# Time Domain Reflectometer

# MEGGER® CFL 535E - TDR2000

User Guide

MEGGER®

# Contents





**Symbols used on the instrument are:**

**Caution: Refer to accompanying notes.**

**Equipment protected throughout by double or reinforced insulation**

**Instrument flash tested to 3.7kV r.m.s. for 1 min.**

**Equipment complies with current EU directives**

## SAFETY WARNINGS

- ★ This instrument meets the safety requirements of IEC 61010 part 1 to 150V cat III. If it is to be used in situations where hazardous live voltages may be encountered then an additional blocking filter must be used.
- ★ CAUTION (Risk of electric shock)
- ★ Although this tester does not generate any hazardous voltages, circuits to which it can be connected could be dangerous due to electric shock hazard or due to arcing (initiated by short circuit). While every effort has been made by the manufacturer to reduce the hazard, **the user must assume responsibility for ensuring his or her own safety**.
- ★ The instrument should **not** be used if any part of it is damaged.
- ★ Test leads, probes and crocodile clips must be in good order, clean and with no broken or cracked insulation.
- ★ Check that **all** lead connections are correct before making a test.
- ★ Disconnect the test leads before accessing the battery compartment.
- ★ Refer to operating instructions for further explanation and precautions.
- ★ **Safety Warnings** and **Precautions** must be read and understood before the instrument is used. They must be observed during use.

**NOTE**

**THE INSTRUMENT MUST ONLY BE USED BY SUITABLY TRAINED AND COMPETENT PERSONS**

# Introduction

Thank you for purchasing this quality AVO product. Before using your new instrument please take the time to read this user guide, ultimately this will save you time, advise you of any precautions you need to take and could prevent damage to yourself and the instrument.

Your TDR2000 is a very advanced instrument capable of identifying a wide range of cable faults. The instrument uses a technique called Time Domain Reflectometry (TDR) which in many ways is similar to radar. Narrow pulses of electrical energy are transmitted along a pair of conductors in a cable. The pulse travels through the cable at a velocity determined by the insulation between the conductors and the resistance to the flow of the pulse is characterised as impedance for the cable. Changes in cable impedance will cause a proportion of the pulse to be reflected. The pulse velocity is normally described as a fraction of the speed of light and is called the Velocity Factor. By measuring the time between the transmitted pulse and the reception of the reflected pulse, and multiplying this by the speed of light and the velocity factor, the actual distance to the reflection point can be given.

Faulty cables, poor joints or discontinuities will all cause a change in impedance.  Impedance's higher than the cable's cause a normal reflection. Impedance's lower than the cable's cause an inverse reflection. Matched terminations absorb all the pulse hence no reflection will occur, the cable appearing endless. Open or Short circuits will reflect all the pulse energy and the TDR will not 'see' the cable beyond that fault.

As a pulse is transmitted down a cable, the size and shape of that pulse is gradually attenuated by losses in the cable: the pulse gets smaller in height and more spread out. The level of attenuation is determined by the cable type, the condition of the cable and any connections along its length. The limit of how far you can see is determined by the point beyond which you will not discern a reflection. To maximise the instruments range, the TDR2000 has an adjustable gain setting on its input that can apply up to 90dB of gain to the reflected signal to allow you to discern a reflection from farther away. By combining this variable gain with increasing pulse widths, the TDR2000 can discern faults up to 16Km away.

The MEGGER TDR2000 can be used on any cable consisting of at least two insulated metallic elements, one of which may be the armouring or screen of the cable. The balancing circuit, which is described in the Operating Instructions, can balance for any cable with a characteristic impedance of 0-120Ω. Dual inputs and the large graphic display allow a wide range of comparative tests to be performed between cable pairs or stored results. The instrument has 15 trace memories, enabling previous test results to be displayed and compared with "live" results. This allows the gradual ageing of a cable to be monitored or characteristic changes to be detected between periodic tests, for example if the cable has suffered water ingress or has been tapped and split.

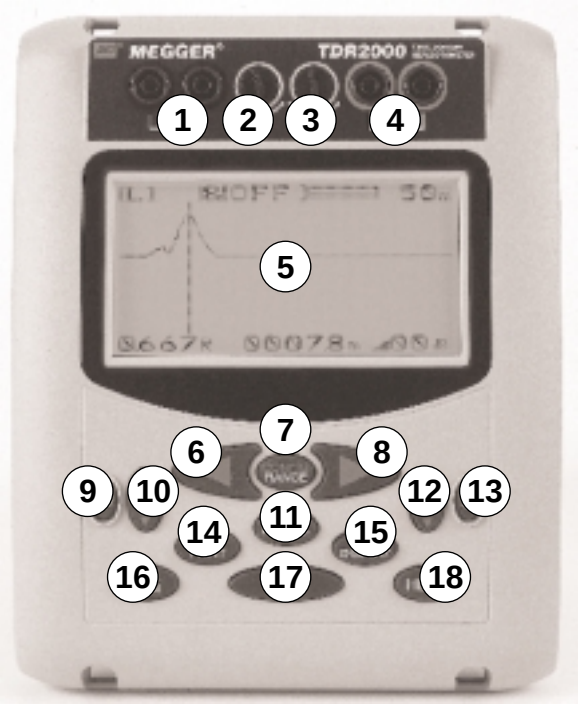
There are four modes of operation to get “live” results, and these are:

| | |
|---|---|
| [L1] & [OFF] | Trace is acquired from L1 only, internal balance circuit used. |
| [L1] & [L2] | Traces are acquired from L1 & L2 for comparison, internal balance circuit used. |
| The | DIFF key selects whether both are displayed or the difference between them is displayed. |
| [L1-L2] & [OFF] | The displayed trace is the difference between L1 & L2, L2 acts as the balance circuit for L1. |
| [Xtalk] & [OFF] | A pulse is transmitted on L1 and any reflection is looked for on L2, only L2 is displayed. |

A setup disk changes the stored language via the serial link, and various user options can be tailored via the CONFIG menu on the instrument. The download feature allows transfer of the waveform data to a computer, for analysis and storage for future reference.  Other setting options include changing the distance units between metres and feet, changing the propagation velocity units between a ratio and a distance per microsecond. Display contrast is fully adjustable to compensate for all viewing conditions. A backlight aids viewing in low ambient light conditions. Should use of the instrument prove difficult then on screen, key sensitive help is available.

The batteries to power the instrument are housed in the compartment on the case back, the cover is held in place with two screws. The batteries are held in a carrier, which hold the batteries securely, and allow rechargeable battery packs to be quickly changed. The instrument can be powered by manganese-alkali, nickel-cadmium or nickel-metal-hydride batteries. All cells must be of the same type.

# Features and Controls




The controls of the TDR have been arranged such that the instrument is easy to use. The instrument controls consist of the following:

**1) L1 Sockets:**
The sockets are designed to accept the leads supplied with the instrument, or the optional mains blocking filter. Line 1 is usually connected to the faulty line or the line under test. In Xtalk mode, this is the transmitting terminal.

**2) Contrast:**
This is a rotary control that lets the user correct the display contrast for user preference and adjust for the extremes of temperature.

**3) Balance:**
This is a rotary control that allows the user to match the impedance of the internal balance circuit to that of the cable under test. When balanced, the transmitted pulse can be nulled out and cable features close to the leads can be detected.

**4) L2 Sockets:**
The sockets are designed to accept the leads supplied with the instrument, or the optional mains blocking filter. They allow a second cable to be tested simultaneously for direct comparison or are used on a known good line to null out the transmitted pulse instead of using the internal balance circuit. In Xtalk mode, this is the receiving terminal.

**5) Instrument Display:**
The display shows the user the current settings of the instrument and the reflected energy trace from the cable(s) connected. It can also display the menu and help screens and stored traces.

**6) Cursor Left:**
This control moves the cursor left or, if in a menu screen, selects a lower value.

**7) Range / Configuration:**
Pressing this button changes the instrument range to the next lower range. If this button and the shift key are pressed together then the CONFIG menu is invoked.

**8) Cursor Right:**
This control moves the cursor right or, if in a menu screen, selects a higher value.

**9) Power:**
Pressing this button will turn the instrument on or off depending on the current state.

**10) Velocity factor:**
This control is a bi-directional switch and can be used to increase or decrease the velocity factor. When in a menu screen it will also navigate up and down the screen.

**11) Mode:**
This control cycles round the display modes, L1 only, L1 and L2, L1 - L2 and Xtalk.

**12) Gain:**
This control is a bi-directional switch and can be used to increase or decrease the gain of the instrument in 6dB steps from 0dB to 90dB. When in a menu screen it will also navigate up and down the screen.

**13) Backlight:**
Pressing this button will toggle the backlight on and off.

**14) Print / PC:**
Pressing this key sends the current screen to an attached EPSON compatible printer as a screen dump. If pressed with the shift key then the instrument will go to computer controlled operation where a computer running the appropriate download program can upload / download saved traces and also change the instruments language.

**15 Display / Diff:**
This key changes the display from the entire range to a zoomed in view, or if pressed with the shift key changes the TDR from dual trace mode to difference mode.

**16) Mem / Save:**
This key allows access to the save and recall of traces. Pressing the key with the shift key allows the trace to be saved. Pressing it without the shift key allows a saved trace to be recalled.

**17) Shift:**
Pressing this key in conjunction with another will result in an alternate function, it the key is dual purpose.

**18) Help:**
Pressing this key toggles the instrument in and out of help mode. In help mode, the instrument will display key sensitive help information.

**Battery cover:**This is on the back of the instrument and provides the user with access to the batteries. The cover must not be removed while the instrument is on or connected to a cable. The instrument must not be operated with the cover open.

# Operation

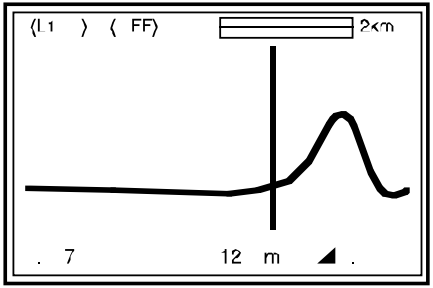
Ensure the test leads are firmly fitted into the sockets of the instrument. Ensure the cable(s) under test is (are) de-energised before connecting the test leads. If working on live power cables, a blocking filter(s) must be used to isolate the instrument from the live line(s).

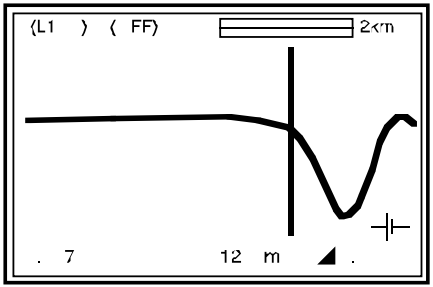
Switch the instrument on and the instrument will display the start screen for a couple of seconds. The TDR will then display a trace. The instrument will have powered up, set to the last used mode, range and velocity factor. If the settings are different for the cable under test (C.U.T) then first use the mode key to cycle through the available modes and select the required one. Next, use the VF bi-directional key to set the velocity factor for the C.U.T. (If this is unknown then follow the steps detailed in the Velocity Factor section.) Finally, cycle through the available ranges until you select a range long enough to see the whole cable length of the C.U.T.

With the gain set at the lowest level required to easily identify the cable feature, e.g. an open or closed circuit, move the cursor to the very beginning of the reflection. To locate the start of the reflection more accurately, press the DISPLAY key to zoom in around the current cursor position. The cursor is now fixed and using the cursor left and cursor right keys, the trace will move relative to that point. The current zoom location with respect to the whole trace range is shown at the top of the display. The distance is then directly read from the display. The distance calculation is performed using the current velocity factor. If this velocity factor is not correct, the displayed distance will be incorrect.

To enable partial cable faults to be identified, i.e. those faults that only reflect part of the signal back to the instrument, the gain of the instrument can be adjusted. With the gain at the minimum required to see the end of the cable on the trace, if a minor fault is suspected then increase the gain until the fault is more visible.

Below are shown two typical trace displays. The top one is an open circuit cable, the open circuit at 1200m away, the second is a short circuit at 1200m away and the instrument is displaying the low battery warning.



# Instrument Features:

**Balance Control**

Without Balance Control (see point 3 in the User Controls and Display section) the transmitted pulse would be visible at the beginning of the trace, swamping any reflections within the pulse length (the dead zone). The balancing circuit attempts to match the characteristic impedance of the cable under test to produce an equivalent pulse. Subtracting this equivalent pulse from the transmitted pulse effectively removes the dead zone and allows cable features much closer in to be detected. Alternatively, using the [L1-L2] & [OFF] mode, where L2 is connected to a known good length of the cable under test, L2 is used instead of the balancing circuit to automatically null the transmitted pulse.

**NOTE:** In many cases, it will be impossible to completely null the transmitted pulse.

**Velocity Factor**

The velocity factor is the scalar that is used to convert the measured time interval into an actual length of cable. It can be displayed in one of two ways: a ratio of the transmitted pulse speed to the speed of light, or as a distance per microsecond. When it is displayed as the distance per µs (either m/µs or ft/µs) the velocity factor will be indicated as half the speed of the pulse in the cable. This is because the pulse in fact has to go along the cable to the cable feature and back again which is twice the distance to the feature.

The table of velocity factors in the HELP pages of the instrument is a rough guide and in practice, the settings are subject to many variable factors. If the exact length of a piece of cable of the same type as the C.U.T is known and the reflection from the cable end is visible then a more accurate value can be determined:

1. Locate the reflection caused by the end of the known length of cable with the instrument set on the shortest possible range to see the end of the cable.
2. Locate the start of this reflection as described in the Operation section of this manual.
3. Adjust the velocity factor until the correct cable length is shown.

The measurement of the distance to the fault can now be made with more confidence that the measurement will be correct. The ability of the instrument to accurately measure the distance to a cable feature relies on the velocity factor being correct, any percentage errors in the velocity factor are directly proportional to distance measurement errors. Hence, the TDR2000 uses the velocity factor to three decimal places to reduce any errors.

**Pulse Widths**

The TDR2000 pulse widths range from 20ns to 16µs to overcome signal attenuation and enable the instrument to see further down a length of cable. In distance terms for the size of the transmitted pulse, this represents a transmitted pulse from as small as 4.0m to 3199m! (This assumes a velocity factor of 0.667.) Without Balance Control, this would be an enormous dead zone, but with the instrument correctly balanced, faults can be seen well within the pulse width.

As the measured distance is taken at the start of the reflected pulse, the size of the pulse width does not affect the accuracy of the measurement. However, if the first feature does not give a complete reflection such that the instrument can see beyond it to a second feature, the ability to discern between features is affected by the pulse widths. If there are multiple features, the instrument can only fully discern between them if the features are more than the pulse width apart. Hence, for discerning multiple features, the instrument should be used with the smallest pulse width that can see both features.

When using the RANGE key to change the instrument's range, the pulse widths are set to the instrument's default for that range. If the attenuation of the C.U.T is too high or there are multiple cable features which the default pulse width can not discern between, the user can override the default by entering the CONFIG Options menu.

**Memory Features**

The TDR2000 has 15 memory locations, which can be used to store traces from previously tested cables. These may be stored for future analysis or be downloaded to the TRACEMASTER software for analysis on a PC. Each memory location stores the graphical trace along with the gain, range and mode settings. With the TRACEMASTER software, the stored trace can be annotated and kept on file for future reference. You can also upload a trace to the instrument using the TRACEMASTER software, including the first 64 characters of any annotation applied to that trace.

With the extensive dual trace and difference modes available to the TDR2000, memory locations can be used as comparisons for live traces. This is useful if the known good cores that would normally be used in the [L1]-[L2] mode are two far away from the C.U.T. Instead, a memory trace of a known good cable can be compared against the C.U.T.

## CONFIGURATION MENU

There are two configuration menus - options and setup. The Options menu includes all those settings that will be adjusted in the everyday use of the instrument. The Setup menu includes those settings that are more for the user preferences and calibration and will only be accessed occasionally. The top line of both menus is the Configuration Menu setting that allows the user to toggle between the Options and Setup menus.

| CONFIGURATION - OPTIONS | | CONFIGURATION - SETUP | |
|---|---|---|---|
| **CONFIG MENU** | **[OPTIONS]** | **CONFIG MENU** | **[SETUP]** |
| **TRACE 1** | **[L1]** | **VF DISPLAY** | **[RATIO]** |
| **TRACE 2** | **[L2** | **ZERO POINT (nS)** | **[20]** |
| **PULSE WIDTHS** | **[200Ns]** | **POWER DOWN (mins)** | **[5]** |
| **DISTANCE UNITS** | **[m]** | **BACKLIGHT OFF (mins)** | **[2]** |
| **AVERAGING** | **[x1]** | **LANGUAGE** | **[1]** |
| **UNIT RANGE** | **[200m]** | **PRINTER DELAY (mS)** | **[05]** |

**Trace 1 & 2:** This option determines which waveforms will be acquired for display as traces 1&2. Though the MODE key can select between the four basic modes of operation (see the introduction), the user has more ability to select modes of operation and can allocate a memory trace to either trace 1 or 2. Trace 1 can be set to L1, L2, L1-L2, Xtalk and any memory trace M1-M15. Trace 2 can be set to L2 and any memory trace M1-M15.

**Pulse Widths:** This option allows the user to override the default pulse width set by the instrument for a particular range and select an alternative pulse width available within the range. (See the Specification section for the table of pulse widths and the section under Instrument Features for more details.)

**Distance Units:** This option allows the user to select whether the cursor distance will be displayed in metres, feet or nano-seconds.

**Averaging:** When trying to locate cable features when a high gain is required, any noise on the C.U.T will be amplified as well as the reflected pulse. This noise may make accurate location of the cable feature more difficult. To overcome this, the TDR2000 has the ability to have averaging where the cable is over-sampled and any random noise should be greatly reduced. This option allows this to be set at 1x, 2x, 3x or 4x over-sampling.

**Note:** A high over-sample rate can reduce the battery lifetime.

**VF Display:** The velocity factor can be displayed as a ratio
of pulse speed to the speed of light or as a distance per microsecond. This option selects the display type. Please refer to the Instrument Feature section for more details.

**Zero Point:** This setting enables the zero point of the instrument to be set at the end of the test leads, so the test lead length is automatically deducted from any distance calculation. The nominal zero point setting for the standard test leads is 20ns, however to zero non standard test leads please take the following steps:

1. From the Config Menu - Options set the Range to a range suitable for the test leads.
2. Set the Distance Units to nS.
3. From the Config Menu - Setup set the Zero Point to 0.
4. Press the MODE key to exit the Config menu and display a trace.
5. Measure the distance (in nS) to the ends of the test leads, to identify this open circuit and close circuit the lead end.
6. In the Config Menu - Setup set the Zero Point to this measured time.

All measured distances will now be shown relative to the end of the test leads.

**Power down:** This allows the user to set the power down to 5, 10 or 15 minutes after the last key press.

**Backlight off:** This allows the user to set the backlight auto turn off to 1, 2 or 5 minutes.

**Language:** This allows the user to select either language 1 or 2. Language 1 is always English but language 2 is set by which language the user uploads to the instrument with the TRACEMASTER software.

**Printer Delay:** The serial port on this instrument is fully opto-isolated as part of the over-voltage category protection. As a result there is no hardware handshaking available, so to allow a line printer to keep up with the instrument a variable delay set by this setting is added between each block of data sent to the printer.

**Techniques to improve accuracy**

To improve on the accuracy of the measurement, numerous methods can be used depending on the situation encountered. Not every situation can be described, but the following points are effective and the most common and easily implemented methods.

**Test the cable from both ends**

When fault finding a cable it is good practice to test the cable from both ends. Particularly in the case of open circuit faults, the true end of the cable is not visible, Thus it is harder to estimate whether the answer obtained is realistic. If the measurement is made from both ends, then the combined answer should add up to the expected length of the cable.

Even in the case when the true end of the cable is still visible, the reflections after the fault may be too obscure to analyse clearly. In this case, measurement from both ends yields a clearer picture as well as improved accuracy.

It is also good practice to follow the cable route with a cable tracer, as not all cable runs will be straight. It can save a great deal of time if the exact route of the cable is known as faults will usually be found at points were human intervention has occurred, junction boxes, splices, recent ground excavation etc.

**Care and Maintenance**

Other than replacing the batteries, the instrument has no user serviceable parts. In the event of failure if should be returned to your supplier or an approved AVO repair agent.
Cleaning the instrument should only be done by wiping with a clean cloth dampened with soapy water or Isopropyl Alcohol (IPA).

# Specification

Except where otherwise stated, this specification applies at an ambient temperature of 20°C.

**Ranges:** 50m, 100m, 200m, 400m, 1km, 2km, 4km, 8km, 16km.

**Resolution:** 0.1m up to 200m
0.2m up to 400m
0.1% of range above 400m

**Measurement Accuracy:** 0.1% of Range
*[**Note** – The measurement accuracy is for the indicated cursor position only and is conditional on the velocity factor being correct.]*

**Input Protection:** The inputs will withstand 150Vdc or 150Vac up to 500Hz.

**Output pulse:** 14 volts peak to peak into open circuit, 7 volts peak to peak into 120Ω

**Pulse width user selectable:**

| | |
|---|---|
| 50m range: | 20ns, 40ns, 60ns, 80ns, 100ns |
| 100m range: | 20ns, 50ns, 800ns, 100ns, 140ns |
| 200m ranges: | 20ns, 60ns, 100ns, 140ns, 200ns |
| 400m range: | 40ns, 80ns, 160ns, 200ns, 400ns |
| 1km range: | 80ns, 160ns, 260ns, 500ns, 1µs |
| 2km range: | 160ns, 260ns, 500ns, 1µs, 2µs |
| 4km range: | 250ns, 500ns, 1µs, 2µs, 4µs |
| 8km range: | 500ns, 1µs, 2µs, 4µs, 8µs |
| 16km range: | 1µs, 2µs, 4µs, 8µs, 16µs |

**Gain:** 0 to 90dB in steps of 6dB

**Velocity Factor:** Variable from 0.300 to 0.999 in steps of 0.001

**Repetition rate:** Burst of 256 pulses every 1 or 10 seconds.

**Output impedance:** Balanced 120Ω

**Balance Adjustment:** 0Ω to 120Ω

**Update Rate:** Once per second.

**Power Down:** Automatic after 5, 10 or 15 minutes with no key press, user selectable.

**Backlight:** Stays on for 1, 2 or 5 minutes when activated, user selectable.

**Communications Port:** RS-232C compatible
1 start bit, 8 data bits, 1 stop bit and no parity, 9 600 baud standard

**Batteries:**
Eight LR6 (AA) type batteries, manganese-alkali or nickel-cadmium or nickel-metal-hydride cells.

**Nominal voltage:** 12V for Alkali or 9.6V for NiCad and NiMH.

Low battery warning occurs at 9.4V (alkali) and 8.56V (rechargeable).

Battery consumption 150mA nominal, 240mA with backlight (10/20 hours continuous use depending on backlight dependency)

**Safety:**
This instrument meets the safety requirements of IEC 61010 part 1 to 150V cat III. If it is to be used in situations where hazardous live voltages may be encountered then an additional blocking filter must be used.

**EMC:**
Complies with Electromagnetic Compatibility Specifications (Light industrial)
BS/EN50081-1-1992
BS/EN50082-1-1992

**Mechanical**
The instrument is designed for use indoors or outdoors and is rated to IP54.

**Case Dimensions:** 250 mm long
200 mm wide
110 mm deep

**Instrument weight:** 1.5kg (3.3lbs)

**Case material:** ABS

**Connectors:** Two pairs of 4mm safety terminals.
9 way D-type connector for serial communication.

**Display:** 256 x 128 pixel Graphics LCD.

**Environmental**

| | |
|---|---|
| Operational Temperature: | -15°C to +50°C (5°F to 122°F) |
| Storage Temperature: | -20°C to 70°C (-4°F to158°F) |
| Operational Humidity: | 95% at 40°C (104°F) |

**Included Accessories**

| | |
|---|---|
| Test and carry Pouch | 6420-114 |
| Miniature Clip Test Lead Set | 6231-654 |
| Carry Strap for Pouch | 6220-611 |
| User Guide | 6172-446 |

**OptionalAccessories**

| | |
|---|---|
| Blocking Filter | 6220-669 |

# Repair and Warranty

The instrument contains static sensitive devices, and care must be taken in handling the printed circuit board. If an instrument's protection has been impaired it should not be used, but sent for repair by suitably trained and qualified personnel.

The protection is likely to be impaired if for example; it shows visible damage; fails to perform the intended measurements; has been subjected to prolonged storage under unfavourable conditions, or has been subjected to severe transport stresses.

**NEW INSTRUMENTS ARE GUARANTEED FOR 3 YEARS FROM THE DATE OF PURCHASE BY THE USER.**

NOTE: Any unauthorized prior repair or adjustment will automatically invalidate the Warranty.

**INSTRUMENT REPAIR AND SPARE PARTS**
For service requirements for MEGGER Instruments contact:

**AVO INTERNATIONAL** or **AVO INTERNATIONAL**

Archcliffe Road
Dover
Kent, CT17 9EN.
England.

Tel: +44 (0) 1304 502243
Fax: +44 (0) 1304 207342

Valley Forge Corporate Centre
2621 Van Buren Avenue
Norristown, PA 19403
U.S.A.

Tel: +1 (610) 676-8579
Fax: +1 (610) 643-8625

For sales Contact: MeterCenter (800) 230-6008 www.MeterCenter.com

**Approved Repair Companies**

A number of independent instrument repair companies have been authorised for repair work on most **MEGGER** instruments, using genuine **MEGGER** spare parts. Consult the Appointed Distributor/Agent regarding spare parts, repair facilities, and advice on the best course of action to take.

**Returning an Instrument for Repair**

If returning an instrument to the manufacturer for repair, it should be sent freight pre-paid to the appropriate address. A copy of the invoice and of the packing note should be sent simultaneously by airmail to expedite clearance through Customs. A repair estimate showing freight return and other charges will be submitted to the sender, if required, before work on the instrument commences.