

# Model R1L-C Series (R1L-C, R1L-CR, R1L-CRA, R1L-CR+62.5) Ground Resistance Test System

## Operation and Maintenance Manual



PN# R1L-C-900-01  
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REV. D

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## SECTION 1

### INSTRUMENT DESCRIPTION

#### INTRODUCTION

##### 1.1 Purpose

The TEGAM R1L-C is a portable ground resistance ohmmeter designed to measure grounding system resistance as well as soil resistivity over ranges from 2  $\Omega$  to 20 k $\Omega$  full scale. Normally, four-point measurements are utilized in order to eliminate any errors caused by the resistance of the leads. Two or three-point measurements may be made, with additional errors on the low resistance ranges caused by the resistance of the test leads. Two leads are used to pass a regulated constant AC current through the resistance under test and two separate leads are used to measure the resulting voltage drop across this resistance. By use of Ohm's Law (Voltage = Current X Resistance), the resistance is automatically calculated and displayed digitally.

The current is well regulated and is constant despite large changes in the unknown resistance and/or the resistance of the connecting leads. If the series resistance is too high for proper performance, a minus sign is displayed (except that on Range 1, the unit will automatically step to Range 2, which can handle greater series resistance). The resistance of the voltage leads can be as high as 20 k $\Omega$ , with no appreciable error in the readings because of the extremely high resistance of the voltage amplifier circuit. However, if this resistance should get high enough to cause errors, a plus sign is turned on in the display and operation ceases. If power-line noise voltage is high enough to cause reading errors, colon signs are turned on to indicate this condition.

## 1.2 Performance Characteristics

This is an automatic range-selection instrument, with manual over-ride of one range step.

Range	Full Scale ( $\Omega$ )	Resolution ( $\Omega$ )	Test Current Peak (mA)	Test Voltage Peak (mV)	Amplifier Gain
1	1.999	1 m	40	80	100X
2	19.99	10 m	4	80	100X
3	199.9	100 m	4	800	10X
4	1999	1	0.4	800	10X
5	19990	10	0.4	8.0	1X

Table 1: Specifications

**Accuracy:** 1.999  $\Omega$  Range:  $\pm 1\%$  of reading + 2 digits.  
All other ranges:  $\pm 2\%$  of reading + 2 digits.

Although the ranges are listed in the sequence of 1, 2, etc., the unit actually starts on range 5 and looks at the voltage signal coming into the  $\pm V$  terminals. If this voltage is too low (less than 10% of full scale), it automatically down-ranges to Range 4, etc. As shown in the above chart, there are three current settings and three amplifier gain settings to cover the 2  $\Omega$  to 20 k $\Omega$  full scale limits. If, for some reason, the reading exceeds approximately 1.950, the unit will automatically Up-Range to the next higher range, where it will read (blank) 1.95; the decimal point moves automatically with the range selected.

The Constant-Current AC Test Current is a 25.6 Hz square wave on all ranges. The values listed above are nominal values, with an accuracy of  $\pm 5\%$ ; the same accuracy applies for the test signal voltage. These accuracies do not affect the overall system accuracy (listed above), because other circuits are trimmed to ensure overall system accuracy.

The constant-current supply is regulated DC constant current at 40, 4, and 0.4 mA. It is then switched by an AC-operated

bridge to reverse the current flow, providing 80 mA<sub>p-p</sub>, etc. Power is from 35 V. However, some of this is used for a 2.5 V reference and three series diodes; so approximately 30 V is available to conduct current through the earth via the  $\pm$  I terminals. Thus, this unit can supply a constant current of 40 mA even if the series resistance is as high as 750  $\Omega$ .

If the series resistance exceeds 750  $\Omega$ , the constant current will be less than 40 mA, reducing the  $I \times R$  voltage signal. To compensate for this possibility, the digital voltmeter is actually a ratio meter, with the test voltage signal being in the numerator and a separate  $I \times R$  signal in the denominator. Thus, as the current decreases, both the numerator and the denominator decrease at the same rate; so the reading (ratio) remains unchanged.

As both signals decrease, although the ratio remains constant, the effects of noise will increase. Therefore, the circuit is designed so that when the current has dropped to half of its normal value, a minus sign will show on the display, indicating that the resistance in series with the current electrodes is excessive for accurate readings. When operating on Range 1 (40 mA), the unit will automatically switch to Range 2 (4 mA), which will tolerate a much higher series resistance.

Thus, this unit will operate successfully with greater than 1.5 k resistance in series with the current electrodes on the 2  $\Omega$  range. Since the current on Range 2 is 4 mA, the unit will operate satisfactorily with greater than 15 k $\Omega$  of resistance in series with the current electrodes.

This unit will operate over a temperature range from -30 to 55 °C. Damage will not occur with storage from -51 to 71 °C. This unit will comply with the requirements of MIL-PRF-28800F for Class 2.

**LCD Indicators:**

MINUS sign: The minus sign displays excessive resistance in series with the current electrodes. If series resistance exceeds:

When Operating in Range	R1L-C Tolerates Series Resistance of
1	>1.5 k $\Omega$ (Automatically steps to range 2)
2	>15 k $\Omega$ (Will not change range)
3	>15 k $\Omega$ (Will not change range)
4	>150 k $\Omega$ (Will not change range)
5	>150 k $\Omega$ (Will not change range)

Note that there are limitations to the performance of this and other similar instruments; they cannot operate in very high resistivity soil, such as dry sand.

PLUS sign: The plus sign is turned on automatically if the resistance in series with the potential electrodes is so high as to cause an appreciable error in the reading. On all ranges, the plus sign will show if resistance is 20 k $\Omega$  or more.

ARROW: The arrow is turned on to indicate low battery voltage (less than 4.6 V).

COLONS: Excessive stray current levels (5 V<sub>P-P</sub>)



### 1.3 Description of Equipment

**Physical:** A rugged heavy-duty case is provided to contain and protect the instrument. When closed, a gasket seals the lid to protect the instrument against water and dirt while the instrument is carried through rainstorms or other hazardous conditions. When the lid is open, for operation, a second gasket provides additional protection. Feet are molded into the bottom of the case and projections provide for stacking several units high during temporary storage. The power cord used to recharge the batteries is normally stored in the accessory case.

Dimensions of the case are 14" x 10.6" x 6.5". Weight is 8 pounds.

With the lid open for operation, the front panel and its controls are readily accessible. The front panel is aluminum with durable markings embedded in the surface of the panel. Controls and connectors may be operated while wearing safety gloves.

**Electrical:** Power is from four rechargeable Ni-Cad C-cells, rated at 3000 mAh each, series connected. Nominal voltage is 1.2 V each, totaling 4.8 V. Current drain varies with range, but is typically less than 500 mA, providing at least four hours operation when fully charged. Charge current is set at approximately 300 mA. This battery may be re-charged from external 12-28 VDC connected to the binding posts so marked, or from 103.5-126.5 VAC at 50 or 60 Hz via the line cord plugged into the front panel AC receptacle. When connected to external DC or AC power, the battery charges automatically until fully charged. The battery will be fully charged (from a discharged condition) in less than 14 hours, permitting operation for at least four hours of normal operation. Recharge when an arrow shows on display.

Charging current required from a 12-28 VDC supply is 300 mA. Charging power consumption from nominal AC power line is less than 10 W.

## Front Panel Controls and Displays (See figure 5)

### CAUTION

**This instrument is to be operated from battery power only, and not from the AC or DC charging power or damage to the instrument may result.**

**TEST pushbutton**, actually the "POWER ON" pushbutton, is a round sealed switch. This pushbutton switch turns on the power to the unit.

**Manual RANGE UP AND RANGE DOWN** pushbuttons are square sealed switches. Note that the unit selects the proper range automatically, but there may be situations in which the operator wishes to move up or down by one range.

**DISPLAY** is a 3½ digit LCD with decimal points, reading from 1.999 to 19990  $\Omega$  full scale.

### NOTE

**On the 19,990  $\Omega$  range, the last digit is displayed as a zero only, in order to have the display read directly in ohms; it does not count as a digit.**

**LOW BATTERY** is indicated by a flashing arrow, which is part of the display.

**Excessive stray current**, typically power line noise, is indicated by flashing colons on the display.

**Excessive current electrode resistance** is indicated by a minus sign and excessive potential electrode resistance is indicated by a plus sign.

**A front panel light-emitting diode** indicates that the battery is being charged.

**Four binding posts** for connection of test leads, with a shorting bar to connect the -I and -V posts, when required.

**Two binding posts** for connection of 12-28 VDC to charge the batteries.

## 1.4 Accessory Kit

Each Model is shipped with the following accessories:

- One pair electrical safety gloves, consisting of an inner rubber voltage protection glove and an outer leather glove to protect against cuts and tears.
- Two spools of 250 ft. 18 AWG lead, on a windable take-up spool assembly with large removable test clip installed on the end (see figure 8). Only one spool of 105 ft. 14 AWG with the R1L-CR+62.5
- Two (One with the R1L-CR+62.5 with 14 AWG) 18" 18 AWG length of wire to terminate with spade lugs to connect the spool assemblies to the instrument.
- Two spools of 75 ft. 18 AWG lead, each with a small test clip on one end and a spade lug on the other end, wrapped around a plastic holder. Only one spool of 65 ft. 14 AWG with the R1L-CR+62.5
- One 6 ft. shorting wire (only with the R1L-CR+62.5)
- A set of four stainless steel ground rods, with helix for easy insertion into earth. (Not provided with R1L-CR) Only 2 rods are provide with the R1L-CR+62.5
- One accessory carrying case consisting of rugged waterproof label, firmly attached to the case, lists the inventory of all accessory items, the line cord and batteries.



Figure 1: Accessory Kit

## 1.5 List of Items Furnished

- 1 each Model R1L-C or R1L-CR or R1L-CRA or R1L-CR+62.5 with power cord and batteries.
- 1 each Instruction Manual.
- 1 each Accessory Kit, as listed in Section 1.4 above.

## 1.6 Tools and Test Equipment Required for Maintenance

- Soldering iron, solder, Phillips No. 2 screwdriver and a small flat-bladed screwdriver.
- Test equipment: See Section 4.3, below.

## 1.7 Storage and Shipping Requirements

- The R1L-C should be stored in a relatively dust free environment.
- Temperature: -51 to +71 °C.
- Relative humidity: 0 to 100%, non-condensing.
- See Section 4.7 below for shipping requirements.

## SECTION 2

### PREPARATION FOR USE AND INSTALLATION

#### 2.1 Unpacking and Inspection

Upon receipt, the R1L-C and its accessory kit should be carefully unpacked and removed from the shipping container. Separate the units from the packing material and inspect both the instrument and the accessory kit for any external damage.

- If any dents, broken, or loose parts are seen, do not use the equipment. Notify the shipping company immediately and follow their instructions as to how to proceed.
- Note that the instrument is shipped with its battery removed. Unwrap the four NiCad C-cells which comprise the battery.
- Open the accessory kit and check the contents against its inventory label. If any items are missing, notify the shipper, if this is a new instrument. If not new, contact the previous user to locate the missing items.

Release the two latches which secure the lid of the instrument and open the lid. Since the lid is well sealed, it may be difficult to open, if there is an appreciable difference between internal and external air pressure.

Inspect the front panel for any loose or broken parts. If any are found, notify the shipping company immediately and follow their instructions as to how to proceed.

## 2.2 Preparation for Use

Remove the ten screws around the outside edge of the panel which secure the instrument to the case. These screws are labeled # 9B on Drawing 13185 (Figure 6). The instrument may now be lifted out of the case by holding the binding posts on both sides of the panel.

Install the four C-cells in their holder at the bottom of the instrument; be sure to install them with the correct polarity, as marked on the holder. While installing the cells, rotate them slightly to ensure connection to the holder contacts. After installing the battery, reinstall the instrument in its case and secure the ten mounting screws.

To charge the battery before use, use either the power cord supplied, with a source of 103.5-126.5 V at 50-60 Hz, or connect 12-28 VDC to the marked binding posts. Note that an internal diode protects against damage caused by wrong polarity; however, polarity must be correct to charge the battery. Allow 14 hours for a full charge. After charging, remove the power line cord and return it to its protective bag (or disconnect the 12-28 VDC); the unit is now ready to use. Note that no harm will result if both AC and DC power are applied simultaneously.

## SECTION 3

## OPERATING INSTRUCTIONS

The R1L-C is designed for bench-top or field operation. Use the four cables (available from TEGAM), connecting their spade lug terminations to the four binding posts marked +I, +V, -V, and -I. Set the shorting bar so that it does NOT connect -I to -V, unless you plan to make two or three-terminal measurements. Note that the test current is actually AC and the + and - indications are used only to signify HIGH and LOW, as well as to indicate that the +V and +I go together and the -V and -I go together. See Section 3.1 for application information for measuring ground resistance and/or soil resistivity.

**CAUTION**

**Although the front panel is normally grounded via the ground pin of the power cable, if this connection is faulty, and if the high side of the power cable is shorted to the panel, the panel could possibly have 115 VAC on it.**

**CAUTION**

**Do not operate this instrument without its internal battery. AC and DC power are to be used only to charge the battery, not for operation of the instrument. Do not depress the TEST pushbutton while the AC line cord is connected to AC power or when the 12-28 VDC power source is connected. Doing this may damage the instrument, if the battery is not installed.**

The Large Wire Spool is built with a supporting bracket and handle and a knob for rapid rewinding of the cable. When rewinding rapidly, the short connection wire connected to the inside of the reel may spin rapidly, causing a problem. In order to avoid this, you may disconnect this short connection wire by loosening the wing nut which keeps it attached to the reel. After winding (or unwinding), reattach this wire, tightening the wing nut securely.

**WARNING**

**Do not touch the binding posts when they are connected to ground electrodes. LETHAL voltages may be present on these posts.**

Operation of the instrument is essentially automatic and extremely simple. There are only three operating controls, and only one of them is used for most operations.

The TEST pushbutton turns on the power to operate the unit. When this button is released, power is shut down. During operation, the unit automatically selects the proper range, starting with the highest (20 k full scale) and working down sequentially to the lowest (2  $\Omega$  full scale). If the measured resistance changes during operation, the unit will automatically track it, up or down. Note that it takes approximately five seconds to settle to the final reading.

Full scale on any range may be described as 2000 (actually 1999) counts, since this is a 3 ½ digit meter. Note that on Range 5, an additional zero is displayed for full scale readings of 19,990  $\Omega$ . This is not an active digit, since it does not change; it functions only to locate the decimal point in its proper location. The display is still basically a 2000 count display, not 20,000 counts.

If the unit sees readings exceeding approximately 1950 counts, it will automatically step to the next higher range, reading 195 counts. If it sees readings less than approximately 150 counts, it automatically steps down a range, so that it will read 1500 counts. Of course, the decimal point is located automatically for the correct reading.

The UP and DOWN pushbuttons will step up or down a single step to the next range. After stepping one step, the range-changing circuits are locked out to prevent repeated hunting between two ranges. To restore the automatic range-changing capability, it is necessary to release the TEST pushbutton, and then depress it again, to restart the operation.



Note that the 1.999  $\Omega$  full-scale range will operate with a maximum current electrode resistance of approximately 1.5 k. If the resistance is greater than that, it will automatically step up to Range 2, which will operate with 15 k in series with the current electrode.

### 3.1 MEASURING GROUND RESISTANCE AND SOIL RESISTIVITY

#### **WARNING**

**Testing of grounds can involve a possible hazard to the operator such as from a difference in potential caused by a return current to the ground under test, and induced voltages in the long wire test leads. The operator should wear electrician's safety gloves consisting of an insulating rubber inner glove and a leather outer glove. Testing should also not be done when there is lightning in the vicinity.**

#### Measuring Ground Resistance

##### Measurement Theory

A three-point measurement is used to determine the resistance to ground of ground rods and ground grids. The ground under test and an auxiliary electrode, spaced a distance from the ground under test, are energized by a constant current. The potential is then measured between the ground under test and a second auxiliary electrode spaced along a line between the ground under test and the energizing constant current auxiliary electrode. Utilizing the measured potential, the known test current, and Ohm's Law, the resistance to ground of the ground under test can be calculated.

##### A. 62% Measurement Method

In measuring the ground resistance, the electrodes need to be spaced far enough apart so that the auxiliary potential measurement electrode is outside the effective resistance areas of the ground under test and the auxiliary current supplying electrode. If the electrode effective resistance areas overlap, an accurate reading of the ground resistance

will not be obtained.

Electrodes should be spaced as far as practical with wire lengths and the site. Methodology has been developed, which given that the ground under test and auxiliary electrodes are spaced sufficiently apart and in a straight line, indicates that the auxiliary potential measuring electrode should be placed at 62% of the distance between the ground under test and the auxiliary current supplying electrode, referenced to the location of the ground under test. Refer to Figure 2. For testing a single ground electrode, the auxiliary current supplying electrode can usually be located about 50 feet from the ground under test, and the auxiliary potential measuring electrode located about 31 feet from the ground under test. For testing a small grid of two ground or earth electrodes, the usual corresponding distances are to 125 feet from the ground under test for the auxiliary current supplying electrode, and 62 to 78 feet from the ground under test for the auxiliary potential measuring electrode. Factors such as the diameter of the ground electrode under test, length of the ground electrode under test, soil homogeneity, and effective electrode resistance areas affect the needed electrode separation. For ground or earth electrode systems consisting of several rods, or plates, etc., separation distances increase. The table below is a guide to approximate auxiliary electrode placement. The above distances and those in the table below are taken from the booklet "Getting Down To Earth" from James G. Instruments, Blue Bell, Pennsylvania. The "Maximum Dimension" figure in the table is calculated by taking the diagonal distance across the ground under test electrode system. For example if the ground under test electrode system measures 10 feet by 10 feet, the diagonal is about 14 feet. Reading the "Maximum Dimension" column of the table, it can be seen the usual separation distances from the ground under test are 120 feet for the auxiliary potential measuring electrode and 190 feet for the auxiliary current supplying electrode. Consult appropriate reference material for ground electrode systems with intermediate or larger dimensions.

Maximum Dimension	Distance to +V	Distance to +I
2	40	70
4	60	100
6	80	125
8	90	140
10	100	160
14	120	190
20	140	220
40	200	320

All dimensions are in feet

Use of the TEAGM Model R1L-C

**WARNING**  
**Do not disconnect the ground of an energized circuit.**

1. Disconnect the supplied shorting bar and any other wires between terminals of the R1L-C.
2. Connect one of the supplied lead wires (short length suggested) between the terminal of the R1L-C and the ground to be measured, using the spade lug at the binding post of the R1L-C.
3. Connect one of the supplied lead wires length suggested between the terminal of the R1L-C and the ground to be measured, using the spade lug at the binding post.

**NOTE**  
**If the operator uses the shorting bar between the R1L-C terminals and only connects one lead wire to the ground to be measured, the reading obtained with the R1L-C will include the resistance of this lead wire, indicating a higher than actual ground resistance value.**

4. Insert the supplied auxiliary potential measurement electrode and auxiliary current supplying electrode into the ground in a straight line with respect to the ground under test at the proper spacing. The auxiliary electrodes have threaded ends to make insertion easier, and should

be inserted to about below the wing nut.

5. Connect one of the supplied lead wires between the +I terminal of the R1L-C and the farther current supplying auxiliary electrode, using the spade lug at the binding post of the lead wire test clip can be placed around the auxiliary electrode rod directly behind the screw, washer, and wing nut assembly, so that the clip jaws grab between the rod and washer. Avoid having the large clip grab on the screw threads. The large test clips on the two supplied longer leads with take-up reels are removable, if desired, for a spade lug connection to the auxiliary electrode rods via the threaded screw, washer, and wing nut assembly.
6. Connect one of the supplied lead wires between the terminal of the R1L-C and the closer potential measurement auxiliary electrode.
7. Depress the TEST switch and read the LCD for a ground resistance reading. Refer to the relevant manual section concerning any outside of range or error conditions.

#### B. Two-Point Simplified Measurement

This is an alternate method to a three-point measurement, and should be used only when there is an excellent ground already available. In areas where there is insufficient space to utilize the two auxiliary electrodes for a three-point measurement, the two-point measurement method may be applied. The reading obtained will be that of the already established excellent ground and the auxiliary electrode ground in series. The already established ground rod or water pipe, etc. must be of very low resistance, so that this resistance is negligible in the two-point measurement. Lead resistances also need to be measured and deducted from the test measurement. The two-point measurement is affected by the distance between the already established ground and the driven test auxiliary electrode. This method should not be used as a standard procedure, but only when space prevents a three-point measurement.

1. Connect the supplied shorting bar between terminals –I and –V of the R1L-C

2. Connect the +I and +V terminals of the R1L-C together with a short piece of wire.
3. Connect one of the supplied short lead wires between the –I terminal of the R1L-C and the ground rod or conductor to be measured, using the spade lug at the binding post of the R1L-C.
4. Insert one of the optional auxiliary electrodes into the ground at the maximum practical separation from the ground rod or conductor to be measured. The depth of insertion should be to about one inch below the wing nut.
5. Connect one of the supplied lead wires between the +I terminal of the R1L-C and the auxiliary electrode. Refer to Section 1.3 for more detailed connection information. To eliminate the possibility of a changing contact resistance between the test clip and auxiliary electrode rod, it is recommended the large test clip be removed when using the longer supplied lead wires in a two-point measurement, and that connection be made to the auxiliary electrode rod via spade lug at the wing nut.
6. Depress the TEST switch and read the LCD for a resistance reading. Refer to the relevant manual section concerning any outside of range or error conditions. Measure the resistance of the connection leads and subtract them from the reading in section to obtain a ground resistance value.

## Measuring Soil Resistivity

### Measurement Rationale and Theory

Soil resistivity measurements are made to obtain data for the design of grounding systems, where it is desirable to locate the area of lowest soil resistance for the most economical grounding system; to acquire data on geological factors below the surface; and as an aid in gauging corrosion (decreased resistivity implies an increase in corrosion activity).

The R1L-C uses a four-point measurement (Wenner) method to determine soil resistivity. This method requires the insertion of four equally spaced electrodes in a straight line. (Refer to figure 3). A known constant current is applied between the two outermost electrodes. The potential developed between the two inner electrodes is then measured, and Ohm's Law is used to obtain a resistance reading for the soil of interest. Once a likely area for investigation is determined, the test operator may wish to make measurements in a grid pattern.

The resistance measured relates via a known formula to the average resistivity of the ground at a depth equivalent to the separation between two electrodes, with the electrodes at a known depth if the electrode separation is at least 20 times the electrode depth, utilizing the measured resistance  $R$  in  $\Omega$ , the formula can be reduced to:

$$\text{Soil Resistivity (ohm-cm)} = 2\pi AR, \text{ if } A \text{ is in cm} \\ 191.5AR, \text{ if } A \text{ is measured in Feet} \\ R \text{ is resistance measured by the R1L-C in } \Omega$$

This resistivity is the average resistivity of the ground at a depth equivalent to the distance between two electrodes.

### Use of the TEGAM Model R1L-C Series

1. Disconnect the supplied shorting bar and any other wires between terminals of the
2. Insert the electrodes (the ends are threaded for easier

penetration) into the ground in a straight line with equal spacing between each electrode, with the spacing distance determined by the depth of the soil sample of interest, and to a depth not exceeding 1/20 of the separation. For example, if the electrode spacing is 10 feet, insert the electrodes to a depth not exceeding 6 inches (1/2 ft.).

3. Connect a lead wire (short length suggested) between the  $-I$  terminal of the R1L-C and the closest electrode, using the spade lug at the binding post of the R1L-C. The lead wire test clip can be placed around the auxiliary electrode rod directly behind the screw, washer, and wing nut assembly, so that the clip jaws grab between the rod and washer. Avoid having the large clip grab on the screw threads. The large test clips on the two supplied longer leads with take-up reels are removable, if desired, for a spade lug connection to the auxiliary electrode rods via the threaded screw, washer, and wing nut assembly.
4. Connect a lead wire between the  $-V$  terminal of the R1L-C and the next closest electrode.
5. Connect a lead wire between the  $+V$  terminal of the R1L-C and the third farthest electrode.
6. Connect a lead wire between the  $+I$  terminal of the R1L-C and the farthest electrode.
7. Depress the TEST switch and read the LCD for a resistance reading. Refer to the relevant manual section concerning any outside of range or error conditions.
8. Calculate soil resistivity per the formula given in Section 'Measuring Soil Resistivity.'

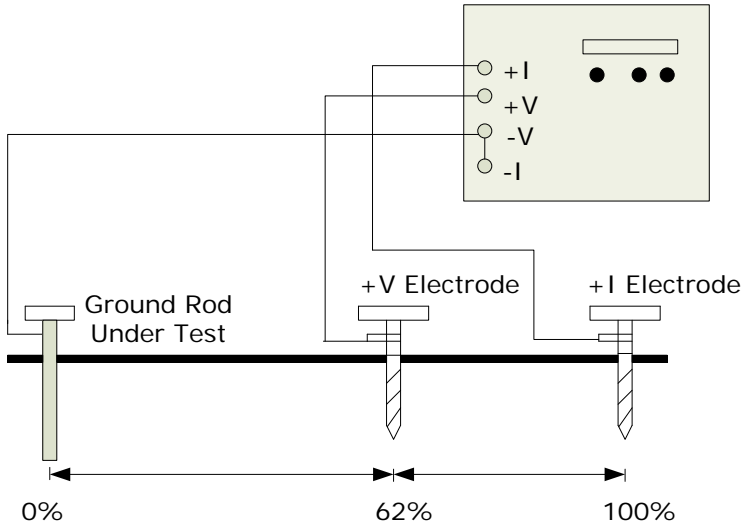


Figure 2: Ground Resistance Configuration

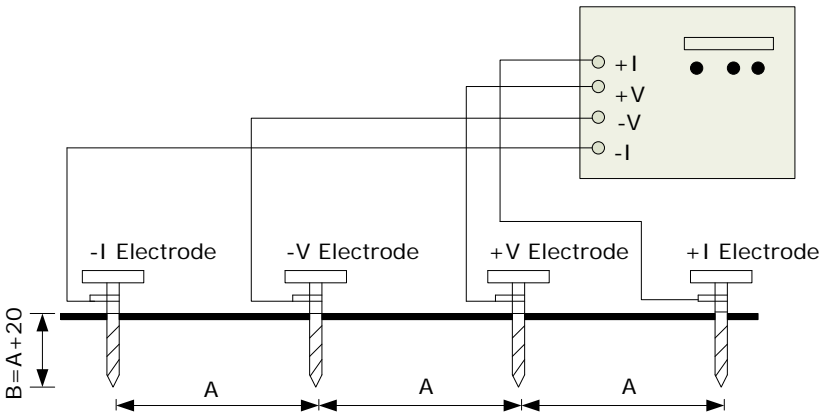


Figure 3: Soil Resistivity Configuration



## SECTION 4

### MAINTENANCE

#### 4.1 Inspection

These units should be inspected semi-annually. Check that the case opens and closes with no binding. Check that the three pushbuttons rate smoothly. Check all six binding posts to ensure that they operate smoothly.

#### 4.2 Cleaning

The instrument should be cleaned periodically, as is necessary, using mild soap and a damp cloth both on the outside of the case and on the front panel. No lubrication is required. The stainless steel ground electrodes should be cleaned after each use, with particular attention to the wing-nut connection area.

#### 4.3 Test Equipment Required for Calibration and Repair

Calibration of the R1L-C is recommended on a yearly basis, and is done at a temperature of  $23 \pm 1$  °C.

Digital multimeter: 4 ½ digits minimum, with 19.999 V and 0.19999 A ranges. Accuracy: 0.02%, or better. Hewlett-Packard Model 34401A or Keithley Model 2000, or equal, are suggested.

Oscilloscope: 5 mV/div. sensitivity, 20 MHz minimum bandwidth. Tektronix Model 2205, or equal, is suggested.

Precision decade resistor box: Settable to 19,999.9  $\Omega$ , with accuracy better than 0.1%. PPM Model R6-111, 111 k is suggested. Power Supply, 50 V, 1.5 A. PPM Model PPS-50-1.5 is suggested.

#### 4.4 Performance Verification and Calibration

1. Connect the four binding posts to the precision decade resistor box. +I and +V to one end of the box; -I and -V to the other end.
2. Set the resistor box to 1  $\Omega$  and operate the TEST pushbutton. Check that the instrument reads within  $\pm 1\% + 2$  digits of the calibrated resistor box resistance value.
3. Set the resistor box to 10  $\Omega$  and operate the TEST pushbutton. Check that the instrument reads within  $\pm 2\% + 2$  digits of the calibrated resistor box resistance value.
4. Repeat for 100  $\Omega$ , 1 k and 10 k $\Omega$ .

#### **WARNING**

**Disconnect the AC power cable and disconnect the 12-28 VDC power source before removing this instrument from its case. Lethal voltages are present with AC power connected.**

Also, never operate this instrument from the AC or DC power. They are to be used only to charge the battery.

There are three jumpers, as listed below, which are moved to facilitate certain steps of the calibration. Note their normal positions, and check that they are returned to these positions before closing up the instrument.

J1001: Normally jumpered between pins 1 and 2. If moved to jumper pins 2 to 3, the TEST pushbutton is bypassed and power stays on indefinitely.

J701: Normally jumpered. Remove, when so indicated in the calibration procedure.

J702: Normally jumpered between pins 1 and 2. To bypass the temperature compensation circuit, move to jumper pins 2 to 3.

## 4.5 Calibration

1. Remove the ten mounting screws as in Section 2.2 above and remove the instrument from the case.
2. Low Battery Indication  
Replace the battery with a power supply set to 4.4 V. Clip the power supply leads to the + and – battery holder terminals, observing proper polarity. Depress the TEST pushbutton and adjust R605 for an arrow on the display. Then set the power supply to 5 V for the remaining calibration.
3. Constant Current Generator  
Connect a 1.000  $\Omega$  resistor with one end tied to the +I and +V binding posts and the other end tied to the -I and -V binding posts. Depress the TEST push button and record the reading on the display.  
Change the 1.000 resistor to 10.00  $\Omega$ . Depress the TEST pushbutton and adjust R109 (for location, see the parts layout drawing 13016) for the same reading (disregarding the decimal point) on the display. Change the 10.00  $\Omega$  resistor to 100.0  $\Omega$ , depress the TEST pushbutton and record the reading. Change the 100.0  $\Omega$  resistor to 1000  $\Omega$  and adjust R107 for the same reading (disregarding the decimal point).
4. CMV Reject Circuit  
Connect a 1.000  $\Omega$  resistor with one end tied to the +I and +V binding posts and the other lead to the –I and –E binding posts. Depress the TEST pushbutton and note the reading on the display. Disconnect the 1.000  $\Omega$  resistor from the + I binding post and connect 100  $\Omega$  in series with this lead. Depress the pushbutton and note the reading on the display. If higher than previous reading adjust R305 clockwise until the display reading is the same as the previous reading. If lower, adjust R305 counterclockwise. Repeat until the reading is the same with 100  $\Omega$  in series with the +I lead as with 0  $\Omega$  in series with this lead.

5. DVM Adjustment  
Change the 1.000  $\Omega$  resistor to 10 k, depress the TEST pushbutton and adjust R803 for a reading of 10000.
6. Amplifier Adjustments  
Change the 10 k resistor to 10.00  $\Omega$ , depress the TEST pushbutton and adjust R504 for a reading of 10.00
7. Change the 10.00  $\Omega$  resistor to 100.0  $\Omega$ , depress the TEST pushbutton and adjust R505 for a reading of 100.0.
8. Temperature Compensation Adjustment  
Remove the jumper at J701 to disable the gain compensation/under-range signal. Switch the power off and then back on, and take a reading at TP701. Adjust R711 for a reading of 3% higher at J702 pin 1. Reinstall J701. Then repeat the adjustment of R803, as described in 5 above.

## 4.6 Troubleshooting

### *Assembly*

After removal of the instrument from its case, as detailed in Section 2.2 above, the basic instrument consists of a front panel assembly, a main printed-circuit board assembly, and a power supply and charger assembly.

The main board assembly is mounted onto the front panel by means of 11 threaded spacers, for a very rigid assembly. The power supply and charger assembly is fastened to the front panel by means of 7 long screws which pass through clearance spacers and then through the main board.

A wiring harness is fastened to components on the front panel; it is connected to the main board and to the power supply charger assembly by means of two connectors, so that these two assemblies may be removed easily, without de-soldering.

Fuse holders on the front panel contain fuses for the AC and DC battery charge sources. A double fuse holder is mounted on the back of the power supply and charger. It contains a fuse for the battery circuit and a spare fuse. All fuses are rated at one ampere.

### *Disassembly*

To disassemble, first remove the 7 screws holding the power supply and charger assembly. Carefully, set these screws and the clearance spacers to one side, leaving the cables connected for trouble shooting. To remove the main board, remove the remaining screws holding the board to the panel spacers, also leaving the cables connected for trouble-shooting. You will now have access to all the components. Save all the screws and spacers.

### *Re-assembly*

After trouble-shooting and repair, re-assemble all parts in reverse order from above. Do not tighten the screws until all have been installed, to ensure that all parts are centered properly.

Test with resistors of 1, 10, 100, 1 k and 10 k $\Omega$  using a four-wire hook-up. If all ranges do not operate properly, connect an oscilloscope across the test points TP301 and COMMON (see schematic 13015-3D). The signal at this point, with a 10 k test resistor, should be an approximate square wave of 25.6 Hz. Amplitude should be 160 mV<sub>p-p</sub> on range 1, 1.6 V<sub>p-p</sub> on ranges 2 & 3, and 16 V<sub>p-p</sub> on ranges 4 & 5.

Following are possible symptoms, diagnosis, and repair suggestions for use in trouble-shooting (the most likely causes are listed first). To avoid holding the TEST pushbutton in, move J1001 to connect pins 2 and 3; this will maintain power in the unit.

<b>SYMPTOM</b>	<b>FAULTY COMPONENT</b>	<b>REPAIR</b>
No display	Battery Fuse	Check Battery Fuse
	Battery needs charge	Charge battery
	Battery connection	Check all four cells
	U801 or U901	Replace U801 or U901
	U802	Replace U802
	C802 or R804	Replace C802 or R804
Range 1 inoperative	K101 or K102	Replace K101, K102
	U903	Replace U903
Ranges 1 & 2 not accurate	K501 or K502	Replace K501, K502
	R504 needs trim	Adjust R504
	U903	Replace U903
Ranges 2 & 3 not accurate	K101 or K102	Replace K101, K102
	R109 needs trim	Adjust R109
	U903	Replace U903
Ranges 3 & 4 not accurate	K501	Replace K501
	R505 needs trim	Adjust R505
	U903	Replace U903
Ranges 4 & 5 not accurate	K101	Replace K101
	R107 needs trim	Adjust R107
	U903	Replace U903
Range 5 bad	R502	Replace R502
Auto-ranging bad	U702, U904, U905	Replace U702, U904, U905
Hi potential electrode K502 resistance bad	K502	Replace K502
Hi current electrode resistance bad	U103	Replace U103
Battery won't charge	U101 on Power Supply	Replace U101
	T101 on Power Supply	Replace T101

Table 2: Fault Symptoms and Repair Actions

After trouble-shooting and repair, the instrument must be recalibrated in accordance with 4.5 above.

#### 4.7 Preparation for Shipment

The original shipping carton is not reusable.

The Model R1L-C is a rugged instrument and requires no special covering, preservation, or special cradles. During shipment, packaging must provide sufficient resilient material in accordance with standard packaging practices to prevent excessive shock to the power supply and display.

#### 4.8 Overhaul Instructions

The Model R1L-C is an all solid-state unit and requires no periodic overhaul, other than routine cleaning and inspection, as listed in Sections 4.1 and 4.2 and circuit calibration, described under Section 4.5 above.

However, some disassembly is required to remove and to install the battery. Disassembly instructions may be found under Sections 2 and 4.6 above. Re-assembly instructions are listed in Section 4.6 as well.

Tools required are listed in Section 1.6 and test equipment required is listed in Section 4.3.

Trouble-shooting is listed in Section 4.6.

The only component expected to require replacement is the battery. Battery designation is listed in the Replacement Parts List in Table 4, and installation instructions are listed in Section 2.1.

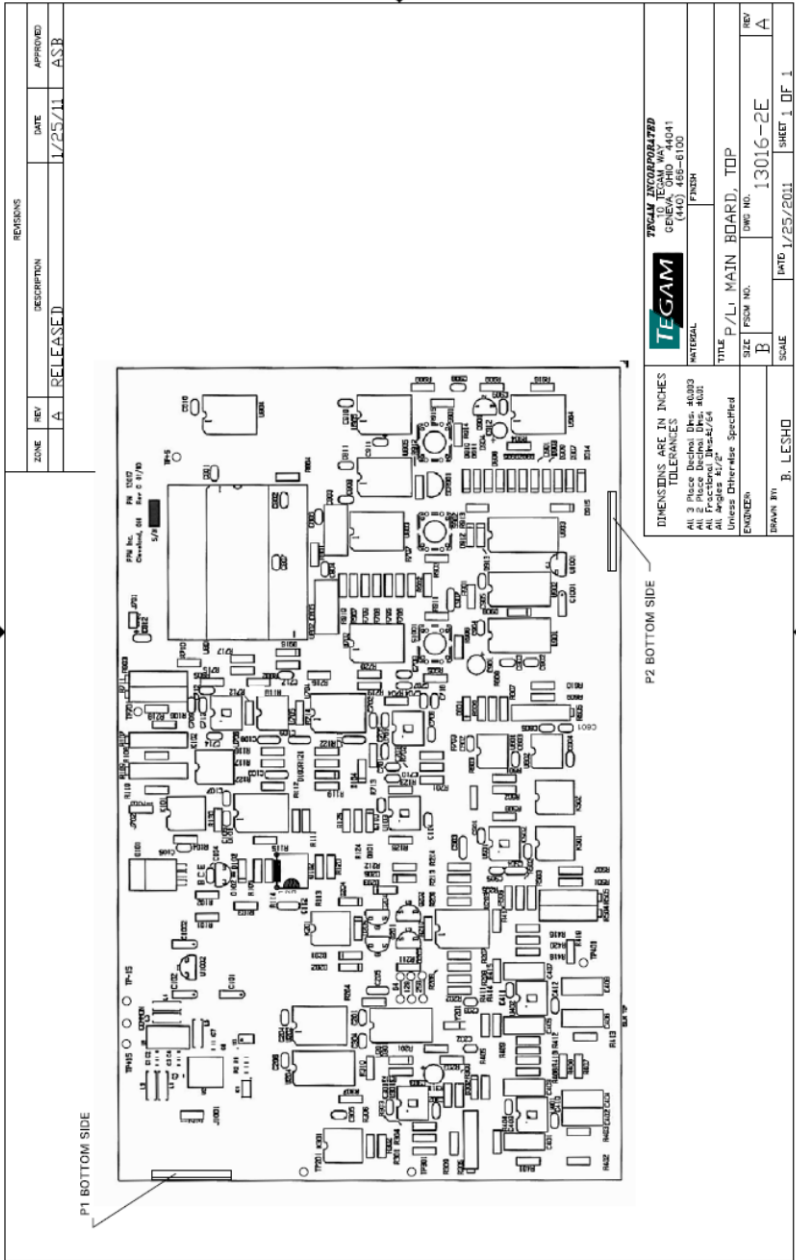


Figure 4: Parts Layout, Main Circuit Board



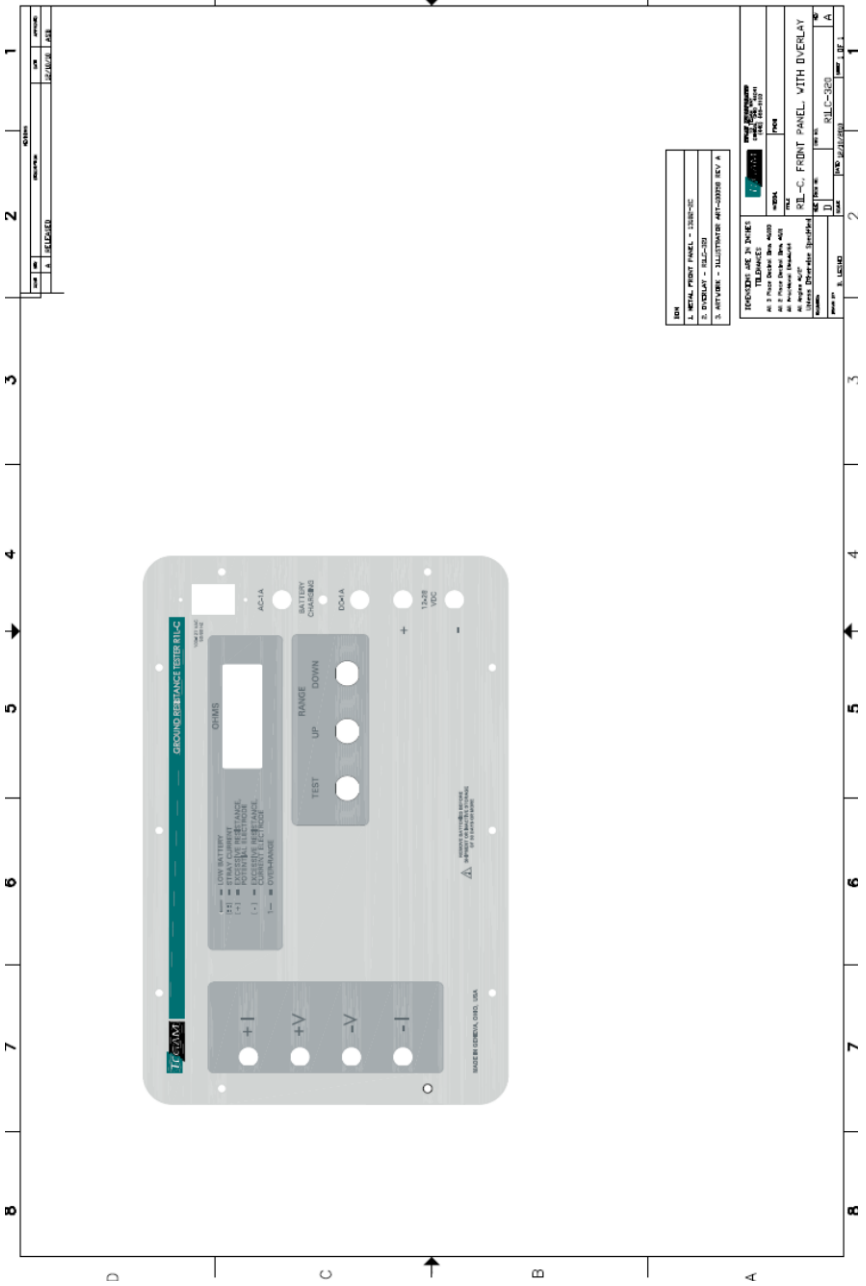


Figure 5: Front Panel Layout

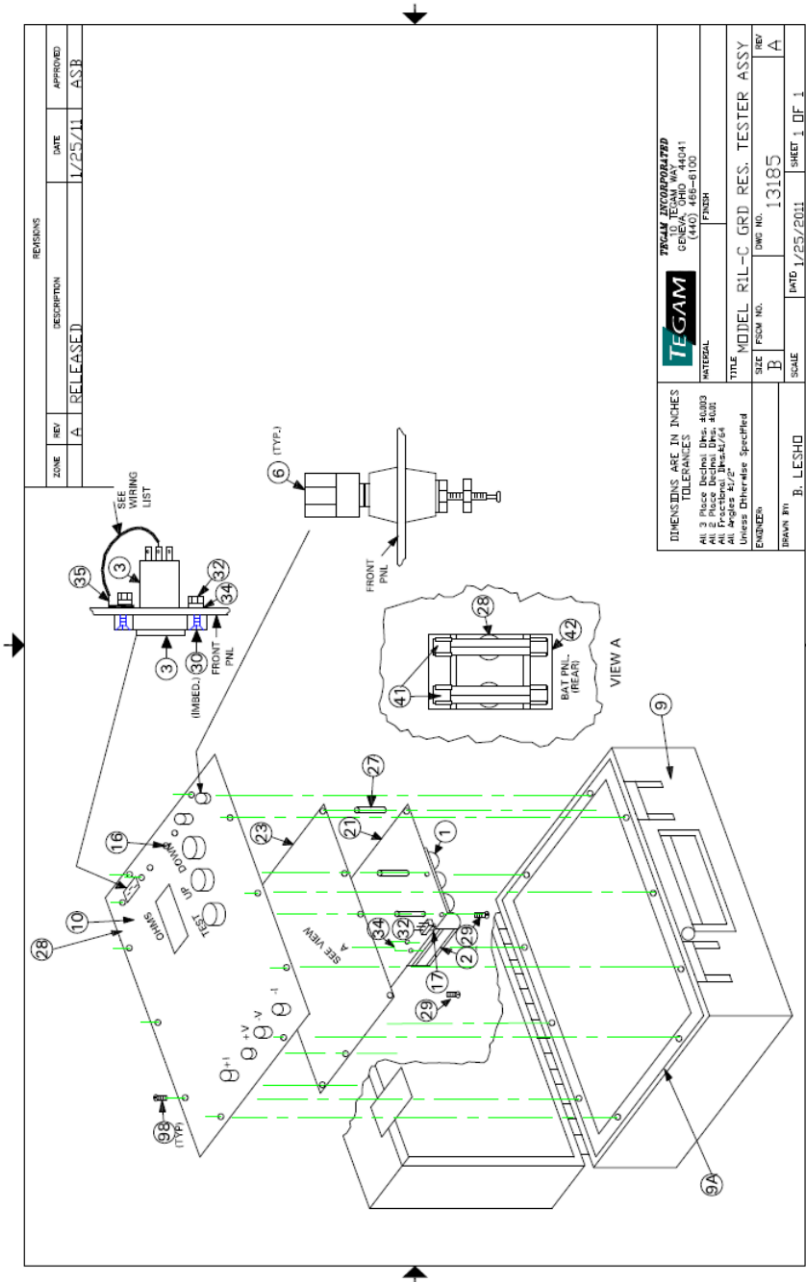


Figure 6: Model R1L-C Assembly Drawing

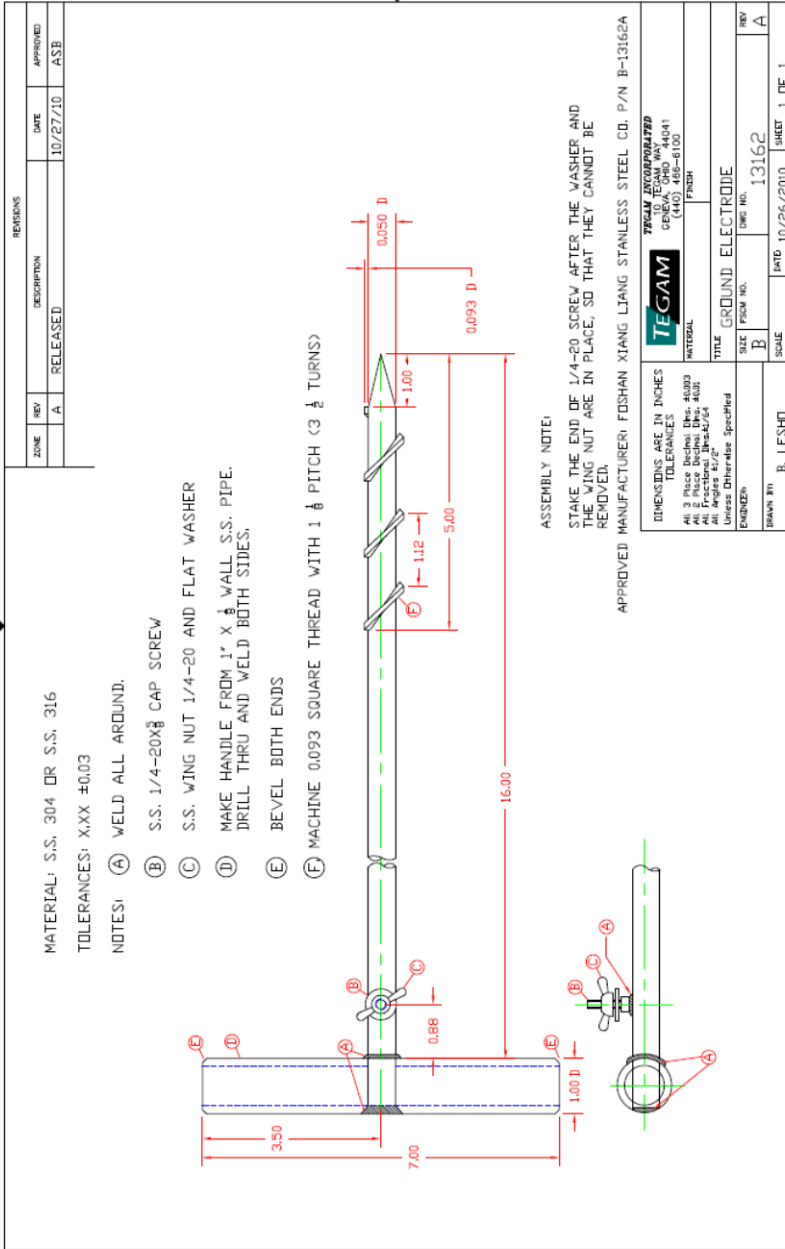


Figure 7: Ground Rod Electrode Drawing

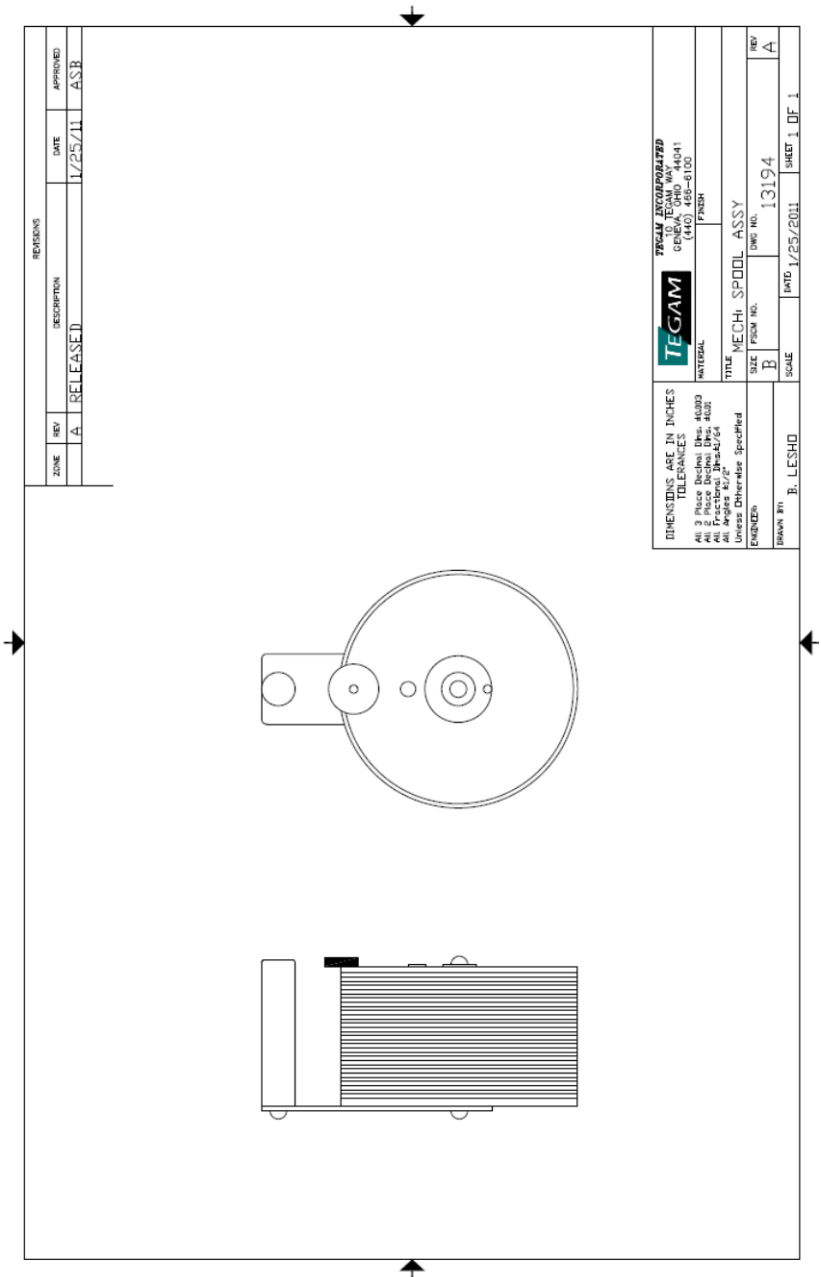


Figure 8: Spool Assembly Drawing

## SECTION 5

### SERVICE INFORMATION

#### Preparation for Calibration or Repair Service

Once you have verified that the cause for R1L-C malfunction cannot be solved in the field and the need for repair and calibration service arises, contact TEGAM customer service to obtain an RMA, (Returned Material Authorization), number. You can contact TEGAM customer service via the TEGAM website, [www.tegam.com](http://www.tegam.com) or by calling 440.466.6100 (*All Locations*) OR 800.666.1010 (*United States Only*).

The RMA number is unique to your instrument and will help us identify you instrument and to address the particular service request by you which is assigned to that RMA number.

Of even importance, a detailed written description of the problem should be attached to the instrument. Many times repair turnaround is unnecessarily delayed due to a lack of repair instructions or of a detailed description of the problem.

This description should include information such as measurement range, and other instrument settings, type of components being tested, are the symptoms intermittent?, conditions that may cause the symptoms, has anything changed since the last time the instrument was used?, etc. Any detailed information provided to our technicians will assist them in identifying and correcting the problem in the quickest possible manner. Use a copy of the Repair and Calibration Service form provided on the next page.

Once this information is prepared and sent with the instrument to our service department, we will do our part in making sure that you receive the best possible customer service and turnaround time possible.

## Expedite Repair & Calibration Form

Use this form to provide additional repair information and service instructions. The Completion of this form and including it with your instrument will expedite the processing and repair process.

RMA#:		Instrument Model #:	
Serial Number:		Company:	
Technical Contact:		Phone Number:	
Additional Contact Info:			

### Repair Instructions:

- |   |   |                                      |
|---|---|--------------------------------------|
| <input type="checkbox"/> Evaluation           | <input type="checkbox"/> Calibration Only | <input type="checkbox"/> Repair Only |
| <input type="checkbox"/> Repair & Calibration | <input type="checkbox"/> Z540             |                                      |

### Detailed Symptoms:

Include information such as measurement range, instrument settings, type of components being tested, is the problem intermittent? When is the problem most frequent?, has anything changed with the application since the last time the instrument was used?, etc.


## Warranty

TEGAM, Inc. warrants this product to be free from defects in material and workmanship for a period of three years from the date of shipment. During this warranty period, if a product proves to be defective, TEGAM Inc., at its option, will either repair the defective product without charge for parts and labor, or exchange any product that proves to be defective.

TEGAM, Inc. warrants the calibration of this product for a period of one year from date of shipment. During this period, TEGAM, Inc. will recalibrate any product, which does not conform to the published accuracy specifications.

In order to exercise this warranty, TEGAM, Inc., must be notified of the defective product before the expiration of the warranty period. The customer shall be responsible for packaging and shipping the product to the designated TEGAM service center with shipping charges prepaid. TEGAM Inc. shall pay for the return of the product to the customer if the shipment is to a location within the country in which the TEGAM service center is located. The customer shall be responsible for paying all shipping, duties, taxes, and additional costs if the product is transported to any other locations. Repaired products are warranted for the remaining balance of the original warranty, or 90 days, whichever period is longer.

## Warranty Limitations

The TEGAM, Inc. warranty does not apply to defects resulting from unauthorized modification or misuse of the product or any part. This warranty does not apply to fuses, batteries, or damage to the instrument caused by battery leakage.

The foregoing warranty of TEGAM is in lieu of all other warranties, expressed or implied. TEGAM specifically disclaims any implied warranties of merchantability or fitness for a particular purpose. In no event will TEGAM be liable for special or consequential damages. Purchaser's sole and exclusive remedy in the event any item fails to comply with the foregoing express warranty of TEGAM shall be to return the item to TEGAM; shipping charges prepaid and at the option of TEGAM obtain a replacement item or a refund of the purchase price.

## Statement of Calibration

This instrument has been inspected and tested in accordance with specifications published by TEGAM Inc. The accuracy and calibration of this instrument are traceable to the National Institute of Standards and Technology through equipment, which is calibrated at planned intervals by comparison to certified standards maintained in the laboratories of TEGAM Inc.

### Contact Information

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