

MAN110

B3-D MULTI-METER MANUAL (Catalog # 1106)

The Model B3-D is a digital version of the analog B3-A2 Multi-Meter. The two digital meters are of the liquid crystal type which are easy to read under outdoor lighting conditions without the use of sunshades. The numeric displays are complete with automatic decimal point, automatic polarity indication, automatic zeroing, automatic overrange indication, automatic low battery indication and automatic function indicators (annunciators). The net result of all these automatic features is greatly simplified operation with very little likelihood of damage through accidental overload. Errors caused by misinterpretation of scales are almost impossible.

The Model B3-D has all the versatility of the B3-A2 plus a 200V AC range and three direct reading resistance ranges which take the place of the contact check circuit and also permit easy measurement of resistance of test leads, bonding resistors, etc.

When your Model B3-D is not in use, all pointed knobs should be pointing straight down. This will conserve batteries and prevent accidental overload of metering circuits.

Left Meter (L Meter):

The Left Meter incorporates the following ranges:

<u>D C Ammeter Ranges*</u>	<u>Capability</u>	<u>Resolution</u>
20 mA	0-19.99mA	.01 mA
200mA	0-199.9mA	.1mA
2A	0-1.999A	1mA
20A	0-19.99A	10 mA

*(all shunts have 20mV full scale IR drop)

<u>DC Voltage Ranges</u>	<u>Capability</u>	<u>Resolution</u>	<u>Input Res.</u>
20mV	0-19.99 mV	.01 mV	1000 ohms
200mV	0-199.9mV	.1mV	10 mega-ohms
2V	0-1.999V	1mV	10 mega-ohms
20V	0-19.99V	10mV	10 mega-ohms
200V	0-199.9V	.1V	10 mega-ohms

<u>Resistance Ranges</u>	<u>Capability</u>	<u>Resolution</u>
20 ohms	0-19.99 ohms	.01 ohm
2K ohms	0-1.999K ohms	1 ohm
2M	0-1.999M ohms	1K ohms

The Left Meter can be used for the following commonly performed tests:

- Rectifier or solar cell output current (external shunt required if above 2.0A)
- Output current of galvanic anode or impressed current anode
- Bond or drainage current
- IR drop on pipe, cable or other metallic structure
- Structure-to-earth potential (200mV range and up)
- Structure-to-water potential (200mV range and up)
- Anode-to-structure potential
- Structure-to-structure potential
- Output voltage of rectifier or solar cell array
- Potential across insulating fitting
- Battery voltage
- Electrode-to-electrode potentials (200mV range and up)
- Resistance of test leads, resistors, etc.
- Resistance of bond connections
- Continuity check of test station wiring
- Contact resistance of probe bars

Right Meter:

The Right Meter incorporates the following ranges:

<u>DC Voltage Ranges</u>	<u>Capability</u>	<u>Resolution</u>	<u>Input Res.</u>
20mV	0-19.99 mV	01 mV	1000 ohms
200mV	0-199.9mv	.1mV	1-200 mega-ohms selectable
2V	0-1.999V	1mV	1-200 mega-ohms selectable
20V	0-19.99V	10mV	1-200 mega-ohms selectable
200V	0-199.9V	.1V	1-200 mega-ohms selectable

<u>AC Voltage Range</u>	<u>Capability</u>	<u>Resolution</u>	<u>Input Impedance</u>
200V	0-199.9V	.1V	450 K ohms

The Right Meter can be used for the following commonly performed tests:

- Structure-to-earth potentials (200mV range and up)
- IR drop on pipe, cable or other metallic structure)
- Structure -to-structure potentials
- Anode-to-structure potentials
- Output voltage of rectifier or solar cell array
- Potential across insulating fitting
- Battery voltage
- Electrode-to-electrode potentials (use only 200mV range and up)
- Ammeter (requires accessory shunt)
- Check for hazardous AC potentials
- Check AC line voltage
- Check rectifier transformer operation

The Left and Right Meters can be used in conjunction with each other for the following types of tests:

- Resistivity of soil or water samples in 4-terminal soil box
- Resistivity of soil by Wenner four electrode method
- Resistance of very low value by four terminal method
- Resistance of over 2K ohms by two or four terminal method
- Current requirement tests
- Coating evaluation tests
- Zero resistance ammeter test
- Diode characteristic curves
- Testing and adjusting electrolysis drain switch
- Null ammeter tests
- Interference tests at foreign line crossings

Liquid Crystal Display:

Overrange Indication:

Display shows "1" followed by blanked digits. Turn to higher range if available. No harm should be done by overranging on any of the voltage ranges 200mV and up by voltages unless over 200V. Maximum voltage applied to the 20mV range should not exceed 10V. Damage to shunt ranges may occur if current is more than double the full scale value.

Polarity Indication:

No polarity indication is displayed unless input polarity is opposite to that marked on panel in which case a "-" sign will appear in the display.

Decimal Point:

Displayed automatically.

Function Annunciator:

As an extra help to the operator, the function being measured is automatically shown in the display - i. e. V, mV, A, mA, Ω , AC, so that there should be no doubt whatsoever as to what is being displayed in the digital readout.

Low Battery Indication:

"Lo Bat" - See "Checking Internal Batteries"

Temperature Limitations:

The liquid crystal display has temperature limitations as listed below:

Temperature Range (Operation): 8° F to 176°F (-14°C to 80°C)

Will tend to be sluggish at low end of temperature range.

Temperature Range (Storage): -37° F to 176°F (-35°C to 80°C)

Storage outside of these temperature limits may damage the liquid crystal display. Exposure to high temperatures above 176°F may occur if meter is stored in truck of dark colored vehicle in summer sunshine. High temperature damage will turn the display permanently black and is **not** covered by the M.C. Miller warranty.

Structure- To-Soil Potentials: (See Fig. # 1)

Either the Right or Left Meter can be used for measuring structure-to-soil potentials (200mv range or above) using reference electrodes such as copper-copper sulphate or calomel. The Right Meter is preferable, however, because of the selectable input resistance feature which permits checking for high resistance in the external measuring circuit as follows:

- (a) With input resistance switch on 10 mega-ohm position, connect test leads to right hand terminals.
- (b) Turn right switch to range which produces a reading of at least 10% of full scale.
- (c) Turn input resistance switch to 25 M position. If displayed value increases, there is high external resistance and it will be necessary to use still higher input resistance by switching to a higher input resistance setting. If the displayed value still continues to increase as switch is changed to 200M position, then it will be necessary to obtain a lower external resistance by wetting down the soil adjacent to the reference electrode. If the same reading is obtained on two adjacent input resistance settings, then the reading is correct and no further correction is necessary.

The above procedure should be followed where electrode is in contact with dry soil, gravel, frozen soil or paving material or any other locations where readings seem to be lower than expected.

In general, it is preferable to use the lowest position on the input resistance switch which gives an accurate reading.

Use of Internal Current Controls: (See Fig. #2)

When using and measuring direct current from an external source such as a dry cell, automobile battery, galvanic anode, bond cable, small rectifier, solar cell, etc., the fine and coarse controls and the rheostat can be cut into the circuit to reduce or control the magnitude of the current. This is accomplished by throwing the ammeter toggle switch to "Amps With Controls" position. To avoid overloading and overheating the controls, the rheostat and controls must be used in proper sequence if current is over .3 A.

The 20 ohm fine control is a special Ohmite Model J 50 -watt potentiometer / rheostat. The maximum current at any setting should be limited to about 1. 5 amperes. It is "special" in that it has about twice the number of turns of resistance wire that the standard 20 ohm 50 watt control has.

The 500 ohm coarse control is an Ohmite Model J 50 -watt standard potentiometer /rheostat. The maximum current at any setting should be limited to about . 3 ampere.

However, the fine and coarse controls will carry 5 amperes or more for a short period when the rotating arm is on either end contact and all the resistance wire is out of the circuit.

With the rheostat and the fine and coarse knobs in the counter clockwise position, the resistance is at a minimum. NOTE that when measuring current from an external source the current usually is slightly less when the amps toggle switch

is thrown to the left than it is when the toggle switch is thrown to the right. This is due to the additional wiring and the resistance of the rheostat together with the slight resistance of the end contacts of the fine and coarse controls.

Considering the maximum carrying capacity of the controls, it is obvious that if the current exceeds 1.5 amperes, the rheostat must be used first to reduce the current to below 1.0 amperes, then use the fine control to further reduce the current value to the value desired or to below. 3 ampere when it is safe to use the coarse control. It is safe to overload the se controls by a factor of 2 for a few seconds (enough time to get a reading).

If the current is initially small (below 1.5 amperes), the fine control can be used. However, when the current is between 4 ampere and 1. 5 ampere, the fine control may produce "jumpy" control as the fine and coarse controls are wire-wound and each wire passed over by a rotating arm results in a relatively large change in resistance. Therefore, use the rheostat for smooth control is suggested. These factors will soon become apparent with use of the B3-D.

Use of Internal Batteries and Current Controls: (See Fig. #3)

The internal batteries may be used in series with an external source of direct current either to increase or decrease the current. VIZ: the internal batteries with controls can be connected in series with a galvanic anode connected to a structure, to increase the output current of the anode (as an example, to determine the amount of current needed to provide protection). Or the internal batteries with controls can be connected in series, but bucking the external current flow to reduce the magnitude of current and in some cases even to reverse the direction of flow.

Also, internal batteries with controls can be used (without any external DC source) to supply test current from a few milliamperes to about 2 amperes (or slightly more for a few seconds testing). The magnitude of the current supplied from internal batteries can be adjusted with internal controls, and can be switched on and off for testing by using the amps toggle switch or the BAT toggle switch (depending on whether it is desired to completely open the current circuit or merely disconnect the batteries leaving the current circuit closed through the shunt and controls circuit). There are many uses for both types of testing.

When supplying test current from the internal batteries, it is essential that the sequence of use of the RHEOSTAT, FINE Control and COARSE Control be carefully followed to avoid overloading and overheating the controls. The following sequence is recommended:

- (a) Be sure all knobs are in the normal vertical position.
- (b) Connect test leads of circuit to be tested.
- (c) Turn left range switch to ampere or milliampere range desired, depending on the value of the current desired for testing.
- (d) Throw AMPS toggle switch to AMPS WITH CONTROLS. Turn BAT toggle switch to 1. 5 or 3 volts, depending on circuit resistance and value of current desired. If only a few milliamperes are desired; (1) turn FINE control slowly. If this does not provide sufficient current, return the control to normal position and (2) turn COARSE control slowly and watch ammeter. Turn control until most sufficient current is provided and then adjust the desired value with the FINE control

If .3 ampere or more current is desired; (1) turn COARSE control slowly until almost the desired value of current is obtained, then (2) turn FINE control to adjust to desired value. If turning COARSE control to the maximum clockwise position does not provide sufficient current, leave the COARSE control in the MAXIMUM position (where the slider is on the maximum end contact) and then turn the FINE control. Note that if the current is above approximately .5 ampere, the adjustment is "jumpy" because of the wire - wound control. Turn the FINE control to provide slightly more current than is desired, and then (3) turn RHEOSTAT clockwise which increases the resistance in the circuit and thus reduces the current. Again, note that the RHEOSTAT is normally left in the counterclockwise position with minimum resistance. Test current can be turned on and off with the AMPS toggle switch and the effects of the test current can be measured on the right meter.

NOTE: When using the internal batteries and controls in series with an external DC source, such as galvanic anode connected to a structure, it often will be found that when the AMPS toggle switch is first thrown to AMPS WITH CONTROLS, the ammeter will show the galvanic current flowing. When the battery is connected and the COARSE control is turned clockwise, the current will first be reduced but when the COARSE control is turned further, the current will increase up to the original value, then further increase when the potential of the battery being applied by the position of the control exceeds the additional resistance put into the circuit. This is somewhat difficult to understand, but a study of the method of connecting the controls and the battery in the circuit will show the reason.

As soon as tests have been completed, turn off left and right meters, turn BATT and AMPS toggle switches to OFF, return control knobs to normal position, THEN disconnect leads.

Null-Ammeter Method: (See Fig. #4)

The primary use of the Null-Ammeter circuit is for the measurement of direct current flowing on structures such as metal-sheathed cables, pipelines and galvanic anode or impressed current anode circuits. This method is especially valuable in locations where it is difficult or impossible to open up a circuit to connect an ammeter in series and it eliminates having to calculate current flow based on IR drop. The Null-Ammeter method of current measurement consists of forcing (by means of batteries and controls) a measured amount of current through an ammeter connected across a short section of the structure under test. The test current is gradually increased until the IR drop on the section of structure becomes zero (null). This indicates that the current flowing through the ammeter is exactly equal to the amount which was formerly flowing along the structure. See "Wiring Diagram for Null-Ammeter Current Measurements". Fig. #4 .

To Measure DC Current by Null-Ammeter Method:

- a. Make connections as shown in " Wiring Diagram for Null-Ammeter Current Measurements", Fig. #4. Make sure that the ammeter and millivoltmeter test connection points on the structure are kept from touching one another. Test leads should not be less than # 16 AWG wire.
- b. Turn right range switch to 20mv range. Use 20 ohm resistance range to verify good contact between test leads and structure.

c. The current necessary to obtain a null on the Right Meter may be obtained from internal batteries (if less than 2 amp) or may be from an external battery. The amount of current may be adjusted by means of the internal fine and coarse controls on the rheostat. See "Use of Internal Batteries and Current Controls" above. If no null can be obtained, reverse leads to Left Meter and try again.

Zero-Resistance Ammeter (Left Terminals): (See Fig. #5)

The zero-resistance ammeter measurement is sometimes necessary when measuring current in a very low resistance low potential circuit such as between a large low resistance galvanic anode bed and a large structure. If the circuit resistance is, for instance, 0.1 ohm total (anode resistance, lead resistance and structure resistance), inserting an ammeter with 0.1 ohm resistance in the circuit to measure the anode current would reduce the current to 1/ 2 while being measured; a 50% error in reading.

A zero-resistance type milli-ammeter / ammeter circuit is built into your meter. It is difficult to use until one is thoroughly familiar with all the circuits and their uses. The zero-resistance ammeter circuit is set up with the "R to L - Normal" toggle switch on "R to L" position. With the Left Meter being used to measure the current, the amps toggle switch is thrown to the right (to Amps with Controls) and the BATT switch is closed to 1. 5 or 3 volts. The current is then "pumped" through circuit and ammeter with batteries, controls and rheostat UNTIL the Right Meter, which is connected across left-hand terminal on R to L position, is adjusted to "0". The right range switch should be on 20 mv range for most accurate results. The ammeter shunt, internal wiring with controls and battery is then equal to zero resistance. This zero-resistance ammeter can be used from a few milliamperes to about 2 amperes.

The zero-resistance ammeter is somewhat "tricky " to use, in that when the coarse and fine controls with batteries are first turned, the current flow is usually first reduced, then when the controls are turned further, the current increases to the original value and then increases further Until the Right Meter reads "0". It is easy to show someone how to use the zero-resistance circuit, but it is rather difficult to explain in writing. A little practice will "do the trick", but use caution at first until the action is understood. When making zero-resistance current measurements, the positive lead of the current source must be connected to the positive (+) terminal of the Left Meter.

Zero-Resistance Ammeter (4 Terminal Method): (See Fig. #6)

Zero-resistance current measurements can also be made with the R to L – Normal toggle switch in the Normal position, in which case the effects of both the ammeter and lead resistances can be completely nullified. Four test leads are required, but otherwise the procedure is the same as described above.

Use of Bias Circuit: (See Fig. #7)

An adjustable DC bias (full scale voltage, either polarity) can be switched into Right Meter circuit at any time. When the bias circuit is in use, a red pilot light on the panel should glow as a **warning signal**. The amount and polarity of the DC bias can be observed directly on the Right Meter before test leads are attached.

The principle use of the Bias is to facilitate measurement of changes in potential (Delta V), such as when measuring the change in a structure-to-soil potential during cathodic protection current requirement tests; measuring resistance of anode, ground bed or structure to remote earth or measuring soil resistivity by the 4-pin (Wenner) method, either in place to various depths or in a Soil Box. For these resistivity tests the bias serves to offset the effects of both polarization and residual galvanic potential between potential pins. Make sure that the bias circuit is turned off when not in use.

IR Drop Measurements: (See Fig. #8)

Either the Left or Right meter can be used to measure voltage drop (IR) on a metallic structure such as a pipe, cable, steel piling, etc. The reading is used in conjunction with known characteristics of the material to calculate magnitude of current flow.

Test leads should be kept as short as possible, preferably #16 or heavier, and connections to the structure must be bright and shiny to insure low contact resistance. Use of the 20 ohm resistance measuring circuit which is built into the Left meter is strongly recommended in order to avoid erroneous readings caused by broken wires in test stations or poor contact with the structure. External circuit resistance should be less than 10 ohms for good accuracy.

Resistance Measurements (Contact Check Circuit): (See Fig. #9)

The Left meter has three direct reading resistance ranges; 0-20 ohms, 0-2000 ohms and 0-2M ohms. Placing the Left range switch on either of these positions permits reading resistances without making any adjustments or calculations. The circuit is designed to obtain accurate enough results when there is an existing IR drop or similar potential of a few millivolts existing in the circuit to be measured.

The principle use of the resistance measuring circuit is to check out test leads or test station wiring for continuity.

When IR drops are to be measured using the 20mv range (internal resistance 1000 ohms) the total external resistance should be kept below 10 ohms if possible. If a long piece of small gauge test lead wire is used having a resistance higher than 2 ohms, the following correction factor should be used:

$$\text{correction factor} = \frac{1,000 + \text{external circuit resistance}}{1,000}$$

To get true IR drop multiply meter reading by the correction factor.

Another use for the resistance measuring circuit include checking resistance of bond wires, checking for short between insulating flange and flange bolts (when bolts are presumably insulated at both ends).

Measuring Resistance by Voltmeter / Ammeter Method: (See Fig. # 10)

There are situations involving very low resistance (less than .001 ohm) or resistances above 2M ohms where the voltmeter / ammeter method must be used. There are two versions of the voltmeter / ammeter method as follows:

a. **Two Terminal Method:**

When the "R to L - Normal" toggle switch, which is located below the Right meter, is thrown to the "R to L" position, the Right meter is connected to the left terminals of the Multi-Combination Meter. This permits easy measurement of the resistance of any test lead, resistor, bond wire or other device which is connected to the left hand terminals.

The necessary test current can be supplied from the internal 1.5 or 3 volt batteries and controlled to any value from less than one milliampere to about 2 amperes. The desired value of test current is supplied and adjusted as outlined in the section "Amps With Internal Controls and Batteries". It is desirable to use multiples of one such as 1ma, 10ma, .1 amp, etc. to facilitate calculations in the field.

The disadvantage of this method is that it includes the resistance of the test leads which may be large in comparison to the resistance of the unknown resistor under test.

b. **Four Terminal Method:**

When the "R to L - Normal" toggle switch is in the "Normal" position the Right meter operates from the right hand terminals, which permits resistance measurement by the four terminal method. This method is used where the effects of test lead and contact resistance must be eliminated. Typical examples are as follows:

- Calibration of 4 lead test stations on pipe or cable
- Resistance-to-earth of structures such as grounding facilities
- Pipe-to-casing resistance

Except as noted above, test procedure is the same as for the two terminal method. Care must be taken to make sure test clips from current and potential leads do not touch each other.

Regardless of which version is employed, resistance = $\frac{\text{voltmeter reading}^*}{\text{ammeter reading}^*}$

*When voltmeter reading is in volts, ammeter reading must be in amperes. When voltmeter reading is in milli-volts, ammeter reading must be in milli-amperes.

Electrode-to-Electrode Measurements (Soil Gradients): (See Fig. #11)

The voltage drop in the earth caused by cathodic protection currents, corrosion currents or DC stray currents can be easily measured by using two matched copper sulfate electrodes placed on the surface of the ground at desired spacing (usually between 5 ft. and 100 ft.). The preferred method is to use the Right meter as outlined above (making use of the variable input resistance feature as necessary). Use only the ranges 200mv and above.

Soil Resistivity Measurements: (See Fig. #12 & 13)

Your Model B-3D can be used to measure soil resistivity over a very wide range of values - over a much wider range than can be covered by any other soil resistivity measuring instrument, by using external batteries or a dynamotor when needed. Connections are shown in Fig. # 13 for use with the 4-pin method for measuring resistivity of soil in place to various depths, or samples of soil or water in

the Soil Box (see Fig. #12). The external battery can be of any voltage up to about 100 volts. Because the magnitude of the current is usually small, a radio type battery (6v to 24v) is usually sufficient.

The DC Bias Circuit is used to facilitate measuring the Delta V or change in potential and the current circuit is opened with the amps toggle switch. The effects of residual galvanic potential between the two potential pins and the polarization of the two potential pins are eliminated by adjusting the Right meter to zero with the current circuit "open". The Delta V is then read directly as soon as the amps switch is closed.

It is essential that the Right meter be on 200mV or higher range because internal resistance of 20mv range is only 1,000 ohms. It is desirable to use an external battery to obtain sufficient test current to provide a good Delta V. The higher the Delta V, the less the error caused by polarization of potential pins.

When the user becomes experienced in the use of the Model B-3D for soil resistivity measurements, it will be found it is ideal for these measurements and will provide accurate measurements at any pin spacing, whereas, errors may be introduced by the AC method when pin spacing exceeds about 100 ft. because inductance and/ or capacitance effects of test leads. The necessity of carrying additional instruments is avoided.

However, the Model B3-D should not be used for soil resistivity measurements by inexperienced personnel without proper and thorough instruction in use and an understanding of the factors which must be watched to obtain accurate results.

If an M. C. Miller Soil Box is used:

$$\text{Resistivity (in ohm-cm)} = \frac{\text{Delta V (change in potential)}}{\text{Current}}$$

If the Four-Electrode Method is used:

$$\text{Resistivity (in ohm-cm)} = \frac{191.5 \times \text{spacing in ft. between adjacent pins} \times \text{Delta V (change in potential)}}{\text{Current}}$$

Or

$$= \frac{6.28 \times \text{spacing in cm} \times \text{Delta V}}{\text{Current}}$$

Note: If V readings are in milli-volts, then current should be in milli-amperes.

If V readings are recorded in volts, then current should be recorded in amperes.

For measuring resistivity of soil or water using the Soil Box or the Four-Electrode Method, current can be supplied from the internal batteries or by the internal batteries with external batteries connected in series in either + or - current lead.

Using Model B-3D to Calibrate MCM's Potentiometric Strip-Chart Recorder:

Your Model B-3D can be used to provide accurate measured potentials for use in quickly checking and calibrating MCM's Potentiometric Strip- Chart Recorder as follows:

1. Connect Left meter terminals of the B-3-D to Recorder input terminals (- terminal of Left meter to + Recorder terminal).
2. Turn Recorder function switch to "zero" position and adjust to mid scale position as necessary. Turn function switch to "use" position and Recorder range switch to 1v range.
3. Turn Left Meter range switch to any ammeter range.
4. Throw "R to L - Normal" toggle switch to "R to L" position.
5. Throw battery toggle switch to 1.5 V position and amps toggle switch to Amps with Controls.
6. Turn large fine and coarse battery controls clockwise until Right meter reads exactly -1.000 volts.
7. Recorder stylus should now be at right hand end of scale. Adjust calibrate control (located behind right hand side of Recorder panel) as necessary to bring stylus to right hand end of scale.
8. Turn Recorder function switch to Calib position. Adjust stylus to right hand end of scale using "2.5mv Adj Control" (located behind right hand side of Recorder panel). Recorder is now calibrated. All ranges should now be accurate within 2% of full scale unless one of the range resistors is defective.
9. Ranges other than 1V can be checked by adjusting battery controls to desired value (between 0 and 3V) and turning Right meter range switch and Recorder range switch accordingly .

Checking or Calibrating Other Meters or Devices:

Almost any DC voltmeter range from 0 to 3V can be easily checked against the Right meter of y our Model B-3-D by using the following technique:

- a. Turn Right range switch to appropriate mV or V range; Turn left range switch to any Amps position.
- b. Throw battery toggle switch to 1.5 or 3V position.
- c. Throw Amps toggle switch to Amps with Controls.
- d. Throw toggle switch to "R to L" position.
- e. Turn fine and / or coarse battery controls clockwise to produce desired reading on Right meter. This same voltage will appear at the left terminals which can be connected to any DC voltmeter, Recorder, relay, diode or other electrical device which is to be tested. When using internal batteries as a source of voltage or current, the (-) negative left hand terminal functions as a (+) positive output terminal.

Accuracy Check of Instruments: (See Fig. # I4)

A comparison of the Left and Right meters can be easily accomplished as follows:

- a. Throw left and right range switches to same range.

- b. Throw toggle switch at bottom center of panel to "R to L" position.
- c. Apply unknown DC voltage to left hand terminals.
- d. Throw Amps - Amps with Controls toggle switch to left position.
- e. Both meters should indicate within 1 % of each other \pm one digit. If there is a greater disparity check meter against known voltage to see which meter is reading erroneously.

Checking Internal Batteries:

All internal batteries should be frequently checked and replaced when necessary to avoid costly damage caused by leaking cells. Remove all batteries when meter is to be stored for more than a few days.

Amplifier Batteries:

Each meter uses one 9V battery, Eveready or equal. These are checked automatically when meter is turned on and if below about 7V the "Lo Bat" indication will appear in the display. When "Lo Bat" indication first appears there is only a few hours left before meter will beg in to give erroneous readings. It is suggested that a spare be carried along when working in remote rural areas. Battery life should exceed 150 hours of "on" time.

Bias Circuit:

Bias circuit uses one 3 volt lithium coil cell located on RH meter switch board, Eveready #CR2032 is preferred. To check cell push bias or/off switch. If bias warning light glows, bias cell is satisfactory. Note: It is not necessary to remove this battery for any reason other than termination of Life.

Resistance Measuring Circuit:

Resistance measuring circuit uses one Alkaline AA cell, Eveready No. E-91 or equal. To check this battery, place Left meter on 20 ohm or 2K ohm position, throw right meter range switch to 2V position and "R to L – Normal" toggle switch to "R to L" position. Battery voltage will appear on Right meter; replace if below 1.30 volts.

1. 5 and 3V Batteries:

Three " D" cell, Eveready No. 950 or equal, are used with internal controls. To check these batteries:

1. Turn left and right range switches to 20V range position.
2. Throw Amps toggle switch to Amps With Controls.
3. Turn fine and coarse controls to full clockwise position.
4. Throw "R to L - Normal" toggle switch to "R to L" position.
5. Throw Bat toggle switch to 1.5V position.
6. The sum of both meters should indicate at least 1. 4V.
7. Throw Bat toggle switch to 3V position.
8. The sum of both meters should indicate at least 2. 8V.

Battery Life:

Under average temperature and use, the batteries should last about six months. Storage or use in high temperature environments tends to shorten battery life. Under low temperature use conditions (below freezing) battery life will be somewhat less.

Use of External Shunts: (See Fig. #15)

The use of an external shunt such as MCM's 100 Ampere Shunt permits either the Left or Right meter to be used as an ammeter. The 100 Ampere Shunt has a resistance of .001 ohm, which means that current flowing through the shunt will produce 1mv drop per ampere. This millivolt drop can be measured by either the Left or Right meter. The 200mv range will make either instrument serve as a 100 ampere ammeter. When using an external shunt with the Left meter, the toggle switch below the left range switch must be in the "Amps, Volts, Ohms" position.

The 100 Ampere Shunt can be mounted directly on the Left or Right hand terminals or can be used several feet away from the Multi-Combination Meter by using suitable test leads connected to the knurled potential terminals of the shunts.

Maintenance of Panel and Case:

Both the meter panel and the "Ruggedized Pelican" case are unusually resistant to wear and tear resulting from normal use. For appearances sake and to prevent possible surface leakage of electrical currents, we recommend that the panel be kept reasonably clean and free of dirt by use of a small folded cloth dampened with denatured alcohol or soap and water. Panel should be allowed to dry thoroughly before use. Similar treatment of Orange Pelican case will keep it clean and attractive.