a c
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performed on any electrode system
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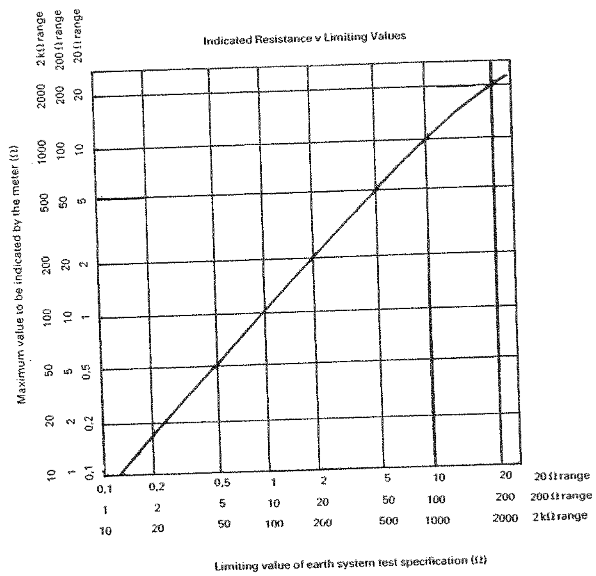
| | | |
|---|---|---|
| **Safety** | | The instruments will, in general, meet the requirements of BS 4743, IEC 348 and VDE 0411 specifications. |
| | DET3 | Safety Class III |
| | DET5 | Safety Class III while operating, Safety Class II while battery charging. |
| **Dimensions** | DET3 | 210 mm x 128 mm x 125 mm (8¼ in x 5 in x 5 in approx.) |
| | DET5 | 180 mm x 128 mm x 125 mm (7 in x 5 in x 5 in approx.) |
| **Weight** | DET3 | 1 kg (2¼ lb approx.) |
| | DET5 | 1,32 kg (2⅞ lb approx.) |

The VDE 0413 part 7 specification stipulates that these instructions should contain a diagram showing the maximum value which the instrument must indicate in certain conditions. An earth test being performed on any electrode system would normally be carried out to a particular specification. Therefore, even at the instrument's worst accuracy, the reading indicated should be such that the actual value is never above the limiting value required by the particular specification in question.

The curve on page 12 shows the maximum value which shall be indicated by the instrument (at its maximum error) to ensure that the limiting value of the earth resistance given in the relevant earth electrode test specification is met.

## SPECIFICATION






## ACCESSORIES

### SUPPLIED WITH THE INSTRUMENT

Four right-angled terminal adaptors to enable
leads with spade connectors (as in the field k
leads with bare ends to be used.
Mains supply lead for battery charging (DET5
Operating instruction book.

### AVAILABLE OPTIONALLY

Carrying case (for instrument only) part no.
Earth testing field accessory kit (ref. ET/KIT).
part no.
comprising a yellow bag and pouch containi
a 1,13 kg (2½ lb) hamm
four galvanised steel spikes 12 mm (½ in
square section, 450 mm (17 in approx.) lo
two spike extractors
30 m (98½ ft approx.) of cable on a cable-
complete with connector and clip
50 m (164 ft approx.) of cable on a cable-
complete with connector and clip
two 3 m (10 ft approx.) leads complete wi
connectors and clips.
Reel of cable, 50 m long part n
C1–P1 shorting bar part n

## ACCESSORIES

### SUPPLIED WITH THE INSTRUMENT

Four right-angled terminal adaptors to enable test leads with spade connectors (as in the field kit) or test leads with bare ends to be used.
Mains supply lead for battery charging (DET5 only).
Operating instruction book.

### AVAILABLE OPTIONALLY

Carrying case (for instrument only) part no. 6420-043
Earth testing field accessory kit (ref. ET/KIT), part no. 6310-755
comprising a yellow bag and pouch containing:—

- a 1,13 kg (2½ lb) hamm
- four galvanised steel spikes 12 mm (½ in approx.) square section, 450 mm (17 in approx.) long
- two spike extractors
- 30 m (98½ ft approx.) of cable on a cable-winder, complete with connector and clip
- 50 m (164 ft approx.) of cable on a cable-winder, complete with connector and clip
- two 3 m (10 ft approx.) leads complete with connectors and clips.

Reel of cable, 50 m long part no. 6121-119
C1–P1 shorting bar part no. 6180-346

Fig. 2 Earth testing kit

# OPERATION

## WARNINGS

1. As a precaution when working near high tension systems where accidental high potentials on the structure and in the ground are possible, it is recommended that the operator wears rubber gloves (to BS 697:1986) and stands on a rubber mat or wears rubber shoes. (See para. 3 below).
2. It is preferable that the earth system to be tested is first isolated from the circuit it is protecting. This is not always possible and so the precaution below is most important.
3. **Safety precautions for all live earths**
   Safety precautions are necessary when any live earths may be encountered e.g. when testing the earth of a "live" substation. If a fault occurs at the substation while a test is being conducted, dangerous voltages may exist between the site earth and remote earths established for test purposes. Therefore:—
   a) The instrument must be used within the perimeter fence of the substation where the test is being conducted, and/or in an area where the voltage difference from the earth under test does not exceed 50 V in any circumstances. If this is not possible then rubber gloves and mats must be used.
   b) The P1 and C1 (or ES and E) terminals must be connected to the earth electrode being tested.
   c) The P2 and C2 (or S and H) terminals must be connected to an isolation switch, whose rating will cope with the maximum fault voltages (refer to Fig. 3).
   d) With the isolation switch open, connections to the remote test spikes (electrodes) may be established. Make the connections to the isolation switch first and then connect the remote test spikes (electrodes).
   e) When the remote test spikes have been established the isolation switch may be closed and a test made.
   f) Whilst the test is in progress care must be taken that no one comes into contact with the remote electrodes or the leads running to the P2 and C2 (or S and H) terminals via the isolation switch.
   g) The isolation switch must be open whilst any personal contact is made with the remote test spikes or the connecting leads, e.g. when changing their positions.
   h) If a fault occurs while a test is being made the instrument may be damaged. Incorporating fuses at the isolation switch, of rating 100 mA and able to cope with the maximum fault voltage, will provide some protection for the instrument (see Fig. 3).

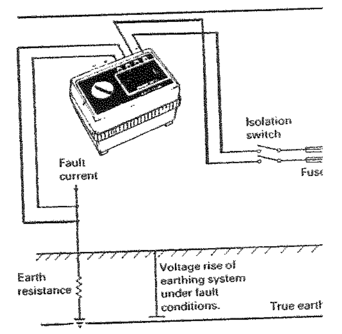



Fig. 3 A method of connection
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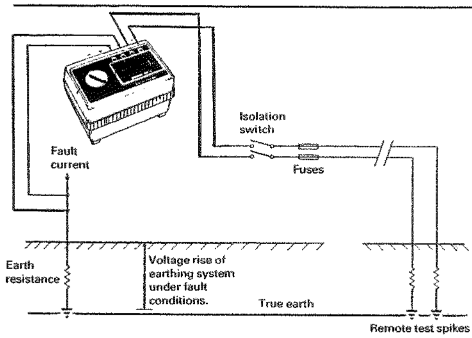


Fig. 3 A method of connection where fault conditions may occur

4. **When charging the DET5 battery:—**
   a) Ensure that the instrument is disconnected completely from any external circuit.
   b) Make sure before switching the supply on, that the correct setting of the voltage selector has been made and also that the correctly rated fuse for that supply has been fitted (see the Specification page 9).
   c) The socket to which the instrument is connected for battery charging should have an on/off switch.
5. Repairs to these instruments must only be carried out by suitably trained and qualified personnel.
6. If an instrument's protection has been impaired it should not be used and must be sent for repair. The protection is likely to be impaired if, for example, it shows visible damage, it fails to perform the intended measurements, it has been subjected to prolonged storage under unfavourable conditions, or it has been subjected to severe transport stresses.

## PRECAUTIONS

1. The instrument circuit contains static sensitive devices. If the instrument casing is opened for any reason, care must be exercised in handling the printed circuit board. This should be done in accordance with DEF STAN 59-98 and BS 5783, specifications for handling electrostatic sensitive devices.

Note:— Opening the casing will automatically invalidate any warranty covering the instrument unless carried out by an approved repair organisation (see page 53).

2. It is advisable that, when working with the DET5 instrument, the battery is fully charged before embarking upon a test sequence. It can be extremely inconvenient if the battery voltage becomes too low while a field test is in progress.

## DISPLAY SYMBOLS

The 3½ digit l.c.d. shows the reading directly and the operator can simply refer to the range switch position for the units of measurement. The instrument's display symbols can also help the operator make certain that the reading is valid. The meaning of each display symbol is given in the following paragraphs.

### Low Generator Cranking Speed (DET3)

If the generator handle on the DET3 is turned too slowly such that there is insufficient output for a test to be performed properly, an arrow '←' appears on the left of the display pointing at the 'Slow Wind' mark on the graphics panel. Any reading on the display should be ignored and the generator turned faster until the arrow disappears before a measured value is accepted.

### Low Battery Voltage (DET5)

Similary on the DET5, if the battery voltage is too low the arrow on the left of the display will appear pointing at the ' ⊣⊢ Lo' mark on the graphics panel. In this case the battery holds only enough power for possibly one or two more measurements and must be recharged before further tests are undertaken.

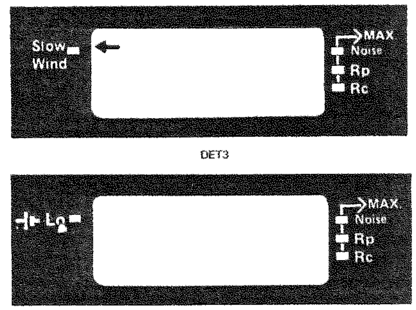


Fig. 4 Low cranking speed and low battery voltage indications.

### Reverse Polarity

When the potential test leads are reversed with respect to the current test leads, the reading on the display is preceded by a negative sign. T still valid, but the potential connections s reversed to remove the negative sign. F measurement the 'C1' and 'P1' (or 'E' ar connections should go to the electrode l i.e. to one end of the resistance, and the (or 'S' and 'H') connections should go to spikes, i.e. the other end of the resistan


Fig. 5 Reverse polarity symb

### High Current Spike Resistance

To indicate that the resistance of the cur too high, a display segment illuminates c 'Rc' mark on the graphics panel. This hap automatically while the tester is switche during a test. Its appearance may be cau open circuit or a poor connection in the t current spike, or, more likely, high resist ground in the vicinity of the current spike contact with that spike. Whatever the ca symbol's appearance it must be remove test can be regarded as valid. Moistenin

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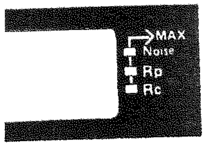


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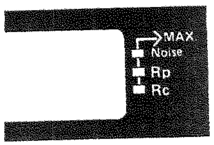


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display is preceded by a negative sign. The reading is still valid, but the potential connections should be reversed to remove the negative sign. For a positive measurement the 'C1' and 'P1' (or 'E' and 'ES') connections should go to the electrode being tested, i.e. to one end of the resistance, and the 'C2' and 'P2' (or 'S' and 'H') connections should go to the test spikes, i.e. the other end of the resistance.


Fig. 5 Reverse polarity symbol

**High Current Spike Resistance**

To indicate that the resistance of the current circuit is too high, a display segment illuminates opposite the 'Rc' mark on the graphics panel. This happens automatically while the tester is switched on, even during a test. Its appearance may be caused by an open circuit or a poor connection in the test lead to the current spike, or, more likely, high resistance in the ground in the vicinity of the current spike and poor contact with that spike. Whatever the cause of the symbol's appearance it must be removed before a test can be regarded as valid. Moistening the ground around the current spike, re-siting the spike in a new position or using more than one spike may solve the problem.

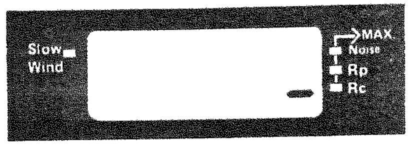


Fig. 6 High current spike resistance symbol.

**High Potential Spike Resistance**

To indicate that the resistance of the potential circuit is too high a display segment illuminates opposite the 'Rp' mark on the graphics panel. This does not happen automatically but should be a preliminary test carried out by the operator pressing the push-button marked 'Test Rp'. The reasons for its appearance may be the same as for the high current spike resistance symbol, and, as in that case, the problem must be removed before a test can be regarded as valid. Again the solution may be moistening the ground or re-siting the potential test spike.

Note:— Operating the 'Test Rp' button will cause the display to go blank except for the decimal point and high potential spike resistance symbol (when relevant).

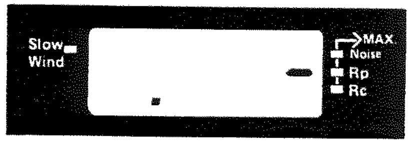


Fig. 7 High potential spike resistance symbol.

**Excessive Noise Interference**

A display segment will automatically appear opposite the 'Noise' mark on the graphics panel when the interference voltage in the earth being measured is beyond the level which can be rejected by the tester. A valid measurement cannot be made in this condition. The solution may be to wait until the interference has subsided if it is transient in nature or, to choose a different position for the test spikes.


Fig. 8 Excessive noise interference symbol.

Note:— This symbol may also appear with the over-range indication if the resistance being measured is very much greater than the range selected.

**Over-range**

To indicate that the resistance being measured is above the range selected, the over-range symbol appears. This is a '1' as the left hand digit with the remainder of the display blank except for the decimal point. When this symbol appears switch to a higher range. If it appears on the '2 kΩ' range there is something seriously wrong with the earth electrode under test, (make sure in this case that the high current spike indicator is not showing — see page 17).

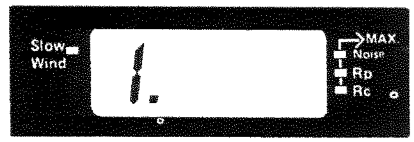


Fig. 9 Over-range symbol.

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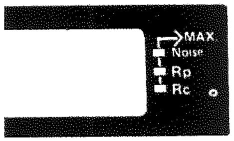


ʼer-range symbol.

## SETTING-UP THE TEST SPIKES ETC.

For earth electrode testing and for earth resistivity surveying, the instrument's test leads are connected to spikes hammered into the ground. The way the connections are made depends on the type of test being undertaken and the details of these are given in the next section, 'Measuring Techniques'.

Test spikes and long test leads are necessary for all types of earth testing and the Earth Testing Field Accessory Kit, ET/KIT, (available as an option) contains the basic equipment.

Recommended test spikes are 13 mm square, or diameter 460 mm long and made of mild steel. These can be driven to a depth of 300 mm with rapid blows from a 1 kg hammer. The size of the cable suitable for use as test leads is not critical but, it should be reasonably flexible and MUST be insulated. At least 100 m length will be needed and a cable size of about 104/0,1 mm is suitable.

When connections are made to the instrument the right angled adaptors should be used. These are supplied with the instrument and they have screw terminals to take hook or spade connectors, bare wires, or 4 mm plugs.

## BASIC TEST PROCEDURE

After the test spikes have been set-up and connected to the instrument for the type of test to be carried out (refer to 'Measuring Techniques'), proceed as follows:—

1. Select the measuring range required. Choose the lowest range if it is uncertain which is correct; this may produce the over-range symbol when the instrument is operated, if so switch to the next range.
2. Turn the generator handle at 120 r.p.m. (minimum) for the DET3.
   Note:—The DET5 energizes the test circuit as soon as the range is selected.
3. Check that the display shows no adverse test conditions, i.e. that the high current circuit resistance and excessive noise symbols are not showing. Also check that the low battery voltage symbol (DET5) or low cranking speed symbol (DET3) is not illuminated.
4. Press the 'Test Rp' push-button to check the potential spike resistance. The high potential circuit resistance symbol should not appear. Release the push-button.
5. If all the conditions for a test are satisfactory the reading given on the display may be accepted as the earth resistance. If any of the display symbols, (except reverse polarity), illuminate, the cause of the adverse condition must be removed before the reading can be accepted.

# OPERATION

## BATTERY CHARGING (DET5)

The battery should be charged as soon as the low battery indicator appears on the display. If the display remains blank when the instrument is switched on, it may be that the battery has become completely exhausted. In this case charge the battery fully before performing any tests.

Note:— It is unwise to allow the battery to become completely exhausted for fear of causing it damage.

Before connecting to the mains supply ensure that the correctly rated fuse is fitted and that the voltage adjuster is set to the right value for the supply to be used. For a 240 V a.c. supply the fuse should be 50 mA and for a 120 V a.c. supply the fuse should be 100 mA. (Type and size of the fuses are given in the Specification). The mains supply fuse is located in the holder which is part of the recessed input plug on the side of the case. Simply slide the holder out to reveal two fuses, the inner one is the working fuse; the outer one is a spare fuse. The voltage adjuster is located on the bottom of the casing. Use a screwdriver to turn the appropriate voltage mark to the indicating arrow.

When the fuse and voltage selector are correctly set, plug the mains supply lead into a suitable socket outlet and switch on. An l.e.d. light on the front panel marked '—|■— CHARGE' will illuminate to show that the instrument is connected to a mains supply. Leave the battery to charge for 10 hours approximately.

Caution:— Do not leave the test leads connected to the terminals while the instrument is being supplied with mains power.

## REPLACING THE CURRENT SOURCE PROTECTING FUSE

In addition to the DET5 mains supply fuse, both the DET3 and DET5 are fitted with a fuse to protect the output current source from input overloads, i.e. voltages applied to the C1 and C2 terminals.

This fuse is rated at 100 mA and is located in a holder in the base of the instrument case. To change this fuse use a screwdriver to unscrew the cap of the fuseholder; the fuse is clipped into this cap. Fit a new fuse and replace the cap.

Caution:— Any replacement fuse must be of the correct type and rating, (see the Specification).



# MODE D'EMPLOI

## AVERTISSEMENTS

1. Lors de travaux à proximité de struc
tension où il est possible de rencont
potentiels dangereux sur les appare
le sol, il est conseillé que l'opérateu
des gants en caoutchouc et se tienr
en caoutchouc (voir paragraphe 3 ci-
2. Il est préférable que la terre à mesu
du circuit qu'elle protège. Ceci n'ét
possible, prendre les précautions ir
ci-après.
3. **Précautions vis-à-vis des terres e**
Il est nécessaire de prendre certain
lors de mesures de terres en servic
pour la terre d'une sous-station en
Si un défaut se produit dans la sous
un essai, des tensions dangereuse
apparaitre entre la terre du site et le
auxiliaires établies pour les essais.
   a) L'appareil doit être utilisé dans
   de protection de la sous-statio
   réalisé et/ou dans une zone où
   potentiel de la terre à mesurer
   50 V. Si ce n'est pas possible u
   et des tapis en caoutchouc.
   b) Les bornes P1 et C1 sont relié
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**TECTOR DE LA**

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### FALL-OF-POTENTIAL METHOD

This is the basic method for measuring the resistance of earth electrode systems. However, it may only be practicable on small, single earth electrodes because of the limitation of the size of the area available to perform the tests.

Hammer the current test spike into the ground some 30 metres to 50 metres away from the earth electrode ('E') to be tested. Connect this spike to the instrument terminal 'C2' (or 'H').

Hammer the potential test spike into the ground mid-way between the current test spike and the earth electrode. Connect this spike to the instrument terminal 'P2' (or 'S').

Note:— It is important that the current spike, the potential spike and the earth electrode are all in a straight line. Also, when running the test leads out to these spikes (remote electrodes), it is preferable not to lay the wires close to each other in order to minimise the effect of mutual inductance.

Connect the 'C1' (or 'E') and the 'P1' (or 'ES') instrument terminals to the earth electrode 'E'. The diagram of Fig. 10 shows the connections.

Operate the DET3 or DET5 as explained in the 'Basic Test Procedure' on page 19, and note the resistance measurement obtained.

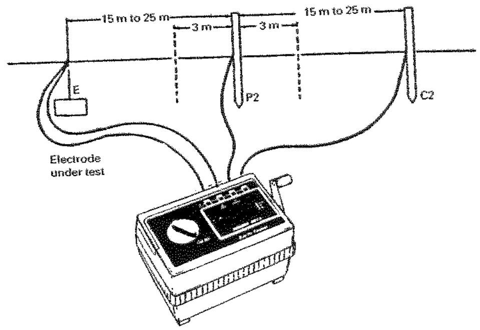



Fig. 10 Fall-of-Potential method for measuring resistance of an earth electrode.

Move the potential spike 3 metres farther away from the earth electrode and make a second resistance measurement. Then move the potential spike 3 metres nearer the earth electrode (than the original position) and make a third resistance measurement.

## MEASURING TECHNIQUES Testing Earth Electrodes

If the three resistance readings agree with each other, within the required accuracy, then their average may be taken as the resistance to earth of the electrode. If the readings disagree beyond the required accuracy then an alternative method should be used e.g. the 61,8% Rule or the Slope method etc.

### Fall-of-Potential Method With Short 'E' Lead

Another way of making connections to the earth electrode 'E' is to join the 'P1' and 'C1' (or 'E' and 'ES') instrument terminals together and then connect both to the earth electrode 'E' using only one test lead, (as shown in Fig. 11). This should ONLY be done if the test lead can be kept short because its resistance will be included in the measurement.

Note:— Earth electrode test lead resistance can be determined separately. First remove it from the electrode 'E' and connect it to the 'C2' and 'P2' (or 'H' and 'S') terminals joined together, then measure its resistance in the normal way. This lead resistance can then be deducted from the earth resistance measurements. This procedure is not, of course, necessary if the 'C1' and 'P1' (or 'E' and 'S') terminals are connected by separate test leads.

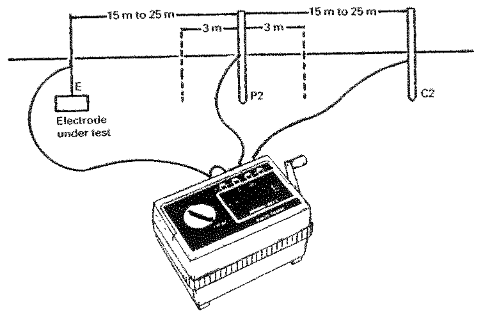



Fig. 11 Fall-of-Potential method using single lead to the earth electrode.

### THE 61,8% RULE

To obtain a sensible reading using the Fall-of-Potential method the current spike must be correctly sited in relation to the earth electrode. Since both possess "resistance areas", the current spike must be sufficiently remote to prevent these areas overlapping. Furthermore, the potential spike must be between these two areas, see the diagram of Fig. 12. If these requirements are not met, the Fall-of-Potential method may give unsatisfactory results.



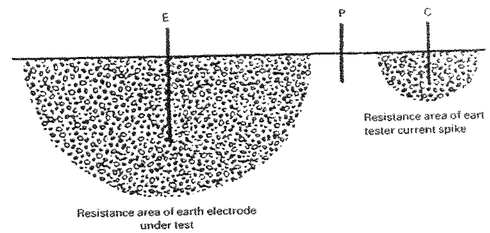
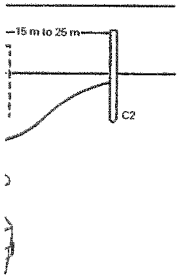



Fig. 12 Resistance areas associated with electrode and current spike.

Theoretically, both the current and potential spikes should be at an infinite distance from the earth electrode! However, by graphical considerations and by actual test it can be demonstrated that:—

The "true" resistance of the earth electrode is equal to the measured resistance when the potential spike is positioned 61,8% of the distance between the earth electrode and the current spike, away from the earth electrode.

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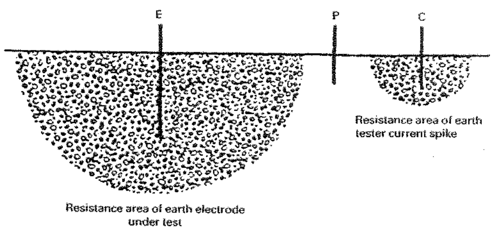


Fig. 12 Resistance areas associated with electrode and current spike.

Theoretically, both the current and potential spikes should be at an infinite distance from the earth electrode! However, by graphical considerations and by actual test it can be demonstrated that:—

The "true" resistance of the earth electrode is equal to the measured resistance when the potential spike is positioned 61,8% of the distance between the earth electrode and the current spike, away from the earth electrode.

This is the 61,8% Rule and strictly only applies when the earth electrode and both current and potential spikes are in a straight line, when the soil is homogeneous and when the earth electrode has a small resistance area that can be approximated by a hemisphere. Bearing these limitations in mind this method can be used, with care, on small earth electrode systems consisting of a single rod or plate etc. and on medium systems with several rods.

The diagram of Fig. 13 shows the layout for the 61,8% Rule.

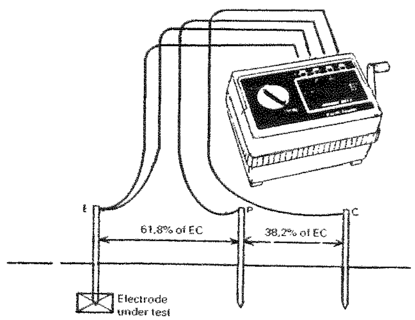


Fig. 13 The 61,8% Rule method.

## MEASURING TECHNIQUES Testing Earth Electrodes

For most purposes the current spike should be 30 metres to 50 metres from the centre of the earth electrode under test. The potential spike should be inserted in the ground 61,8% of this distance, between and in a straight line with, the current spike and the earth electrode. The distance is measured from the earth electrode.

If the earth electrode system is of medium size containing several rods, then these distances must be increased. The following table gives a range of distances which agree with the rule. In the first column "Maximum dimension" is the maximum distance across the earth electrode system to be measured.

| Maximum dimension in metres | Distance to potential electrode in metres from centre of earth system | Distance to current electrode in metres from centre of earth system |
|---|---|---|
| 5 | 62 | 100 |
| 10 | 93 | 150 |
| 20 | 124 | 200 |

For greater accuracy an average reading can be calculated by moving the current spike, say 10 metres, towards and then away from its first position and making further resistance measurements. (Remember that the potential spike must also be moved in accordance with the 61,8% Rule). The average of the three readings can then be calculated.

### THE SLOPE METHOD

This method is more applicable to larger earth electrode systems or where the position of the centre of the earthing system is either unknown or inaccessible (e.g. if the system is beneath the floor of a building). The Slope method can also be used if the area available for siting the test spikes is restricted. It can be tried if the previous methods prove unsatisfactory and generally yields results of greater accuracy than those methods.

The equipment is set-up as shown in Fig. 14. The remote current spike is placed 50 metres or more away from the earth electrode system to be measured and connected to the instrument's 'C2' (or 'H') terminal. The potential spike is inserted at a number of positions consecutively, between the earth system and the current spike, and connected to the 'P2' (or 'S') terminal. The test spikes and the earth system should all be in a straight line.

The instrument's 'C1' and 'P1' (or 'E' and 'ES') terminals are connected separately to some point on the earth electrode system.



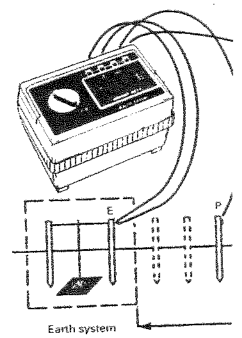


Fig. 14 Connections for

The earth resistance is m
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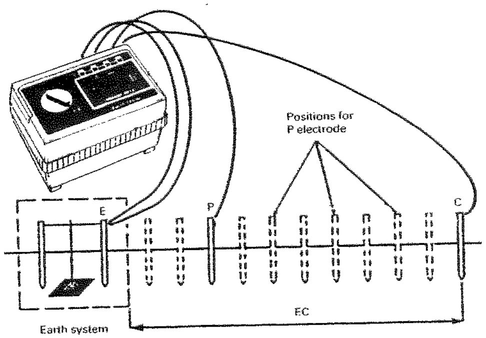



Fig. 14 Connections for the Slope method.

The earth resistance is measured at each separate position of the potential spike and the resistance curve plotted from the results. At least six readings are needed. The diagram of Fig. 15 shows an example. Drawing the curve will show up any incorrect points which may be either re-checked or ignored.

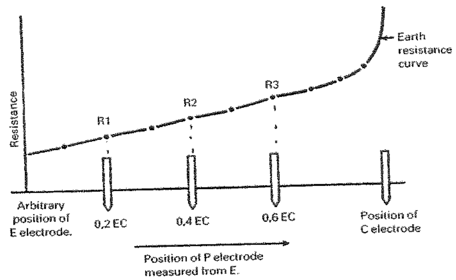



Fig. 15 Resistance curve from Slope method tests.

Suppose the distance from the earth electrode system to the current spike is EC. From the curve equivalent resistance readings to potential spike positions 0,2 EC, 0,4 EC and 0,6 EC can be found. These are called R1, R2 and R3 respectively.

Calculate the slope coefficient $\mu$

where $$\mu = \frac{R3 - R2}{R2 - R1}$$

which is a measure of the change of slope of the earth resistance curve.

From the table on page 27 obtain the value of

$$\frac{P_T}{EC}$$

for this value of $\mu$.

$P_T$ is the distance to the potential electrode at the position where the true resistance would be measured.

Multiply the value of $\frac{P_T}{EC}$ by EC to obtain the distance $P_T$.

From the curve read off the value of resistance that corresponds to this value of $P_T$. The value obtained is the earth electrode system's resistance.

Notes:— (i) If the value of $\mu$ obtained is not covered in the table on page 39 then the current spike will have to be moved farther away from the earthing system.

(ii) If it is necessary, further sets of test results can be obtained with different values of EC, or different directions of the line of EC.

From the results obtained of the resistance for various values of the distance EC another curve can be plotted, as shown in Fig. 16 for example.

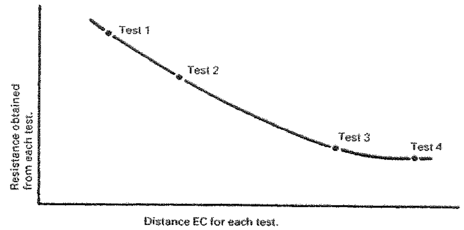



Fig. 16 Possible results from several Slope method tests.

This shows how the resistance is decreasing as the distance chosen for EC is increased.

The curve indicates that the distances chosen for EC in tests (1) and (2) were not large enough, and that those chosen in tests (3) and (4) were preferable because they would give the more correct value of the earth resistance.

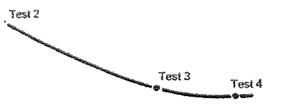
(iii) It is unreasonable to expect a total accuracy of more than 5%. This will usually be adequate, bearing in mind that this sort of variation occurs with varying soil moisture conditions or non-homogeneous soils.



## Chart for use with the S

VALUES OF $P_T$/EC for VALUES OF $\mu$

| $\mu$ | 0 | 1 | |
|---|---|---|---|
| **0.40** | 0.6432 | 6431 | 64 |
| **0.41** | 0.6418 | 6416 | 64 |
| **0.42** | 0.6403 | 6402 | 64 |
| **0.43** | 0.6389 | 6387 | 63 |
| **0.44** | 0.6374 | 6373 | 63 |
| **0.45** | 0.6360 | 6359 | 63 |
| **0.46** | 0.6346 | 6344 | 63 |
| **0.47** | 0.6331 | 6330 | 63 |
| **0.48** | 0.6317 | 6315 | 63 |
| **0.49** | 0.6302 | 6301 | 63 |
| **0.50** | 0.6288 | 6286 | 62 |
| **0.51** | 0.6273 | 6271 | 62 |
| **0.52** | 0.6258 | 6256 | 62 |
| **0.53** | 0.6242 | 6241 | 62 |
| **0.54** | 0.6227 | 6226 | 62 |
| **0.55** | 0.6212 | 6210 | 62 |
| **0.56** | 0.6197 | 6195 | 61 |
| **0.57** | 0.6182 | 6180 | 61 |
| **0.58** | 0.6166 | 6165 | 61 |
| **0.59** | 0.6151 | 6150 | 61 |
| **0.60** | 0.6136 | 6134 | 61 |
| **0.61** | 0.6120 | 6118 | 61 |
| **0.62** | 0.6104 | 6102 | 61 |
| **0.63** | 0.6087 | 6086 | 60 |
| **0.64** | 0.6071 | 6070 | 60 |




ıce EC for each test.

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acy of more than 5%. This will
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ort of variation occurs with varying
ıoisture conditions or non-
ɔgeneous soils.

## Chart for use with the Slope method

VALUES OF $P_T$/EC for VALUES OF $\mu$

| $\mu$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **0.40** | 0.6432 | 6431 | 6429 | 6428 | 6426 | 6425 | 6423 | 6422 | 6420 | 6419 |
| **0.41** | 0.6418 | 6416 | 6415 | 6413 | 6412 | 6410 | 6409 | 6408 | 6406 | 6405 |
| **0.42** | 0.6403 | 6402 | 6400 | 6399 | 6397 | 6396 | 6395 | 6393 | 6392 | 6390 |
| **0.43** | 0.6389 | 6387 | 6386 | 6384 | 6383 | 6382 | 6380 | 6379 | 6377 | 6376 |
| **0.44** | 0.6374 | 6373 | 6372 | 6370 | 6369 | 6367 | 6366 | 6364 | 6363 | 6361 |
| **0.45** | 0.6360 | 6359 | 6357 | 6356 | 6354 | 6353 | 6351 | 6350 | 6348 | 6347 |
| **0.46** | 0.6346 | 6344 | 6343 | 6341 | 6340 | 6338 | 6337 | 6336 | 6334 | 6333 |
| **0.47** | 0.6331 | 6330 | 6328 | 6327 | 6325 | 6324 | 6323 | 6321 | 6320 | 6318 |
| **0.48** | 0.6317 | 6315 | 6314 | 6312 | 6311 | 6310 | 6308 | 6307 | 6305 | 6304 |
| **0.49** | 0.6302 | 6301 | 6300 | 6298 | 6297 | 6295 | 6294 | 6292 | 6291 | 6289 |
| **0.50** | 0.6288 | 6286 | 6285 | 6283 | 6282 | 6280 | 6279 | 6277 | 6276 | 6274 |
| **0.51** | 0.6273 | 6271 | 6270 | 6268 | 6267 | 6265 | 6264 | 6262 | 6261 | 6259 |
| **0.52** | 0.6258 | 6256 | 6255 | 6253 | 6252 | 6252 | 6248 | 6247 | 6245 | 6244 |
| **0.53** | 0.6242 | 6241 | 6239 | 6238 | 6236 | 6235 | 6233 | 6232 | 6230 | 6229 |
| **0.54** | 0.6227 | 6226 | 6224 | 6223 | 6221 | 6220 | 6218 | 6217 | 6215 | 6214 |
| **0.55** | 0.6212 | 6210 | 6209 | 6207 | 6206 | 6204 | 6203 | 6201 | 6200 | 6198 |
| **0.56** | 0.6197 | 6195 | 6194 | 6192 | 6191 | 6189 | 6188 | 6186 | 6185 | 6183 |
| **0.57** | 0.6182 | 6180 | 6179 | 6177 | 6176 | 6174 | 6172 | 6171 | 6169 | 6168 |
| **0.58** | 0.6166 | 6165 | 6163 | 6162 | 6160 | 6159 | 6157 | 6156 | 6154 | 6153 |
| **0.59** | 0.6151 | 6150 | 6148 | 6147 | 6145 | 6144 | 6142 | 6141 | 6139 | 6138 |
| **0.60** | 0.6136 | 6134 | 6133 | 6131 | 6130 | 6128 | 6126 | 6125 | 6123 | 6121 |
| **0.61** | 0.6120 | 6118 | 6117 | 6115 | 6113 | 6112 | 6110 | 6108 | 6107 | 6105 |
| **0.62** | 0.6104 | 6102 | 6100 | 6099 | 6097 | 6096 | 6094 | 6092 | 6091 | 6089 |
| **0.63** | 0.6087 | 6086 | 6084 | 6083 | 6081 | 6079 | 6076 | 6076 | 6074 | 6073 |
| **0.64** | 0.6071 | 6070 | 6068 | 6066 | 6065 | 6063 | 6061 | 6060 | 6058 | 6057 |

## Chart for use with the Slope method (contd.)

| $\mu$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **0.65** | 0.6055 | 6053 | 6052 | 6050 | 6049 | 6047 | 6045 | 6044 | 6042 | 6040 |
| **0.66** | 0.6039 | 6037 | 6036 | 6034 | 6032 | 6031 | 6029 | 6027 | 6026 | 6024 |
| **0.67** | 0.6023 | 6021 | 6019 | 6018 | 6016 | 6015 | 6013 | 6011 | 6010 | 6008 |
| **0.68** | 0.6006 | 6005 | 6003 | 6002 | 6000 | 5998 | 5997 | 5995 | 5993 | 5992 |
| **0.69** | 0.5990 | 5989 | 5987 | 5985 | 5984 | 5982 | 5980 | 5979 | 5977 | 5976 |
| **0.70** | 0.5974 | 5973 | 5971 | 5969 | 5967 | 5965 | 5964 | 5962 | 5960 | 5959 |
| **0.71** | 0.5957 | 5955 | 5953 | 5952 | 5950 | 5948 | 5947 | 5945 | 5943 | 5942 |
| **0.72** | 0.5940 | 5938 | 5936 | 5935 | 5933 | 5931 | 5930 | 5928 | 5926 | 5924 |
| **0.73** | 0.5923 | 5921 | 5920 | 5918 | 5916 | 5914 | 5912 | 5911 | 5909 | 5907 |
| **0.74** | 0.5906 | 5904 | 5902 | 5900 | 5899 | 5897 | 5895 | 5894 | 5892 | 5890 |
| **0.75** | 0.5889 | 5887 | 5885 | 5883 | 5882 | 5880 | 5878 | 5877 | 5875 | 5873 |
| **0.76** | 0.5871 | 5870 | 5868 | 5866 | 5865 | 5863 | 5861 | 5859 | 5858 | 5856 |
| **0.77** | 0.5854 | 5853 | 5851 | 5849 | 5847 | 5846 | 5844 | 5842 | 5841 | 5839 |
| **0.78** | 0.5837 | 5835 | 5834 | 5832 | 5830 | 5829 | 5827 | 5825 | 5824 | 5822 |
| **0.79** | 0.5820 | 5818 | 5817 | 5815 | 5813 | 5812 | 5810 | 5808 | 5806 | 5805 |
| **0.80** | 0.5803 | 5801 | 5799 | 5797 | 5796 | 5794 | 5792 | 5790 | 5788 | 5786 |
| **0.81** | 0.5785 | 5783 | 5781 | 5779 | 5777 | 5775 | 5773 | 5772 | 5770 | 5768 |
| **0.82** | 0.5766 | 5764 | 5762 | 5760 | 5759 | 5757 | 5755 | 5753 | 5751 | 5749 |
| **0.83** | 0.5748 | 5746 | 5744 | 5742 | 5740 | 5738 | 5736 | 5735 | 5733 | 5731 |
| **0.84** | 0.5729 | 5727 | 5725 | 5723 | 5722 | 5720 | 5718 | 5716 | 5714 | 5712 |
| **0.85** | 0.5711 | 5709 | 5707 | 5705 | 5703 | 5701 | 5699 | 5698 | 5696 | 5694 |
| **0.86** | 0.5692 | 5690 | 5688 | 5686 | 5685 | 5683 | 5681 | 5679 | 5677 | 5675 |
| **0.87** | 0.5674 | 5672 | 5670 | 5668 | 5666 | 5664 | 5662 | 5661 | 5659 | 5657 |
| **0.88** | 0.5655 | 5653 | 5651 | 5650 | 5648 | 5646 | 5644 | 5642 | 5640 | 5638 |
| **0.89** | 0.5637 | 5635 | 5633 | 5631 | 5629 | 5627 | 5625 | 5624 | 5622 | 5620 |



| $\mu$ | 0 | 1 | 2 |
|---|---|---|---|
| **0.90** | 0.5618 | 5616 | 561 |
| **0.91** | 0.5598 | 5596 | 559 |
| **0.92** | 0.5578 | 5576 | 557 |
| **0.93** | 0.5557 | 5555 | 555 |
| **0.94** | 0.5537 | 5535 | 553 |
| **0.95** | 0.5517 | 5515 | 551 |
| **0.96** | 0.5497 | 5495 | 549 |
| **0.97** | 0.5477 | 5475 | 547 |
| **0.98** | 0.5456 | 5454 | 545 |
| **0.99** | 0.5436 | 5434 | 543 |
| **1.00** | 0.5416 | 5414 | 541 |
| **1.01** | 0.5394 | 5391 | 538 |
| **1.02** | 0.5371 | 5369 | 536 |
| **1.03** | 0.5349 | 5347 | 534 |
| **1.04** | 0.5327 | 5325 | 532 |
| **1.05** | 0.5305 | 5302 | 530 |
| **1.06** | 0.5252 | 5280 | 527 |
| **1.07** | 0.5260 | 5258 | 525 |
| **1.08** | 0.5238 | 5235 | 523 |
| **1.09** | 0.5215 | 5213 | 521 |
| **1.10** | 0.5193 | 5190 | 518 |
| **1.11** | 0.5168 | 5165 | 516 |
| **1.12** | 0.5143 | 5140 | 513 |
| **1.13** | 0.5118 | 5115 | 511 |
| **1.14** | 0.5093 | 5090 | 508 |

| 6 | 7 | 8 | 9 |
|---|---|---|---|
| 045 | 6044 | 6042 | 6040 |
| 029 | 6027 | 6026 | 6024 |
| 013 | 6011 | 6010 | 6008 |
| 997 | 5995 | 5993 | 5992 |
| 980 | 5979 | 5977 | 5976 |
| 964 | 5962 | 5960 | 5959 |
| 947 | 5945 | 5943 | 5942 |
| 930 | 5928 | 5926 | 5924 |
| 912 | 5911 | 5909 | 5907 |
| 895 | 5894 | 5892 | 5890 |
| 878 | 5877 | 5875 | 5873 |
| 861 | 5859 | 5858 | 5856 |
| 844 | 5842 | 5841 | 5839 |
| 827 | 5825 | 5824 | 5822 |
| 810 | 5808 | 5806 | 5805 |
| 92 | 5790 | 5788 | 5786 |
| 73 | 5772 | 5770 | 5768 |
| 55 | 5753 | 5751 | 5749 |
| 36 | 5735 | 5733 | 5731 |
| 18 | 5716 | 5714 | 5712 |
| 99 | 5698 | 5696 | 5694 |
| 81 | 5679 | 5677 | 5675 |
| 62 | 5661 | 5659 | 5657 |
| 44 | 5642 | 5640 | 5638 |
| 25 | 5624 | 5622 | 5620 |

| $\mu$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **0.90** | 0.5618 | 5616 | 5614 | 5612 | 5610 | 5608 | 5606 | 5604 | 5602 | 5600 |
| **0.91** | 0.5598 | 5596 | 5594 | 5592 | 5590 | 5588 | 5586 | 5584 | 5582 | 5580 |
| **0.92** | 0.5578 | 5576 | 5574 | 5572 | 5570 | 5568 | 5565 | 5563 | 5561 | 5559 |
| **0.93** | 0.5557 | 5555 | 5553 | 5551 | 5549 | 5547 | 5545 | 5543 | 5541 | 5539 |
| **0.94** | 0.5537 | 5535 | 5533 | 5531 | 5529 | 5527 | 5525 | 5523 | 5521 | 5519 |
| **0.95** | 0.5517 | 5515 | 5513 | 5511 | 5509 | 5507 | 5505 | 5503 | 5501 | 5499 |
| **0.96** | 0.5497 | 5495 | 5493 | 5491 | 5489 | 5487 | 5485 | 5483 | 5481 | 5479 |
| **0.97** | 0.5477 | 5475 | 5473 | 5471 | 5469 | 5467 | 5464 | 5462 | 5460 | 5458 |
| **0.98** | 0.5456 | 5454 | 5452 | 5450 | 5448 | 5446 | 5444 | 5442 | 5440 | 5438 |
| **0.99** | 0.5436 | 5434 | 5432 | 5430 | 5428 | 5426 | 5424 | 5422 | 5420 | 5418 |
| **1.00** | 0.5416 | 5414 | 5412 | 5409 | 5407 | 5405 | 5403 | 5400 | 5398 | 5396 |
| **1.01** | 0.5394 | 5391 | 5389 | 5387 | 5385 | 5383 | 5380 | 5378 | 5376 | 5374 |
| **1.02** | 0.5371 | 5369 | 5367 | 5365 | 5362 | 5360 | 5358 | 5356 | 5354 | 5351 |
| **1.03** | 0.5349 | 5347 | 5345 | 5344 | 5340 | 5338 | 5336 | 5333 | 5331 | 5329 |
| **1.04** | 0.5327 | 5325 | 5322 | 5320 | 5318 | 5316 | 5313 | 5311 | 5309 | 5307 |
| **1.05** | 0.5305 | 5302 | 5300 | 5298 | 5296 | 5293 | 5291 | 5289 | 5287 | 5284 |
| **1.06** | 0.5252 | 5280 | 5278 | 5276 | 5273 | 5271 | 5269 | 5267 | 5264 | 5262 |
| **1.07** | 0.5260 | 5258 | 5255 | 5253 | 5251 | 5249 | 5247 | 5244 | 5242 | 5240 |
| **1.08** | 0.5238 | 5235 | 5233 | 5231 | 5229 | 5229 | 5224 | 5222 | 5219 | 5217 |
| **1.09** | 0.5215 | 5213 | 5211 | 5209 | 5206 | 5204 | 5202 | 5200 | 5197 | 5195 |
| **1.10** | 0.5193 | 5190 | 5188 | 5185 | 5183 | 5180 | 5178 | 5175 | 5173 | 5170 |
| **1.11** | 0.5168 | 5165 | 5163 | 5160 | 5158 | 5155 | 5153 | 5150 | 5148 | 5145 |
| **1.12** | 0.5143 | 5140 | 5137 | 5135 | 5132 | 5130 | 5127 | 5125 | 5122 | 5120 |
| **1.13** | 0.5118 | 5115 | 5113 | 5110 | 5108 | 5105 | 5103 | 5100 | 5098 | 5095 |
| **1.14** | 0.5093 | 5090 | 5088 | 5085 | 5083 | 5080 | 5078 | 5075 | 5073 | 5070 |

## Chart for use with the Slope method (contd.)

| $\mu$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **1.15** | 0.5068 | 5065 | 5062 | 5060 | 5057 | 5055 | 5052 | 5050 | 5047 | 5045 |
| **1.16** | 0.5042 | 5040 | 5037 | 5035 | 5032 | 5030 | 5027 | 5025 | 5022 | 5020 |
| **1.17** | 0.5017 | 5015 | 5012 | 5010 | 5007 | 5005 | 5002 | 5000 | 4997 | 4995 |
| **1.18** | 0.4992 | 4990 | 4987 | 4985 | 4982 | 4980 | 4977 | 4975 | 4972 | 4970 |
| **1.19** | 0.4967 | 4965 | 4962 | 4960 | 4957 | 4955 | 4952 | 4950 | 4947 | 4945 |
| **1.20** | 0.4942 | 4939 | 4936 | 4933 | 4930 | 4928 | 4925 | 4922 | 4919 | 4916 |
| **1.21** | 0.4913 | 4910 | 4907 | 4904 | 4901 | 4899 | 4896 | 4893 | 4890 | 4887 |
| **1.22** | 0.4884 | 4881 | 4878 | 4875 | 4872 | 4870 | 4867 | 4864 | 4861 | 4858 |
| **1.23** | 0.4855 | 4852 | 4849 | 4846 | 4843 | 4841 | 4838 | 4835 | 4832 | 4829 |
| **1.24** | 0.4826 | 4823 | 4820 | 4817 | 4814 | 4812 | 4809 | 4806 | 4803 | 4800 |
| **1.25** | 0.4797 | 4794 | 4791 | 4788 | 4785 | 4783 | 4780 | 4777 | 4774 | 4771 |
| **1.26** | 0.4768 | 4765 | 4762 | 4759 | 4756 | 4754 | 4751 | 4748 | 4745 | 4742 |
| **1.27** | 0.4739 | 4736 | 4733 | 4730 | 4727 | 4725 | 4722 | 4719 | 4716 | 4713 |
| **1.28** | 0.4710 | 4707 | 4704 | 4701 | 4698 | 4696 | 4693 | 4690 | 4687 | 4684 |
| **1.29** | 0.4681 | 4678 | 4675 | 4672 | 4669 | 4667 | 4664 | 4661 | 4658 | 4655 |
| **1.30** | 0.4652 | 4649 | 4645 | 4642 | 4638 | 4635 | 4631 | 4628 | 4625 | 4621 |
| **1.31** | 0.4618 | 4614 | 4611 | 4607 | 4604 | 4601 | 4597 | 4594 | 4590 | 4586 |
| **1.32** | 0.4583 | 4580 | 4577 | 4573 | 4570 | 4566 | 4563 | 4559 | 4556 | 4553 |
| **1.33** | 0.4549 | 4546 | 4542 | 4539 | 4535 | 4532 | 4529 | 4525 | 4522 | 4518 |
| **1.34** | 0.4515 | 4511 | 4508 | 4505 | 4501 | 4498 | 4494 | 4491 | 4487 | 4484 |
| **1.35** | 0.4481 | 4477 | 4474 | 4470 | 4467 | 4463 | 4460 | 4457 | 4453 | 4450 |
| **1.36** | 0.4446 | 4443 | 4439 | 4436 | 4432 | 4429 | 4426 | 4422 | 4419 | 4415 |
| **1.37** | 0.4412 | 4408 | 4405 | 4402 | 4398 | 4395 | 4391 | 4388 | 4384 | 4381 |
| **1.38** | 0.4378 | 4374 | 4371 | 4367 | 4364 | 4360 | 4357 | 4354 | 4350 | 4347 |
| **1.39** | 0.4343 | 4340 | 4336 | 4333 | 4330 | 4326 | 4323 | 4319 | 4316 | 4312 |



| $\mu$ | 0 | 1 | 2 |
|---|---|---|---|
| **1.40** | 0.4309 | 4305 | 430 |
| **1.41** | 0.4267 | 4263 | 425 |
| **1.42** | 0.4225 | 4221 | 421 |
| **1.43** | 0.4183 | 4178 | 417 |
| **1.44** | 0.4141 | 4136 | 413 |
| **1.45** | 0.4099 | 4094 | 409 |
| **1.46** | 0.4056 | 4052 | 404 |
| **1.47** | 0.4014 | 4010 | 400 |
| **1.48** | 0.3972 | 3968 | 396 |
| **1.49** | 0.3930 | 3926 | 392 |
| **1.50** | 0.3888 | 3883 | 387 |
| **1.51** | 0.3840 | 3835 | 383 |
| **1.52** | 0.3791 | 3786 | 378 |
| **1.53** | 0.3740 | 3735 | 373 |
| **1.54** | 0.3688 | 3683 | 367 |
| **1.55** | 0.3635 | 3630 | 362 |
| **1.56** | 0.3580 | 3574 | 356 |
| **1.57** | 0.3523 | 3517 | 351 |
| **1.58** | 0.3465 | 3459 | 345 |
| **1.59** | 0.3405 | 3399 | 339 |

| 6 | 7 | 8 | 9 |
|---|---|---|---|
| 052 | 5050 | 5047 | 5045 |
| 027 | 5025 | 5022 | 5020 |
| 002 | 5000 | 4997 | 4995 |
| 977 | 4975 | 4972 | 4970 |
| 952 | 4950 | 4947 | 4945 |
| 925 | 4922 | 4919 | 4916 |
| 896 | 4893 | 4890 | 4887 |
| 867 | 4864 | 4861 | 4858 |
| 838 | 4835 | 4832 | 4829 |
| 809 | 4806 | 4803 | 4800 |
| 780 | 4777 | 4774 | 4771 |
| 751 | 4748 | 4745 | 4742 |
| 722 | 4719 | 4716 | 4713 |
| 693 | 4690 | 4687 | 4684 |
| 664 | 4661 | 4658 | 4655 |
| 631 | 4628 | 4625 | 4621 |
| 597 | 4594 | 4590 | 4586 |
| 563 | 4559 | 4556 | 4553 |
| 529 | 4525 | 4522 | 4518 |
| 494 | 4491 | 4487 | 4484 |
| 460 | 4457 | 4453 | 4450 |
| 426 | 4422 | 4419 | 4415 |
| 391 | 4388 | 4384 | 4381 |
| 357 | 4354 | 4350 | 4347 |
| 323 | 4319 | 4316 | 4312 |

| $\mu$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **1.40** | 0.4309 | 4305 | 4301 | 4296 | 4292 | 4288 | 4284 | 4280 | 4275 | 4271 |
| **1.41** | 0.4267 | 4263 | 4258 | 4254 | 4250 | 4246 | 4242 | 4237 | 4233 | 4229 |
| **1.42** | 0.4225 | 4221 | 4216 | 4212 | 4208 | 4204 | 4200 | 4195 | 4191 | 4187 |
| **1.43** | 0.4183 | 4178 | 4174 | 4170 | 4166 | 4162 | 4157 | 4153 | 4149 | 4145 |
| **1.44** | 0.4141 | 4136 | 4132 | 4128 | 4124 | 4120 | 4115 | 4111 | 4107 | 4103 |
| **1.45** | 0.4099 | 4094 | 4090 | 4086 | 4082 | 4077 | 4073 | 4069 | 4065 | 4061 |
| **1.46** | 0.4056 | 4052 | 4048 | 4044 | 4040 | 4035 | 4031 | 4027 | 4023 | 4018 |
| **1.47** | 0.4014 | 4010 | 4005 | 4001 | 3997 | 3993 | 3989 | 3985 | 3980 | 3976 |
| **1.48** | 0.3972 | 3968 | 3964 | 3959 | 3955 | 3951 | 3947 | 3943 | 3938 | 3934 |
| **1.49** | 0.3930 | 3926 | 3921 | 3917 | 3913 | 3909 | 3905 | 3900 | 3896 | 3892 |
| **1.50** | 0.3888 | 3883 | 3878 | 3874 | 3869 | 3864 | 3859 | 3854 | 3850 | 3845 |
| **1.51** | 0.3840 | 3835 | 3830 | 3825 | 3820 | 3816 | 3811 | 3806 | 3801 | 3796 |
| **1.52** | 0.3791 | 3786 | 3781 | 3776 | 3771 | 3766 | 3760 | 3755 | 3750 | 3745 |
| **1.53** | 0.3740 | 3735 | 3730 | 3724 | 3719 | 3714 | 3709 | 3704 | 3698 | 3693 |
| **1.54** | 0.3688 | 3683 | 3677 | 3672 | 3667 | 3662 | 3656 | 3651 | 3646 | 3640 |
| **1.55** | 0.3635 | 3630 | 3624 | 3619 | 3613 | 3608 | 3602 | 3597 | 3591 | 3586 |
| **1.56** | 0.3580 | 3574 | 3569 | 3563 | 3557 | 3552 | 3546 | 3540 | 3534 | 3528 |
| **1.57** | 0.3523 | 3517 | 3511 | 3506 | 3500 | 3494 | 3488 | 3482 | 3477 | 3471 |
| **1.58** | 0.3465 | 3459 | 3453 | 3447 | 3441 | 3435 | 3429 | 3423 | 3417 | 3411 |
| **1.59** | 0.3405 | 3399 | 3393 | 3386 | 3380 | 3374 | 3368 | 3362 | 3355 | 3349 |

### METHOD WHEN "DEAD" EARTH IS AVAILABLE

The techniques using test spikes explained earlier are the preferred methods of earth testing. In congested areas it may not be possible to find suitable sites for the test spikes, nor sufficient space to run the test leads. In these cases an alternative low resistance earth such as a water main may be available. This is referred to as a "dead" earth.

This must be of very low resistance to earth and connections are as shown in Fig. 17. This test will give the combined resistance of the two earths in series. If that of the "dead" earth is negligible then the reading may be taken as that of the electrode under test.

However, great care must be taken before deciding to adopt this method and its use is not to be encouraged. This is because non-metallic piping and jointing materials are commonly found in water main and other installations nowadays and such materials are totally unsuitable as a substitute earth spike. Before employing this method, the user must be quite sure that no part of the "dead" earth installation contains plastic or other non-metallic materials.

The Star-Delta method is therefore preferable for use in congested urban areas and it is explained (along with the other methods referred to here) in the book "A Simple Guide to Earth Testing" published by MEGGER INSTRUMENTS LIMITED.

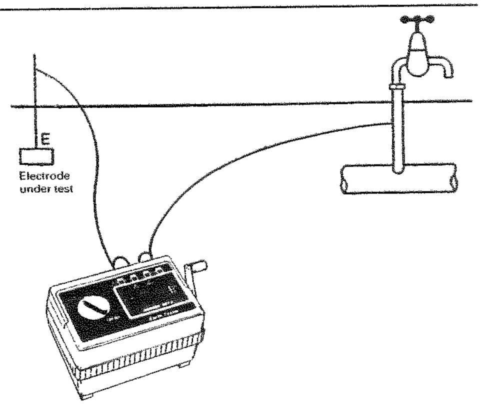



Fig. 17 "Dead" earth method.

If only two test leads are used as shown in the diagram, the resistance of both leads will be included in the measurement. The resistance of the leads can be found by joining their ends together, operating the instrument and taking the reading in the usual way. This value should be subtracted from the total to obtain the combined resistance of the earth electrode and the "dead" earth.



### 15th EDITION IEE WIRING REGULAT REQUIREMENT

Regulation 613-4 of the 15th Edition IE Regulations specifies that the resistan electrodes must be measured and the used is described in Appendix 15 Item basically the Fall-of-Potential method, t that the potential spike must be movec either side of the central position for th third resistance measurements (see Fi three results are in substantial agreem average of them is taken as the resista electrode. If there is no agreement the spike must be moved farther away fro and the tests repeated.

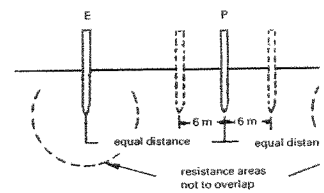
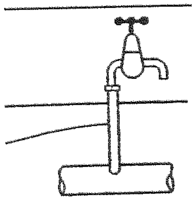



Fig. 18 Test spike positions for the 15 IEE Wiring Regulations.



1.

l as shown in the
h leads will be included
stance of the leads can
together, operating the
ding in the usual way.
ed from the total to
e of the earth electrode

## 15th EDITION IEE WIRING REGULATIONS REQUIREMENT

Regulation 613-4 of the 15th Edition IEE Wiring Regulations specifies that the resistance of earth electrodes must be measured and the method to be used is described in Appendix 15 Item 4. This is basically the Fall-of-Potential method, but specifies that the potential spike must be moved 6 metres either side of the central position for the second and third resistance measurements (see Fig. 18). If the three results are in substantial agreement, the average of them is taken as the resistance of the earth electrode. If there is no agreement then the current spike must be moved farther away from the electrode and the tests repeated.

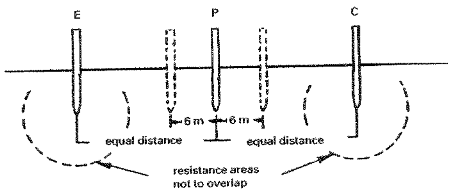



Fig. 18 Test spike positions for the 15th Edition IEE Wiring Regulations.

## OTHER METHODS

There are other earth electrode resistance testing methods among which are the Four Potential method, the Intersecting Curves method and the Star-Delta method which is suitable for congested urban areas.

MEGGER INSTRUMENTS LIMITED have produced a book entitled "A Simple Guide to Earth Testing" which explains all these test methods and gives other helpful information about earth testing. It is available from the instrument manufacturer or one of his approved distributors and has the part no. 6171-230.

### TOUCH POTENTIAL

Touch potential is the potential difference a person would experience across his body if he were, for example, standing on the ground outside the earthed perimeter fence of a substation and touching the fence at the time a fault to earth occurred.

Connect the instrument in the following way:—
Terminal 'C1' (or 'E') to the substation earth.
Terminal 'C2' (or 'H') to the current spike inserted in the ground some distance away.
Terminal 'P1' (or 'ES') to the structure being tested e.g. the perimeter fence.
Terminal 'P2' (or 'S') to a potential spike inserted in the ground 1 metre away from the perimeter fence adjacent to the point where a person might stand.

Operate the instrument and record the resistance indicated. This is the effective resistance between the point of test on the fence and the potential spike as seen by the test current.

The maximum value of the current that would flow in the earth when a fault to earth occurred at the substation must be known. The maximum fault current has to be calculated from the parameters associated with the substation ratings involved. From Ohm's Law (V = I x R), the Touch potential can be calculated.

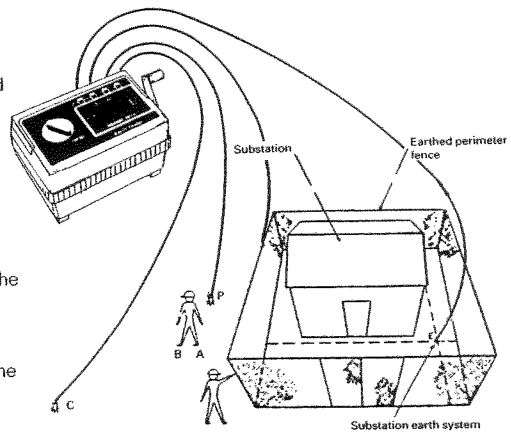



Fig. 19 Determining 'Touch' and 'Step' potential.



### STEP POTENTIAL

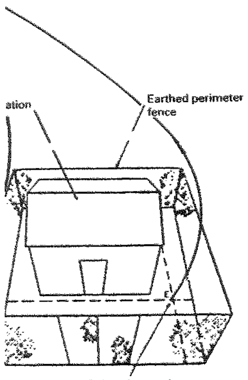
Step potential is the potential differen
would experience between his feet a
across the ground in which a fault cur
flowing.

Connect the 'C1' and 'C2' (or 'E' and '
described for touch potential measur
Connect the 'P1' and 'P2' terminals t
inserted in the ground at positions A a
respectively, (see Fig. 19); A is neare
substation earth. Positions A and B a
or the length of a step.

Operate the instrument and record th
indicated. This is the effective resista
positions A and B, as seen by the tes

The maximum value of the current th
the earth when a fault to earth occur
substation must be known (as is the
potential). From Ohm's Law (V = I x
potential can be calculated.

tep' Potential




Touch' and 'Step' potential.

**STEP POTENTIAL**

Step potential is the potential difference a person would experience between his feet as he walked across the ground in which a fault current was flowing.

Connect the 'C1' and 'C2' (or 'E' and 'H') terminals as described for touch potential measurement above. Connect the 'P1' and 'P2' terminals to test spikes inserted in the ground at positions A and B respectively, (see Fig. 19); A is nearest to the substation earth. Positions A and B are 1 metre apart, or the length of a step.

Operate the instrument and record the resistance indicated. This is the effective resistance across the positions A and B, as seen by the test current.

The maximum value of the current that would flow in the earth when a fault to earth occurred at the substation must be known (as is the case with Touch potential). From Ohm's Law ($V = I \times R$), the Step potential can be calculated.

### TYPICAL VARIATIONS IN SOIL RESISTIVITY

The resistance to earth of an earth electrode is influenced by the resistivity of the surrounding soil. The resistivity depends upon the nature of the soil and its moisture content and can vary enormously as seen in the table below:—

| Material | Specific resistance in ohm-cms | Source of information |
|---|---|---|
| Ashes | 350 | Higgs |
| Coke | 20-800 | — |
| Peat | 4,500-20,000 | — |
| Garden earth – 50% moisture | 1,400 | Ruppel |
| " " – 20% moisture | 4,800 | " |
| Clay soil – 40% moisture | 770 | " |
| " " – 20% moisture | 3,300 | — |
| London clay | 400-2,000 | — |
| Very dry clay | 5,000-15,000 | — |
| Sand – 90% moisture | 13,000 | Ruppel |
| " – normal moisture | 300,000-800,000 | — |
| Chalk | 5,000-15,000 | — |
| Consolidated sedimentary rocks | 1,000-50,000 | Broughton Edge & Laby |

Because it is impossible to forecast the resistivity of the soil with any degree of accuracy it is important to measure the resistance of an earth electrode when it is first laid down and thereafter at periodic intervals. Before sinking an electrode into the ground for a new installation it is often advantageous to make a preliminary survey of the soil resistivity of the surrounding site. This will enable decisions to be made on the best position for the electrode(s) and to decide whether any advantage is to be gained by driving rods to a greater depth. Such a survey may produce considerable savings in electrode and installation costs incurred trying to achieve a required resistance.

### LINE TRAVERSE

The most common method of measuring soil resistivity is often referred to as the line traverse. Four test spikes are driven into the ground in a stright line at equal distances 'a' and to a depth of not more than 1/20 of 'a'. The instrument is connected to the test spikes as shown in Fig. 20.

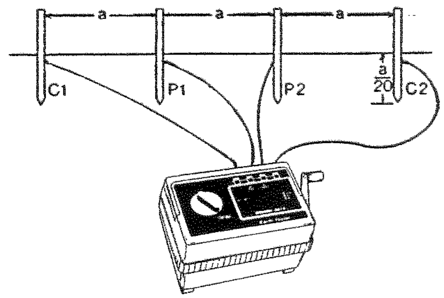



Fig. 20 Connections for resistivity testing.



The instrument is operated and the m
made in the normal way. The resistivi
calculated from the formula given opp
nomogram shown in Fig. 21 on page 5
average soil resistivity to a depth 'a'.

The four test spikes are then re-positi
tests along a different line. If both the
the depth '1/20 a' are maintained, a d
comparable reading will be obtained e
thus regions of lowest resistivity can
given area (at the constant depth 'a').

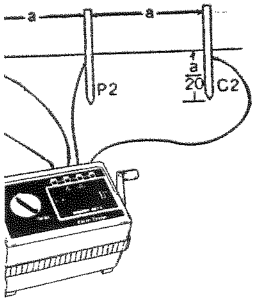
Re-spacing the test spikes at separat
etc. will yield results from which a pr
resistivity at new depths '1/20 b', '1/2
etc. can be obtained.

If the same line for the test spikes is
the separation of them is progressive
resistivity values at various depths ca
this means depth surveys may be ma
INSTRUMENTS LIMITED, publication
Guide to Earth Testing" gives more in
the line traverse and depth surveys.

## Soil

ı for the electrode(s) and to
ntage is to be gained by
lepth. Such a survey may
ings in electrode and
l trying to achieve a required

ıod of measuring soil
ed to as the line traverse. Four
o the ground in a stright line
l to a depth of not more than
nt is connected to the test
20.




ınections for resistivity testing.

The instrument is operated and the measurement made in the normal way. The resistivity may be calculated from the formula given opposite or from the nomogram shown in Fig. 21 on page 50. This is the average soil resistivity to a depth 'a'.

The four test spikes are then re-positioned for further tests along a different line. If both the spacing 'a' and the depth '1/20 a' are maintained, a directly comparable reading will be obtained each time, and thus regions of lowest resistivity can be located over a given area (at the constant depth 'a').

Re-spacing the test spikes at separations 'b', 'c', 'd', etc. will yield results from which a profile of the resistivity at new depths '1/20 b', '1/20 c', '1/20 d', etc. can be obtained.

If the same line for the test spikes is maintained, but the separation of them is progressively widened resistivity values at various depths can be obtained. By this means depth surveys may be made. MEGGER INSTRUMENTS LIMITED, publication "A Simple Guide to Earth Testing" gives more information about the line traverse and depth surveys.

### CALCULATION OF RESISTIVITY

Assuming that the soil in which the tests were made is homogeneous the resistivity is given by the formula:—

$$\rho = 2\pi aR$$

where R is the resistance measured in ohms, a is the test spike spacing in metres and $\rho$ is the resistivity in ohm-metres.

For non-homogeneous soils the formula will give an apparent resistivity which is very approximately the average value to a depth equal to the test spike spacing 'a'.

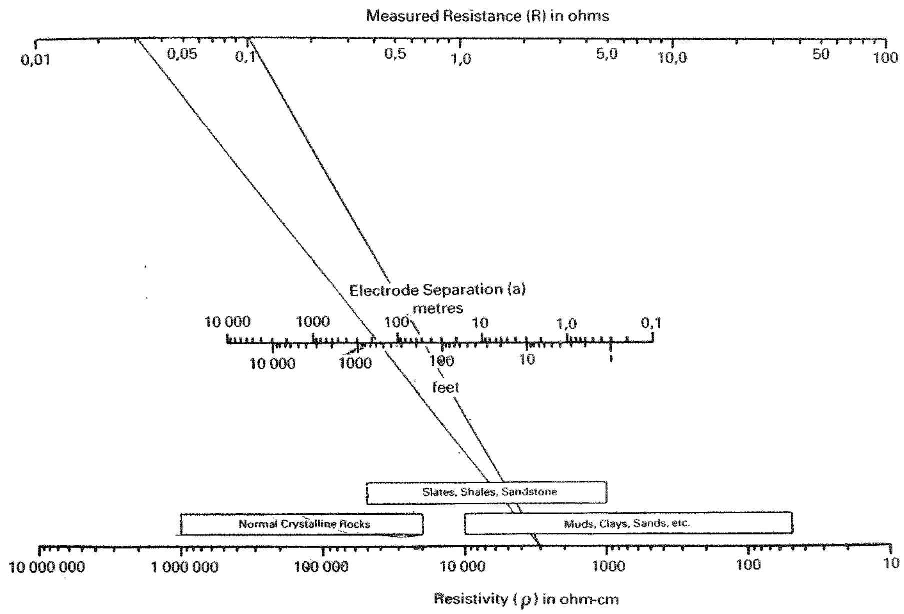



Fig. 21 Nomogram for resistivity calculations.



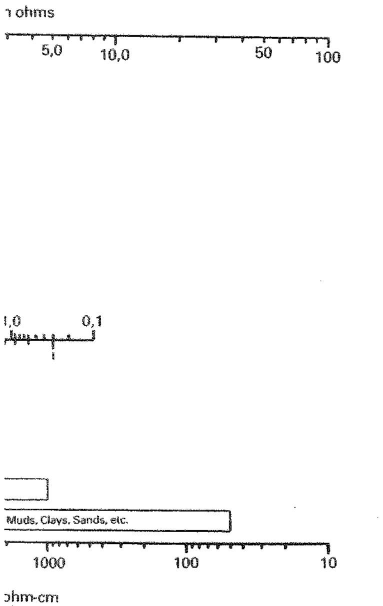


To test the continuity of conduit or other earth conductors the instrument is connected as shown i Fig. 22. It will measure metallic resistances of low inductance or capacitance. Make sure that the circu is 'dead' i.e. de-energized, before connecting the instrument for measurement.

Due to the inherent high accuracy of the instrument and the low continuity resistance to be measured, t contact resistance between the test lead clips and t conduit becomes a factor in the measured value. Contact resistance should therefore be kept as low possible.

The resistance of the test leads may be found by connecting them to the 'P1' and 'P2' (or 'ES' and 'S terminals and joining their free ends together. 'C1' a 'P1', and 'C2' and 'P2' (or 'E' and 'ES', and 'S' and 'H must be joined together before the measurement is made in the normal way. The test lead resistance is subtracted from the original reading to give the valu of the continuity resistance. Alternatively use of the four terminal technique will eliminate the test lead resistance.

## tivity of the Soil




alculations.

## MEASURING TECHNIQUES Continuity Testing

To test the continuity of conduit or other earth conductors the instrument is connected as shown in Fig. 22. It will measure metallic resistances of low inductance or capacitance. Make sure that the circuit is 'dead' i.e. de-energized, before connecting the instrument for measurement.

Due to the inherent high accuracy of the instrument and the low continuity resistance to be measured, the contact resistance between the test lead clips and the conduit becomes a factor in the measured value. Contact resistance should therefore be kept as low as possible.

The resistance of the test leads may be found by connecting them to the 'P1' and 'P2' (or 'ES' and 'S') terminals and joining their free ends together. 'C1' and 'P1', and 'C2' and 'P2' (or 'E' and 'ES', and 'S' and 'H'), must be joined together before the measurement is made in the normal way. The test lead resistance is subtracted from the original reading to give the value of the continuity resistance. Alternatively use of the four terminal technique will eliminate the test lead resistance.

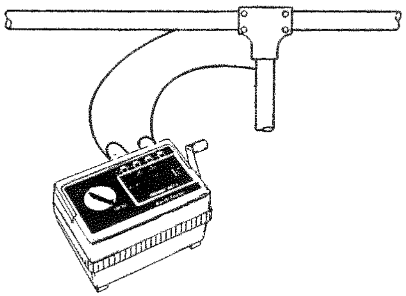


Fig. 22 Continuity testing.

## CIRCUIT DESCRIPTION

The instrument employs the four terminal measurement principle, and so the potential drop across the earth resistance under test is fed to the measuring circuit via terminals 'P1' and 'P2' (or 'ES' and 'S'). An input buffer stage prevents the measuring circuit from loading the earth resistance being tested.

The test signal controls a constant current a.c. source powered from a 'floating' supply and switched to provide the three ranges. The test current is passed via the 'C1' and 'C2' (or 'E' and 'H') terminals through the earth under test.

A crystal controlled oscillator is at the heart of the waveform generator circuit. The fundamental frequency so derived is then sub-divided to provide a test signal of 135,3 Hz. Waveforms are also generated to operate the phase sensitive filter and detector circuits.

To remove noise imposed on the test signal as it passes through the earth under test, a phase sensitive filter is employed. The measurement signal is shown on the display directly in the units of ohms.

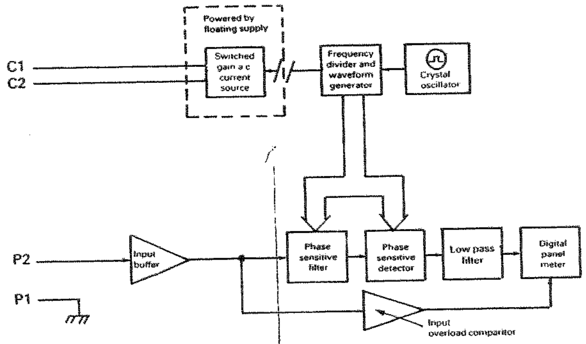



Fig. 23 Block diagram of instrument circuit.



## INSTRUMENT REPAIRS AND SPARE PARTS

The manufacturer's service and spare parts organisation for MEGGER® instruments:—

***MEGGER INSTRUMENTS LIMITED,***

**Archcliffe Road,**
**Dover,**
**Kent CT17 9EN,**
**England.**
**Tel: Dover (0304) 202620**
**Fax: Dover (0304) 207342**
**Telex: 96283 Avomeg G**

### Approved Repair Companies

A number of independent instrument repair companies in the U.K. have been approved for repair work on most MEGGER® instruments, using genuine MEGGER® spare parts. Their names and addresses are listed in the Warranty Card supplied with each new instrument.

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**Overseas**

Instrument owners outside Great Britain should consult the Appointed Distributor/Agent for their country regarding spare parts and repair facilities. The Distributor/Agent will advise on the best course of action to take.

If returning an instrument to Britain for repair, it should be sent, freight pre-paid, to the address shown opposite. A copy of the Invoice and of the Packing Note should be sent simultaneously by airmail to expedite clearance through the U.K. Customs.

A repair estimate showing freight return and other charges will be submitted to the sender, if required, before work on the instrument commences.

**NEW MEGGER® INSTRUMENTS ARE GUARANTEED FOR 12 MONTHS FROM THE DATE OF PURCHASE BY THE USER.**