INTRODUCTION

This manual covers the use, operation and maintenance of the following meter:

Model M3A1 (Series 3), Standard (Zero 10% Up-Scale Instruments).

This manual can also be applied to all earlier versions of the Model M3A1. The only readily visible differences are in the panel markings. However, in the earlier versions, the internal wiring is somewhat different. Also, the left meter on earlier versions was not protected against burnout when used as a milliammeter/ammeter.

The new panel introduced with the Series 3 Meter was designed to aid the operator in using and understanding his M3A1. The following conventions were adopted to help simplify operation of the meter:

a.) Red markings indicate potential (volts) ranges for functions.

b.) Black markings indicate current (amps) ranges or functions.

c.) Green markings indicate resistance (ohms) ranges or functions.

d.) Switches or controls used in conjunction with each other have been connected with lines or enclosed within boxes where possible or practical.

e.) Small colored dots have been included on the panel as position indicators to simplify battery testing procedures.

OPERATING & MAINTENANCE MANUAL

MODEL M3A1

TABLE OF CONTENTS

MODEL M3A1

CAN BE UTILIZED IN MAKING THE FOLLOWING TESTS *

Structure-to-Soil Potentials.
Current Measurements.
IR Drops.
Calibration of IR Drop Test Stations
Soil or Water Resistivity by Soil Box method.
Soil Resistivity by 4 Pin method.
Soil Potential Gradients.
Continuity tests.
Pipe Coating Resistance tests.
Pipe Coating Fault Survey (over-the-ground method).
Galvanic Anode tests.
Rectifier Output tests.
Cathodic Protection Interference tests.
Cathodic Protection test.
Duct Slug Survey on lead covered cables.
Concrete Bridge Deck Survey.
pH Determination.
Grounding tests.
Temperature measurements using thermocouples.

*Auxiliary equipment such as reference electrode, test leads, external battery or temporary ground bed required in most cases.

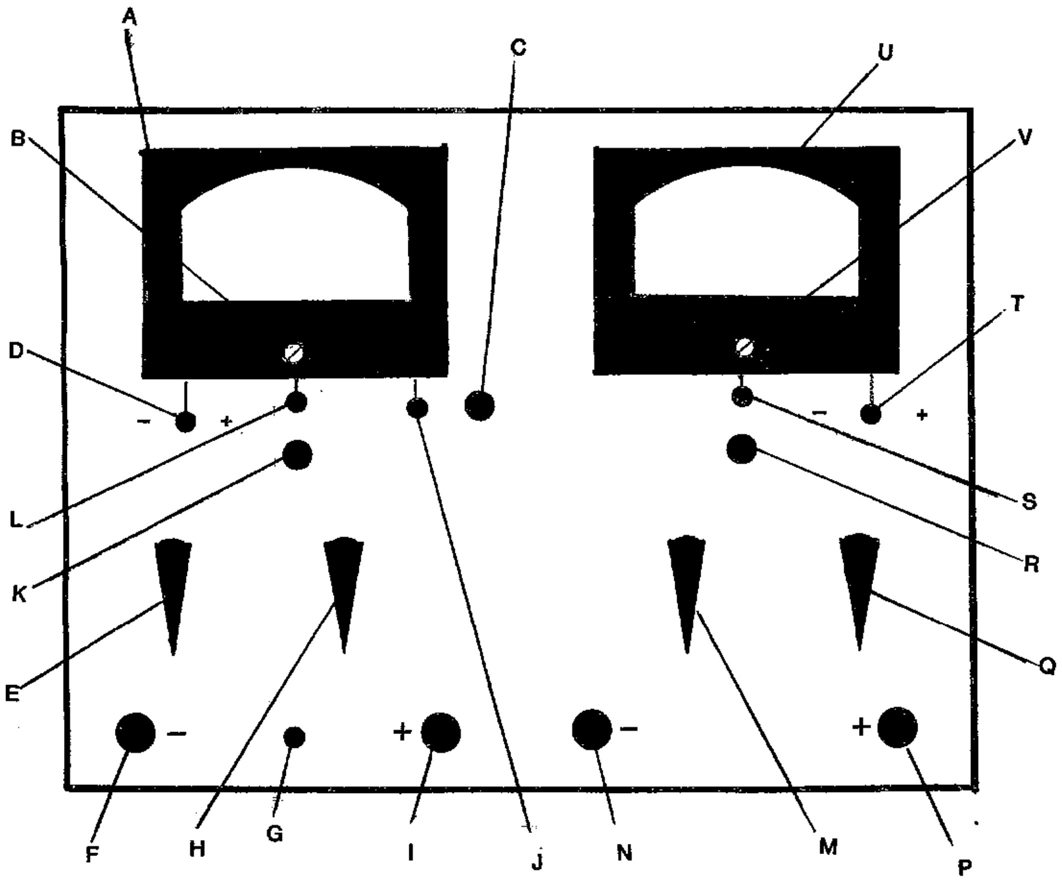
SWITCHES & CONTROLS

(See Illustration)

A	Left-Hand Meter.
B	Mechanical Zero Adjust For Left-Hand Meter.
C	Adjust Control For Contact Check Circuit.
D	Polarity Switch For Left-Hand Meter.
E	Ammeter Range Switch.
F	Negative Terminal For Left-Hand Meter.
G	Amps/Volts Toggle Switch.
H	Voltmeter Range Switch - Left-Hand Meter.
I	Positive Terminal For Left-Hand Meter.
J	On/Off Toggle Switch For Contact Check Circuit.
K	Zero Adjust Push-Button For Left-Hand Meter.
L	Electronic Zero Adjust Control For Left-Hand Meter.
M	Range Switch For Right-Hand Meter.
N	Negative Terminal For Right-Hand Meter.
P	Positive Terminal For Right-Hand Meter.
Q	Input Resistance Switch For Right-Hand Meter.
R	Zero Adjust Push-Button For Right-Hand Meter.
S	Electronic Zero Adjust For Right-Hand Meter.
T	Polarity Switch For Right-Hand Meter.
U	Right-Hand Meter.
V	Mechanical Zero Adjust For Right-Hand Meter.

SWITCHES & CONTROLS

MODEL M3A1



OPERATING & MAINTENANCE MANUAL

MODEL M3A1

GENERAL

The Model M3A1 is a state-of-the-art successor to the popular M-3-M. The many improvements incorporated into the M3A1 include solid state temperature compensated buffer amplifiers for both the left-hand and right-hand meters, more rugged interchangeable meter movements, simplified operation and even greater versatility.

In this manual we have included diagrams showing typical external connections for all of the commonly performed corrosion and cathodic protection tests. Also shown are typical positions of various meter controls and switches for these tests.

When the M3A1 is not actually in use, all pointed knobs should be pointing straight down and toggle switches should be in the "off" position. This will conserve batteries and prevent accidental overload of metering circuits.

On the special center-zero model all ranges of mV, V, mA and A are one half of the values shown or mentioned in this manual, since this manual specifically describes the standard Zero 10% Up-Scale Model.

The connections and switch positions outlined herein are only suggestions and may not apply in all situations or where the practice of some organizations may differ from that of the M. C. Miller Co. For example, some organizations connect the reference electrode to the negative terminal and use the polarity switch to produce upscale readings.

Before attempting field tests it is recommended that the meter operator familiarize himself with applicable D.O.T. regulations. Attendance at one or more of the several annual short courses on corrosion control sponsored by the National Association of Corrosion Engineers is also recommended.

Many of the tests which will be made with the meter will involve the use of a reference electrode. If the electrode is not used and maintained in accordance with manufacturer's instructions, it is possible to obtain readings which are greatly in error.

If there are any questions regarding any of the following material, we suggest you contact the M. C. Miller Co. for clarification.

The left-hand meter incorporates the following ranges:

Ammeter ranges:	2mA	2mV shunt drop
	10mA	10mV shunt drop
	20mA	20mV shunt drop
	.1A	2mV shunt drop
	.2A	10mV shunt drop
	1A	20mV shunt drop
	2A	2mV shunt drop
	10A	10mV shunt drop
	20A	20mV shunt drop
Voltage ranges:	2mV	1000 ohms input resistance
	10mV	1000 ohms input resistance
	20mV	10 megohms input resistance
	.1V	10 megohms input resistance
	.2V	10 megohms input resistance
	1V	10 megohms input resistance
	2V	10 megohms input resistance
	10V	10 megohms input resistance
	100V	10 megohms input resistance

The left-hand meter can be used for the following commonly performed tests:

Rectifier or solar cell output current.
Anode output current.
Bond or drainage current.
IR drop on pipe, cable or other metallic structure.
Structure-to-earth potential (20mV range and up).
Anode-to-structure potential.
Rectifier or solar cell output voltage.
Potential across insulating flange.
Battery voltage.
Electrode-to-electrode potential (20mV range and up).

The right-hand meter incorporates the following ranges:

2mV	1000 ohms input resistance
10mV	1000 ohms input resistance
20mV	Selectable: 1 thru 200 megohms
.1V	"
.2V	"
1V	"
2V	"
10V	"
20V	"

A Contact Check Circuit is provided to check continuity and contact resistance when measuring IR drops.

The right-hand meter can be used for the following commonly performed tests:

Structure-to-earth potential (20mV range and up).
IR drop on pipe, cable or other metallic structure.
Structure-to-structure potential.
Anode-to-structure potential.
Output voltage of rectifier or solar cell.
Potential across insulating flange.
Battery voltage.
Electrode-to-electrode potential (20mV range and up).
Current measurements (requires accessory shunt).

The left-hand and right-hand meters can be used in conjunction with each other for the following types of tests:

Resistivity of soil or water samples in Soil Box.
Resistivity of soil by Wenner four-electrode method.
Current requirement tests.
Coating evaluation tests.
Calibration of IR drop test station.

Adjusting Electronic Zero

When using any range of either the left-hand or right-hand meter, it will be necessary to check and adjust the electronic zero periodically, especially during the first few minutes of operation. This can be quickly accomplished by depressing the zero push button and adjusting the pointer to read zero. It is not necessary to remove test leads while checking and adjusting zero.

Structure-To-Soil Potential (See Fig. #1)

Either the right-hand or the left-hand meter can be used for measuring structure-to-soil potential (20mV range and up) using reference electrodes such as copper-copper sulphate or silver chloride. The right-hand 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 1 megohm position connect test leads to right hand terminals.

b.) Turn right switch to a voltage range which produces deflection of at least 20% of full scale.

c.) Turn input resistance switch from 1M to 10M position. If pointer moves further upscale, there is high external resistance and it will be necessary to use still higher input resistance by switching to a higher input resistance range. If the pointer still continues to deflect upscale as the 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 required. If wetting does not solve the problem, use the potentiometer method described elsewhere in this manual.

The foregoing procedure should be followed where the electrode is in contact with dry soil, gravel, frozen soil, paving material, or any other locations where 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.

Current Measurements (See Fig. #2)

The built-in multi-range shunt enables the left-hand meter to measure direct current from a fraction of a milliampere to 20 amperes. For higher values see the section describing the use of external shunts elsewhere in this manual.

To use the ammeter the left-hand voltmeter switch must be in the "off" position and the amps toggle switch must be in the "Amps" position. Always start with the ammeter range switch in the 20A position and switch to lower ranges as necessary to obtain sufficient pointer deflection for accurate reading. Remember to periodically check the electronic zero.

IR Drop Measurements (See Fig. #3)

Either the left-hand or the right-hand 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. Remember to check the electronic zero periodically.

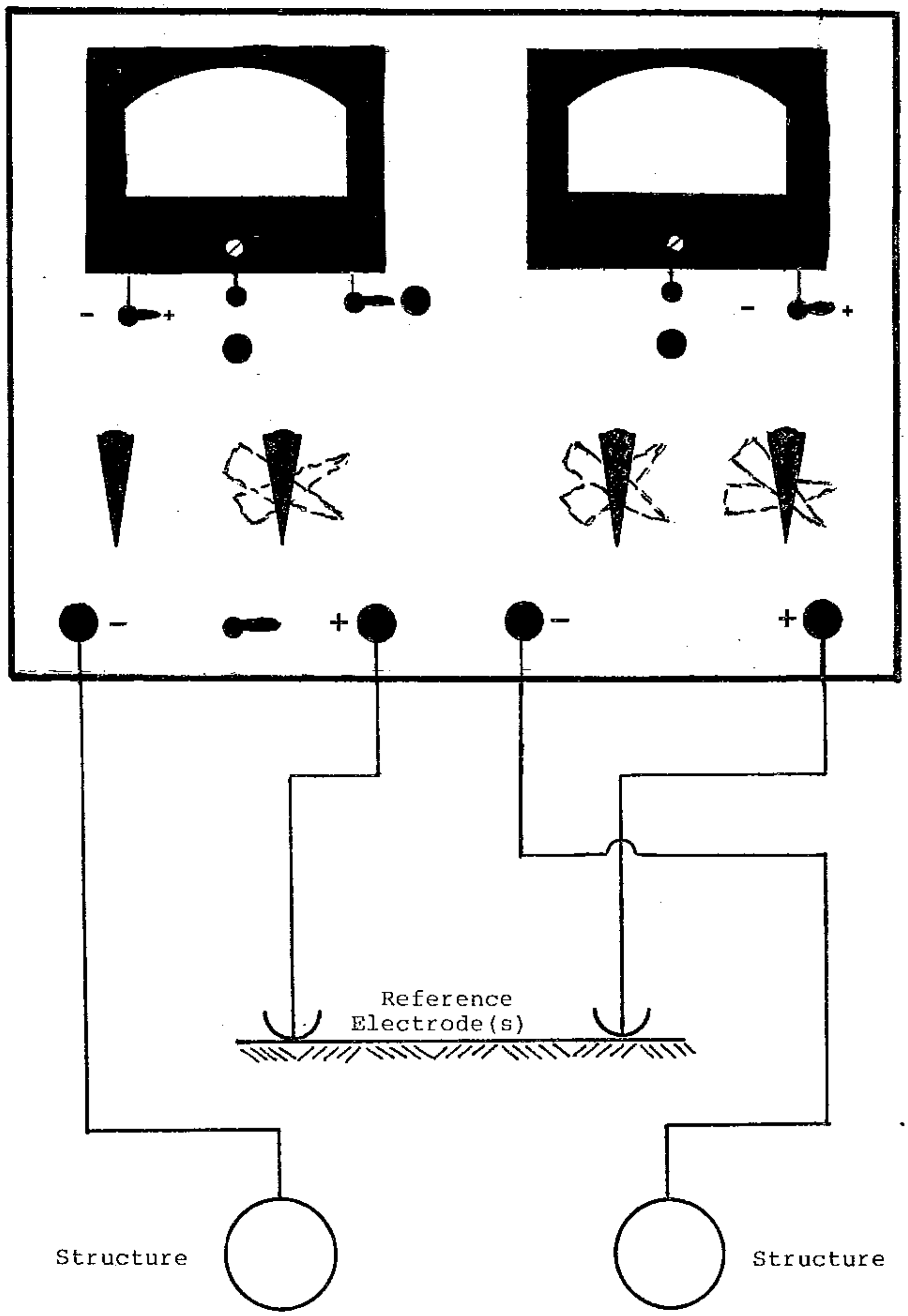


FIGURE 1
Structure-To-Soil Potentials

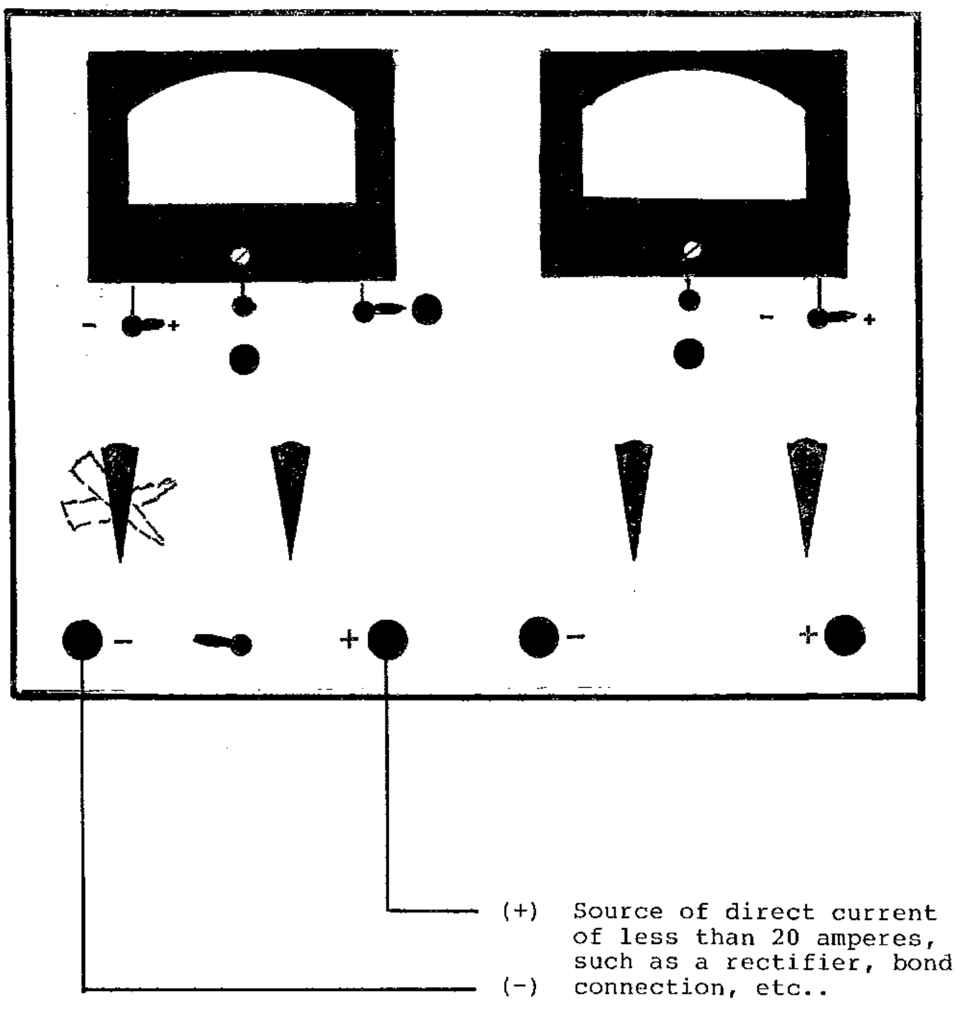


FIGURE 2

Current Measurements

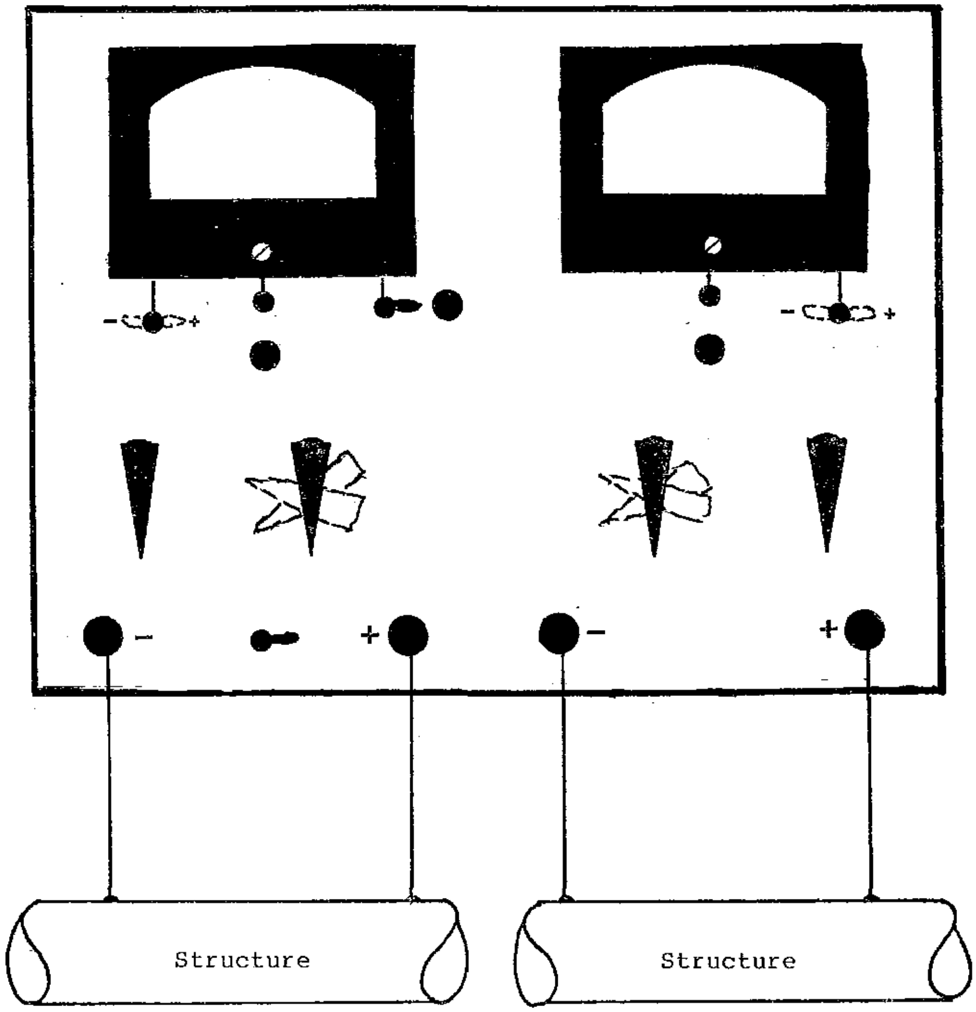


FIGURE 3

Use of either left-hand or right-hand meter to measure IR drop on structure, such as pipe or cable.

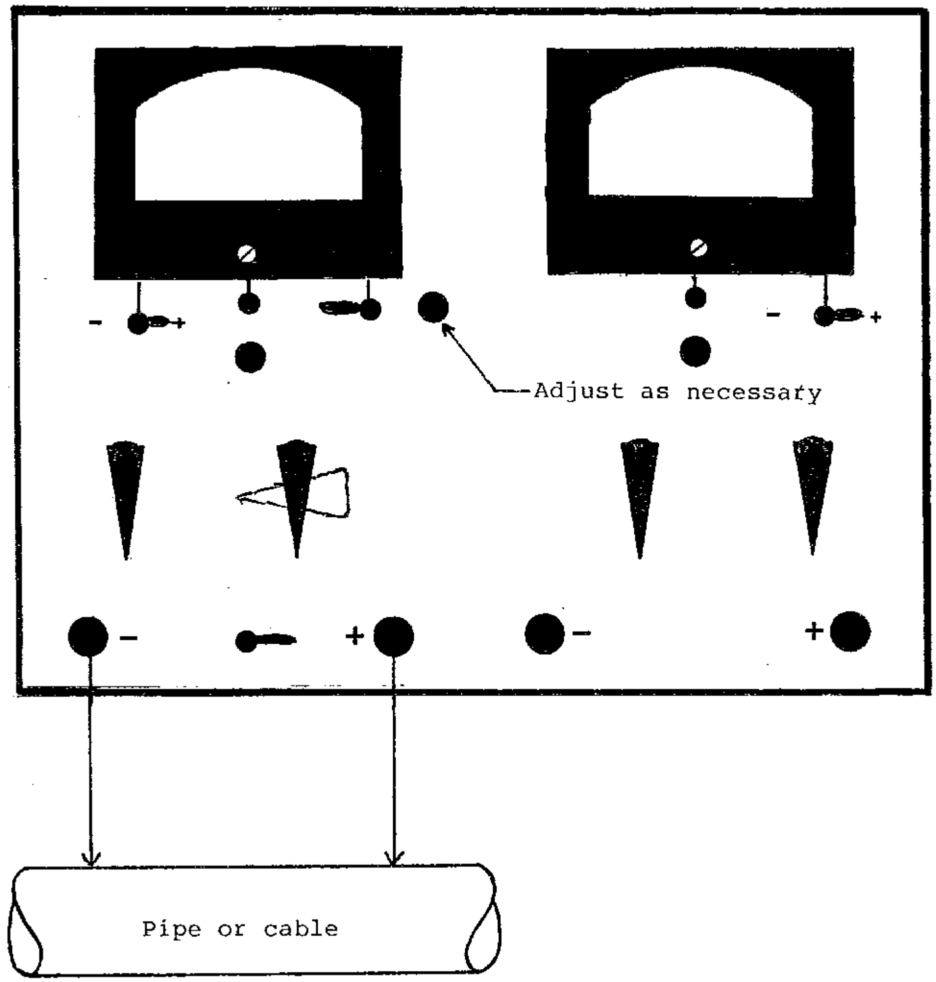


FIGURE 4

Typical use of Contact Check Circuit to test continuity of test circuit.

Test leads should be kept as short as possible, preferably #16 AWG wire or heavier, and connections to the structure must be bright and shiny to insure low contact resistance. Use of the contact check circuit which is built into the left-hand meter circuit is strongly recommended in order to avoid erroneous readings caused by broken wires in test stations or poor contact with the structure. See the section "Use And Operation of Contact Check Circuit."

IR drop measurements are normally made on the 2mV and 10mV ranges, where the input resistance of both the right-hand and left-hand meter is 1000 ohms.

<u>Use And Operation of Contact Check Circuit</u> (See Fig. #4)

The contact check circuit functions and is used like an ohmmeter.

To use the circuit:

a.) Contact check circuit toggle switch to "on" position.

b.) Short together the ends of the test leads being used and adjust the left-hand meter to full scale using the contact check circuit control. This is the same as adjusting zero on an ohmmeter.

c.) Any additional resistance inserted into the circuit after step b. above will cause the meter to read less than full scale. When the circuit is not continuous (open), the meter will read zero.

When making contact with cable sheaths, pipes or other structures, the pointer of the left-hand meter will return to full scale when the contacts have practically zero resistance. If the resistance of the two contacts is approximately 1 ohm, the pointer will be at about .85 on the lower scale.

When good contacts have been obtained, return the toggle switch to the "Normal" position and proceed to take IR drop readings. If the readings do not "look" right, repeat the contact check, as a slight movement of the contact or probe bars may have introduced resistance.

Typical applications:

a.) Check contacts when probing down to pipe for IR drop test.

b.) Check continuity of test station wiring.

c.) Check for broken test lead.

d.) Check for shorted flange bolt (where bolts are insulated at both ends).

Electrode-To-Electrode Measurements (Soil Gradients) (See Fig. #5)

The voltage drop in the earth caused by cathodic protection currents, corrosion currents, or stray DC currents can be easily measured by using two matched copper-sulphate electrodes placed on the surface of the ground at desired spacing (usually between 5' and 100'). The preferred method is to use the right-hand meter as described in the section "Structure-To-Soil Potential", making use of the selectable input resistance feature as necessary. Use only on ranges 20mV and above.

When one electrode is placed over the pipe and the other is placed to one side, the measurement is called a "side drain." This type of measurement is frequently used on bare pipe lines to ascertain whether the pipe is picking up or discharging current. The best results are obtained when measurements are taken on both sides of the pipe. If the electrode located over the pipe is negative to the electrode placed a few feet to either side of the line then the pipe is probably picking up current. If the reverse is true, the pipe is probably discharging current (corroding).

Soil or Water Resistivity Measurements

The M3A1 can be used to measure 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. Connections are shown in Fig. #6 and #7 for the "Wenner" four-pin method for measuring resistivity of soil in place to various depths, and for samples of soil or water in the soil box.

It is essential that the right-hand meter be on the 20mV range or higher. It is desirable to use a high voltage battery (12V or higher) to obtain sufficient test current to provide a good Delta V.

When the operator becomes experienced in the use of the M3A1 for soil resistivity measurements, it will be found that the meter can provide accurate measurements at any pin spacing, whereas errors may be introduced by the AC methods when pin spacing exceeds about 100'. The necessity of carrying additional instruments is avoided.

Note, however, that the M3A1 should not be used for soil resistivity measurements by inexperienced personnel without proper and thorough instruction in its use and an understanding of the factors which must be watched to obtain accurate results.

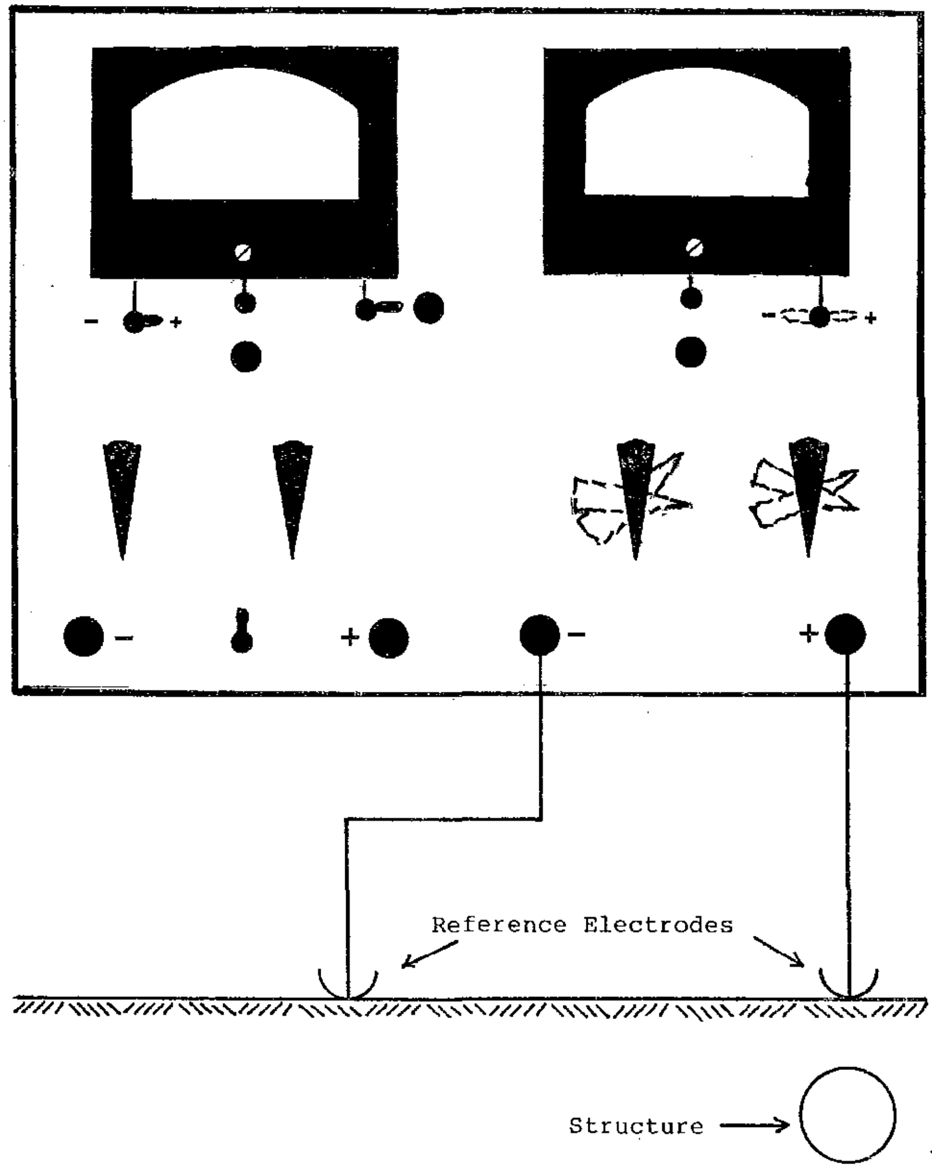


FIGURE 5

Electrode-to-electrode voltage measurements (voltage gradients or "side drains").

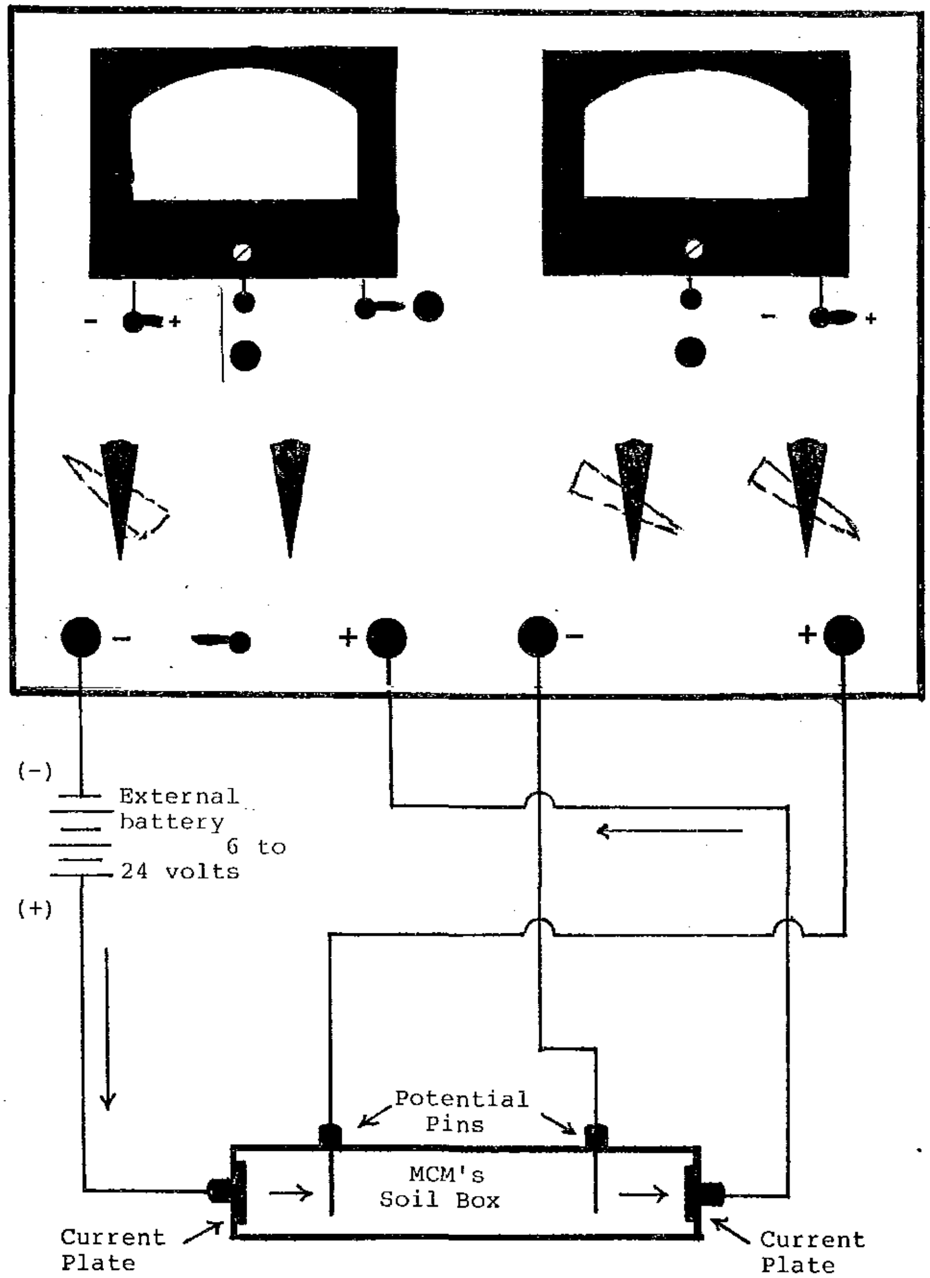


FIGURE 6

Measuring resistivity of soil or water sample by soil box method. Soil box must be completely full.

For measurements at spacings of 25' or less, the Vibroground Models 263 and 293 or Nilsson Model 400 will be found to be faster than the B3A1 and somewhat simpler to use.

Soil Resistivity Measurements (Soil Box Method) (See Fig. #6)

Fill soil box to the rim. Soil samples should be firmly tamped in order to simulate field conditions. Temporary removal of potential pins will facilitate the tamping process.

$$\text{Resistivity (in ohms/cm)} = \frac{\text{Delta V (change in potential)*}}{\text{Current}}$$

Where:

Delta V = change in potential which occurs when test current is switched on. This is read on the right-hand meter.

Current = reading on the left-hand meter, when the amps toggle switch is thrown to the "Amps" position.

Soil Resistivity Measurements (Four Pin Method) (See Fig. #7)

$$\text{Resistivity (in ohms/cm)} = 191.5 \times a \times \frac{\text{Delta V*}}{\text{Current}}$$

Where:

a = spacing between adjacent pins (in feet)

Delta V = change in voltage reading produced by the test current. This is read on the right-hand meter.

Current = reading obtained on the left-hand meter.

* If Delta V is in volts, current must be in amperes. If Delta V is in millivolts, current must be in milliamperes.

Accuracy Comparison of Left-Hand & Right-Hand Meters (See Fig. #8)

Sometimes during use the meter is "banged" with a sudden overload or the reading "looks" wrong, and the operator may wonder if one of the meters is inaccurate.

Meters can be checked by the comparison method as follows:

a.) Turn left and right range switches to the same range, for example, the "2V" range.

b.) Connect a new flashlight battery or other source of steady voltage to the left terminals.

c.) Connect jumpers between left and right sets of terminals.

If both instruments read the same or within one or two divisions it can be assumed that both are within 1-2% accuracy, since the probability of both being damaged or inaccurate to the same degree at the same time is very remote. However, if either the left-hand or right-hand meter is more than 2% high or low, the indication is that one or the other is inaccurate. Normally, the same difference (in percent) between the two instruments will be found on all ranges. Therefore, it can be assumed that the trouble is in the meter itself or in the damping resistor, if used. However, if the difference occurs on only one or two ranges, the trouble probably is in the series range resistor.

Use of External Shunts (See Fig. #9)

The use of an external shunt, such as MCM's 100 Ampere Shunt, permits either the right-hand or the left-hand 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 product lmV drop per ampere. This millivolt drop can be measured by either the left-hand or the right-hand meter. The ".lV" range (100 millivolts) will make either instrument serve as a 100 ampere ammeter. When using an external shunt with the left-hand meter, the amps toggle switch must be in the "Volts" (open) position. Use of the lower mV ranges will provide lower ampere ranges. For example, the "2mV" range would yield a 2 ampere range when using the 100 Ampere Shunt. It is permissible to measure up to 200 ampere for a few seconds, using the ".2V" (200 millivolts) range.

External shunts must be used if current exceeding 20 amperes is to be measured, or if it is desired to use the right-hand meter to measure current.

Checking Internal Batteries

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

Amplifier Batteries - Four "AA" Alkaline Penlite Cells per amplifier. Place both left and right voltmeter range switches in "Bat" position. Pointers should come to rest in "Bat'y Test" sector. If pointer does not reach "Bat'y Test" sector, replace batteries. If pointer does not deflect at all, check batteries to make sure all are in place and there are no corroded contacts.

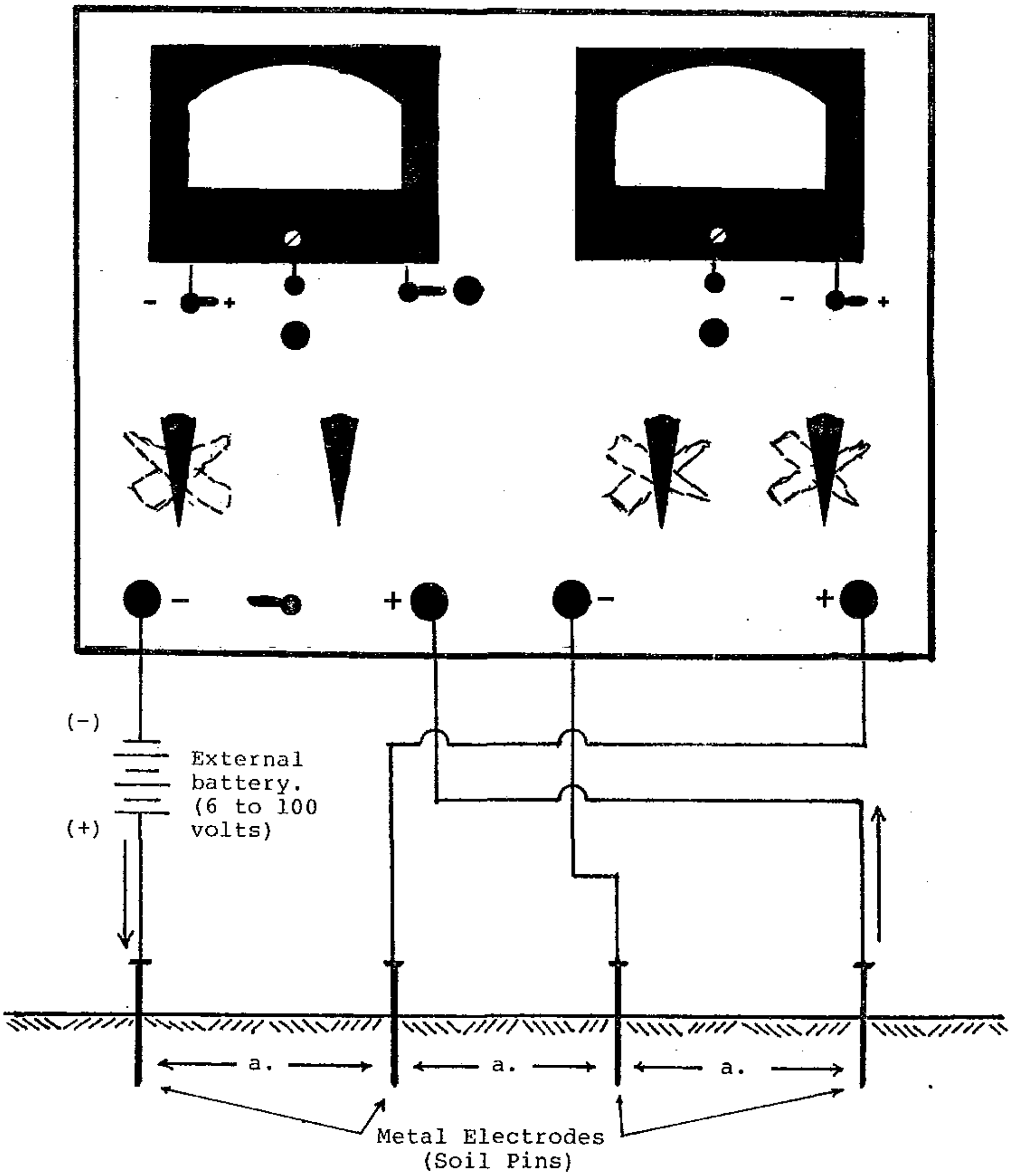


FIGURE 7

Measuring resistivity of soil by four-electrode method.

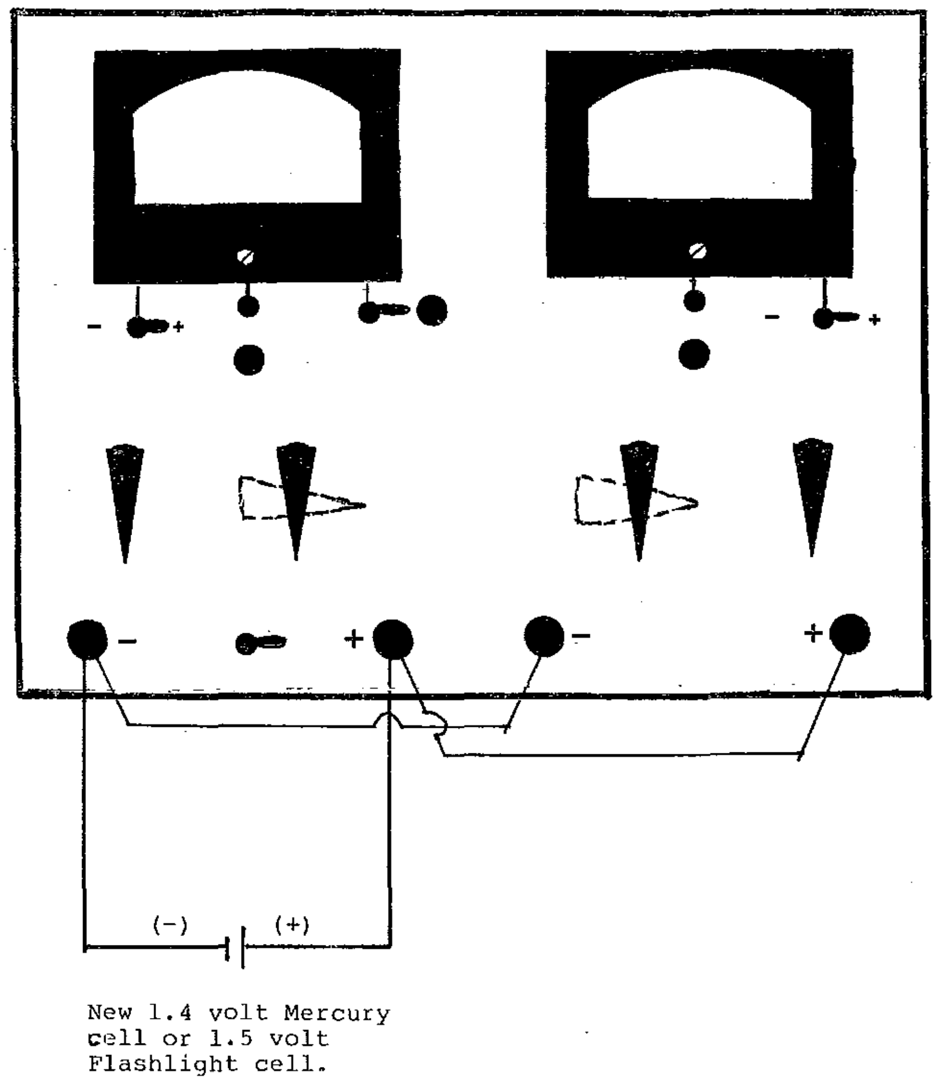


FIGURE 8

Comparison check of left-hand meter and right-hand meter for accuracy using external battery.

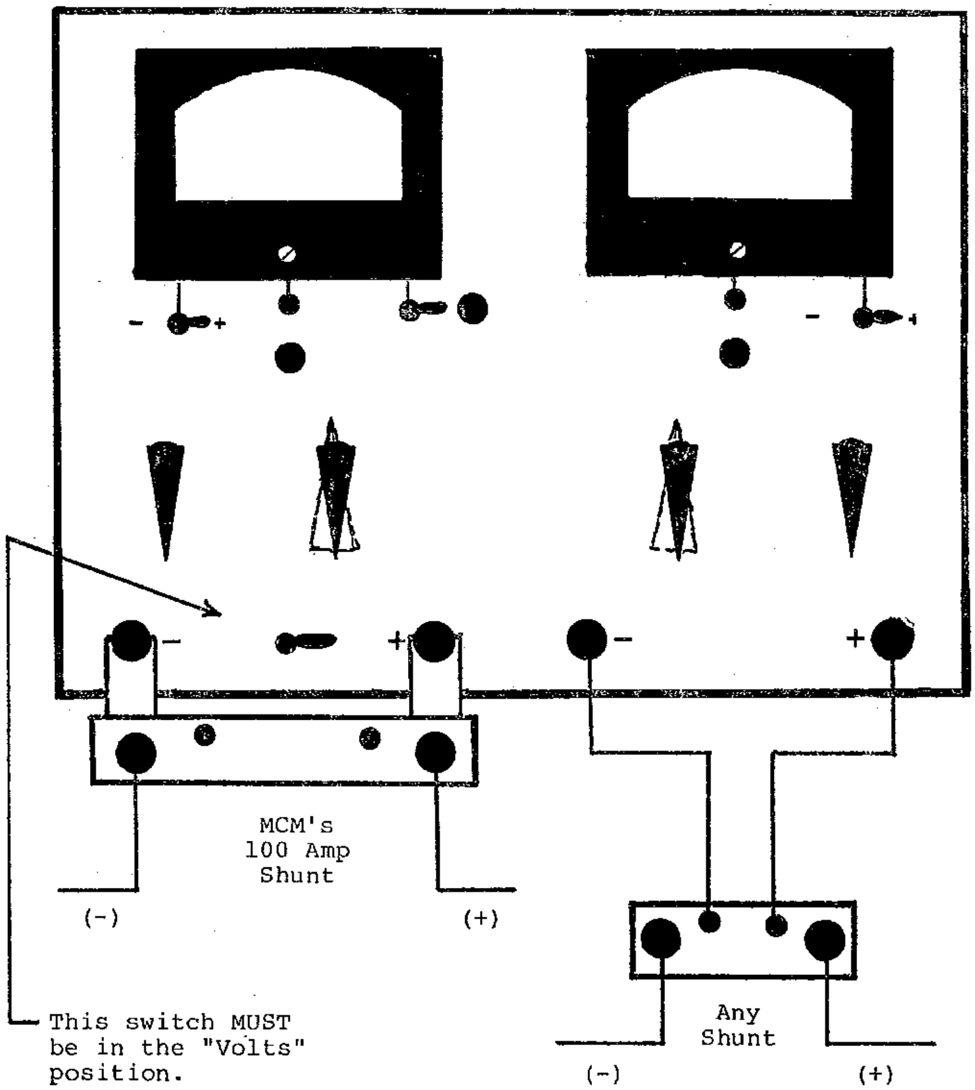


FIGURE 9

Use of external shunt with either the left-hand or right-hand meters.

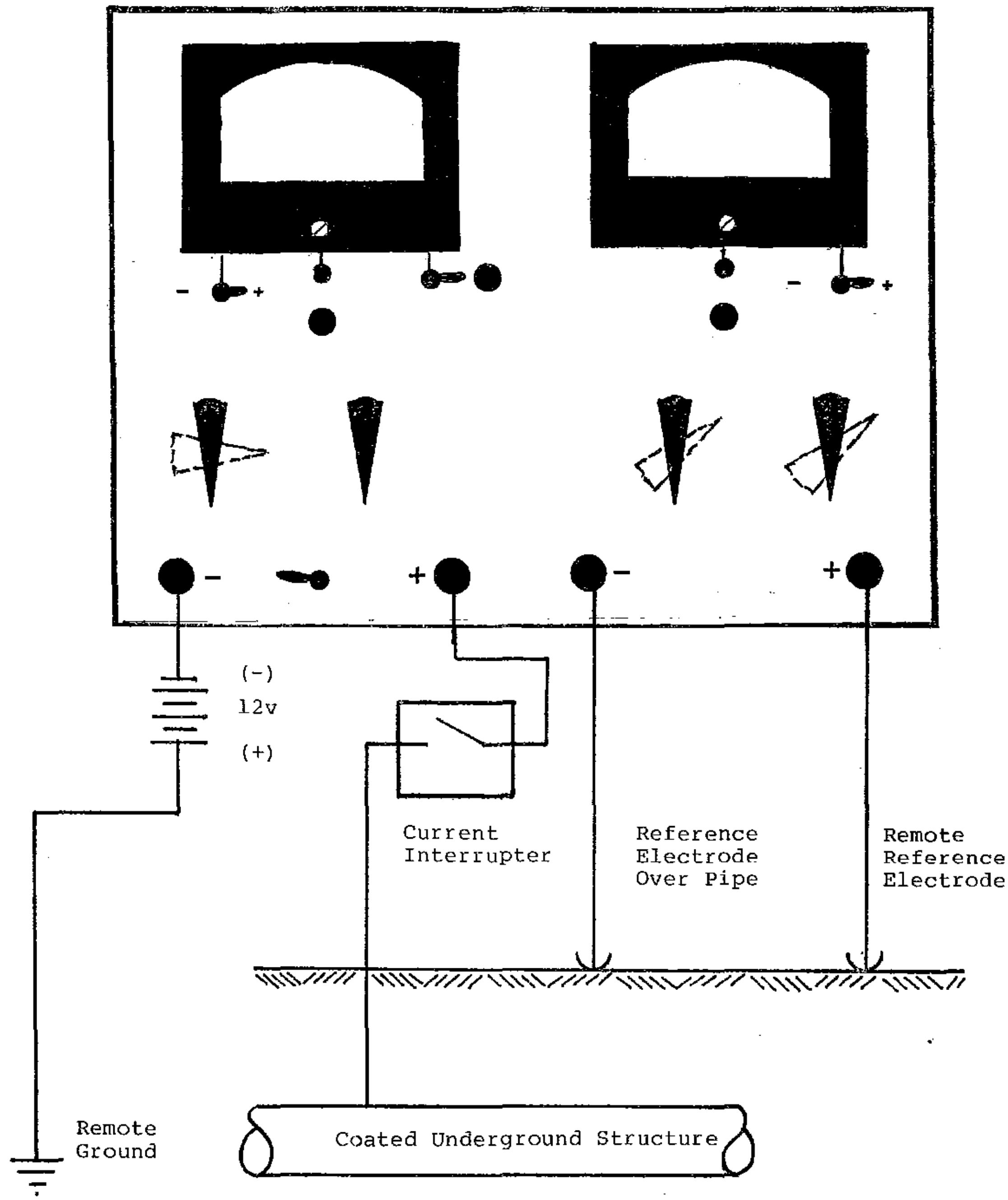


FIGURE 10

Coating Fault Survey

Contact Check Circuit - One "C" Cell.

- Contact check toggle switch to "On" position.
- Right range switch to "2V" range.
- Amps/volts toggle switch to "volts" position.
- Connect jumpers between left and right sets of terminals - to - and + to +.
- Right meter should indicate at least 1. 4v. If not, replace battery.

Note that a colored dot has been marked on the panel at the various switch and control locations as an aid in making battery tests.

Battery Life

Under average temperature and use conditions the batteries should last about six months. Storage and use under either high or low temperatures (below freezing) conditions tend to shorten battery life somewhat. It is strongly recommended that amplifier batteries be checked before each day's use. There is no harm in leaving amplifiers turned on all day in order to get a minimum zero drift.

The function of each battery and its proper orientation (polarity) is indicated on the battery platform.

Coating Fault Surveys (See Fig. #10)

Model M3A1 is well suited for making coating fault surveys on buried coated structures such as pipelines, jacketed cables, and coated underground storage tanks.

The survey consists of electrically isolating the structure under test from all ground connections, and then applying an interrupted negative DC potential to the structure using some other piping system or ground rod as a temporary reference ground. Voltage readings are then taken between a reference electrode located off to the side of the structure and another reference electrode which is moved along the surface of the ground at short intervals (say 5') over the structure under test. At locations where there is electrical leakage from areas where the coating has become damaged there will be produced an easily measured rise in potential. The use of a Current Interrupter in the circuit permits the gradient produced by the test current to be seen separately from any other gradient which may exist from some other current source. This is best accomplished by setting the Current Interrupter to a fairly identifiable On-Off cycle (say 2 seconds On and 1 second Off).

Interference Testing (See Fig. #11)

In areas where two or more underground structures cross or come close together the cathodic protection installation on one of these structures can have undesirable effects of the structure-to-soil potential of the other structure. This undesirable effect is called interference. The most common method of testing for interference is to employ a Current Interrrupter to periodically interrupt the cathodic protection current from one structure while measuring the pipe-to-soil potentials of all foreign structures at close intervals throughout the area of their proximity.

The Model M3A1 has two sensitive voltmeters. Each one can be connected so that it measures the pipe-to-soil potential of one of the structures. If the potential on any foreign line swings in a positive direction when the cathodic protection installation is energized, an "interference" condition exists. Action may or may not be required, depending on actual value of the potential obtained. The interference may only be lessening the degree of overprotection rather than causing a corrosion current to flow. Further action must be determined by agreement between the two concerned parties.

Coating Resistance Tests (See Fig. #12)

The average resistance of one square foot of pipe coating can be determined by applying a negative potential to the pipe using a cathodic protection rectifier installation or storage batteries and a temporary ground bed located at least 100' away from the pipe. The average change in potential produced by the test current is then determined on the basis of at least two measurements.

$$\text{Average Coating Resistance} = \frac{\text{Average Change in Potential}}{\text{Test Current Picked Up In Section Under Test.}} \times \text{Area of Pipe Coating}$$

Because resistance values tend to be high, some people prefer to use conductance rather than resistance.

$$\text{Conductance} = \frac{1}{\text{Resistance}}$$

The unit of conductance is the siemens (formerly Mho). Coating conductivity is often given in terms of micro-siemens.

Calibrating IR Drop Test Station (See Fig. #13)

For several types of corrosion tests it is vital to know how much direct current is flowing at various points along a pipe or cable and to know the direction of current flow.

At present the only practical method on most pipes or cables, particularly the larger ones, is to use a section of the pipe or cable as a current measuring shunt. This is accomplished by making four connections to the structure and bringing these wires up to a test station.

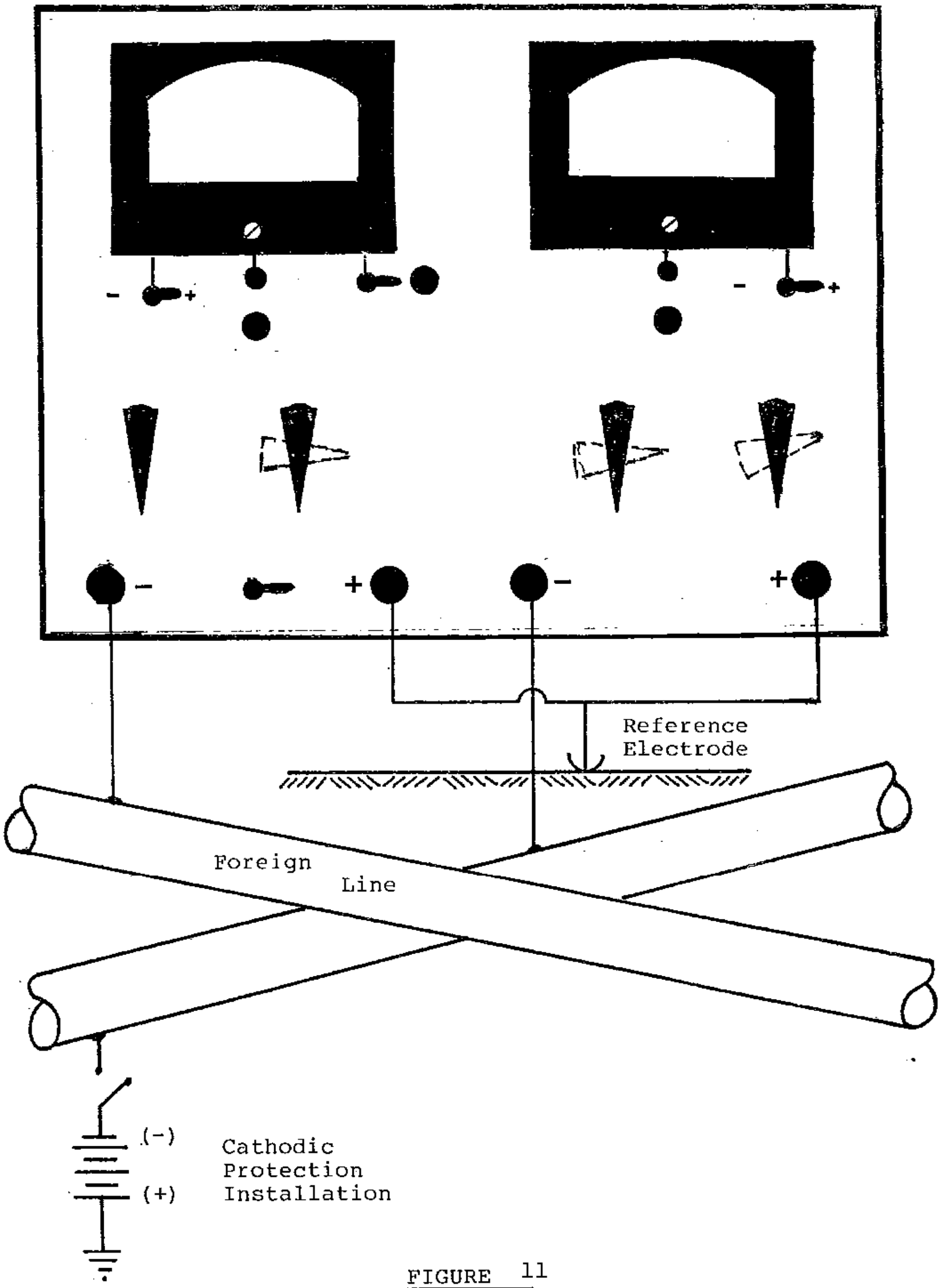


FIGURE 11

Interference test at foreign line crossing.

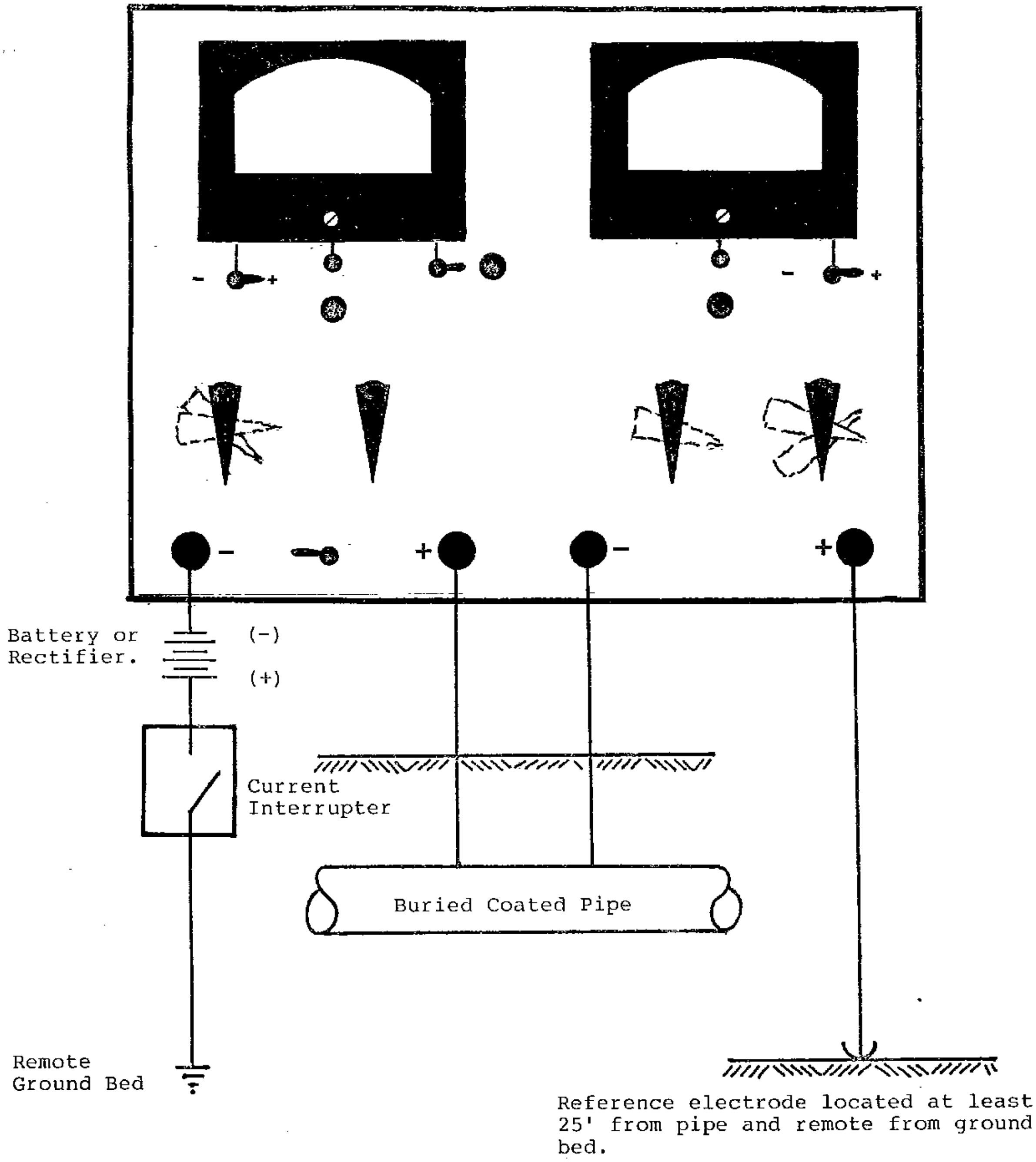


FIGURE 12

Coating Resistance Test.

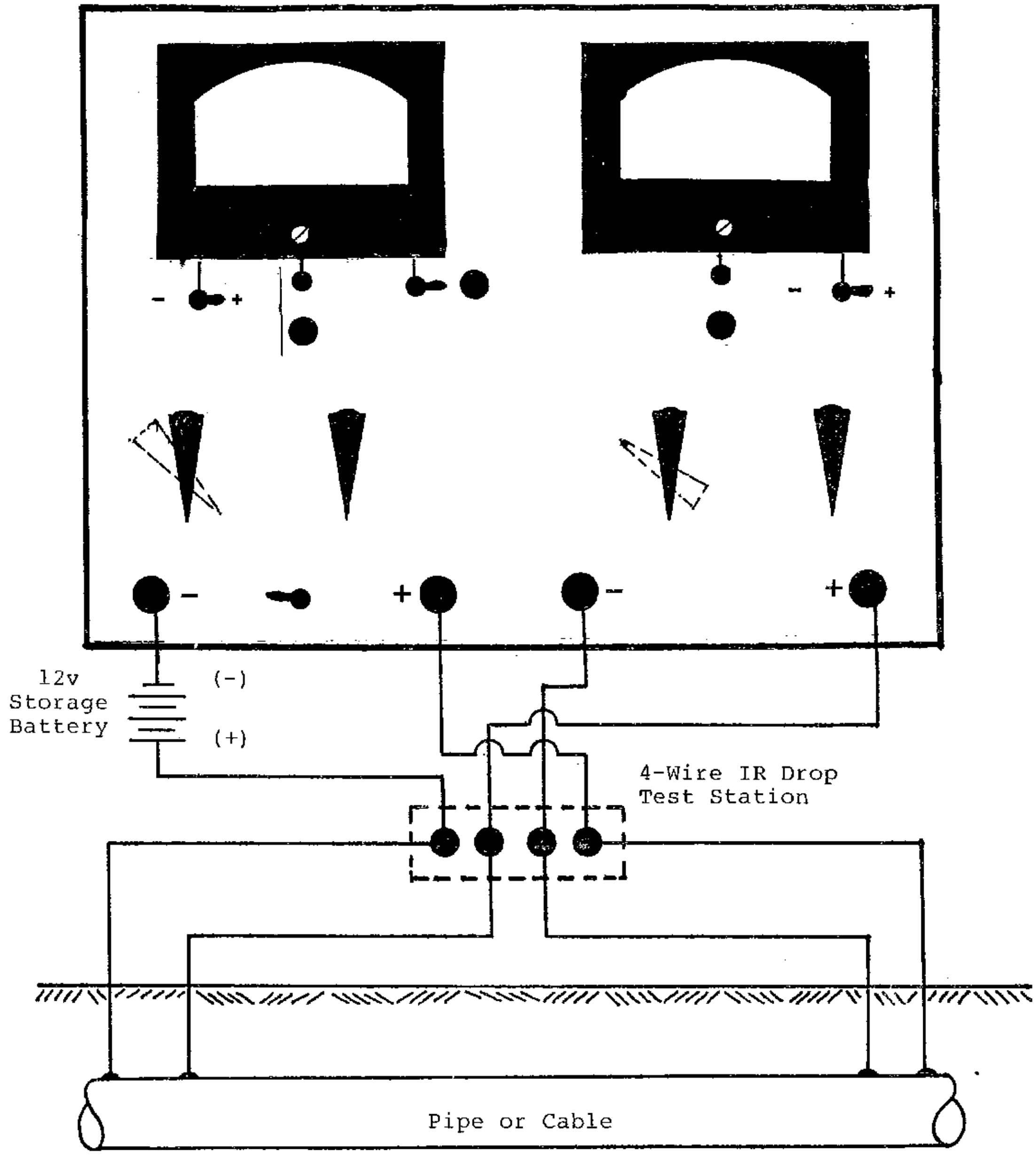


FIGURE 13

Calibration of IR Drop Test Station.

The resistance of the shunt can be calculated if both the length of the test span and the resistance per foot of the structure are known accurately. However, the resistance varies with temperature and contractors do not always measure the span accurately.

For these reasons many companies prefer to calibrate the test station using measured current from a storage battery to produce an IR drop in the structure which can be accurately measured using a millivoltmeter. Since there will often be an existing current in the structure, it is essential that the millivolt drop be measured with the test current off and then again with the test current applied. The algebraic difference between the two readings is then used to make the calculation.

For example, if the existing mV IR drop in the test span in .21mV with the east end being positive, and the IR drop with 10 amperes test current applied is 3.39mV with the east end being negative, the algebraic difference produced by the test current = 3.39 + .21 = 3.60mV. The calibration of this test station wold be .36mV per ampere, which also can be expressed as 2.78 amperes per mV.

For a pipe of 24" or larger, the test current should be at least 10 amperes. It is not necessary to know the span or the diameter of the pipe or cable in order to calibrate the test station.

Ideally the test span should be long enough so that the test curent will produce several mV IR drop.

Once the span has been calibrated it is not necessary to repeat the calibration procedure unless the temperature of the structure has changed considerably. Radical changes of pipe temperature often occur downstream from gas compressor stations. Power cable and pipe type cable installations can also change temperature considerably.

The relative location of the test leads must be known if the direction of current flow is to be determined.

If the relative location of the test leads is not known, it can be determined by turning on and off a nearby cathodic protection rectifier. When the rectifier is on, the current flow should be towards the rectifier.

Maintenance Of Panel & Case

Both the meter panel and the "Ruggedized Formica" case are surfaced with a layer of melamine resin which is unusually resistant to wear and tear resulting from normal use. For appearance sake and to prevent possible surface leakage of electrical currents, we recommend that the panel be kept reasonably free of dirt. Clean with a small folded cloth dampened with denatured alcohol or soap and water. The panel should be allowed to dry thoroughly before use. Clean the case in a similar manner.

Effects of Static Electricity

In dry climates or under winter conditions rubbing or dusting off the meter glass may produce a static charge on the glass that attracts or repels the instrument pointer, thus producing an apparent error or causing the matter to appear defective. The quickest way to dissipate the charge is to wipe the glass with a clean cloth slightly moistened with water or to breathe heavily on the glass until it becomes temporarily clouded with condensation. The use of anti-static compounds on the glass will also be helpful. Re-application will usually be necesary ever few days.

Transportation of Meter

The Model M3A1 is designed to be transported in any position. Preferred transport methods in a vehicle would be on the seat with seat belt fastened thru the handle or in a foam padded bin.

If the meter is to be shipped it should be in a sturdy container with at least 1 1/2" of plastic foam padding or foam plastic pellets surrounding the meter on all sides.

TROUBLE SHOOTING GUIDE

Symptom	Probable Cause	Suggested Remedy
Electronic zero adjust won't zero the meter. "Batt Test" indicates batteries OK.	One or two penlite cells not making contact on negative side of amplifier power supply. "Batt Test" position on checks the cells on positive side of the amplifier.	Re-insert or replace penlite cells, check to make sure contacts are clean.
Left-hand meter won't read correctly.	Contact check toggle switch accidentally left in "On" position.	Throw switch to "Off" position.
Left-hand or right-hand meter reads incorrectly by factor of 2 or 5.	Range switch knob has slipped one position.	Re-index knob using allen wrench in cover of Formica case.
Left-hand or right-hand meter reads low on lower ranges but OK on upper ranges.	Poor contact between meter movement and printed circuit board which is mounted on terminal of the meter.	Remove meter movement nuts, clean contacts and re-install nuts tightly.
After wiping off meter glass the pointer seems to be stuck or moves erratically.	Static electricity on glass.	Wipe off glass with slightly moistened cloth.
Contact check circuit inoperative.	Polarity switch in wrong position.	Throw left-hand meter polarity switch to (+) position.
Pointer on left-hand or right-hand meter hangs up solid.	Probable broken taut-band suspension caused by mechanical shock.	Replace meter movement.
Incorrect ampere value obtained when MCM's 100 Amp Shunt installed on left terminals.	Switches in wrong position.	Turn ammeter range switch to "Off" position; left voltmeter to ".1V" range; Amps toggle switch to "Volts" position.

Symptom	Probable Cause	Suggested Remedy
Left-hand or right-hand meter reads incorrectly; pointer jumps around (especially on lower ranges).	Excessive radio interference from nearby transmitter.	Move meter further away from transmitter if possible.
Reading on left-hand or right-hand meter changes as meter is tilted.	Loose balance weights on meter movement.	Replace meter movement, or have it rebalanced.
On three adjacent ammeter ranges the pointer "pegs" when attempting to measure current.	One of the shunts burnt out by high overload.	Send back to MCM Co. for repair.
Pointer jumps around when test leads attached but not connected to anything.	Nothing wrong. This is normal, especially on 20mV range.	------
No reading on 2mV and 10mV ranges when measuring electrode-to-electrode potentials.	Nothing wrong. These ranges not intended for use with reference electrode (input resistance only 1000 ohms).	Use 20mV range or higher.

PARTS LIST

QUAN.	DESCRIPTION
Carrying Case	
1	"Ruggedized Formica" Case, complete with Hardware, Rubber Feet, and Handle Assembly.
	Replacement Parts for Case
	Rubber Feet, with Screws.
	Case Latches, with Screws.
	Case Hinges, with Screws.
	Case Handle, complete.
Panel & Panel Hardware	
1	Panel, drilled and tapped as required.
4	Terminal Assembly, complete. Specify positive or negative.
7	Knob, Large.
2	Knob, small.
Right-Hand Meter & Circuit	
1	Meter, complete with calibration board. Calibrated.
1	Amplifier Assembly for right-hand meter, complete.
1	Control, Zero-Adjust.
1	Push-Button Switch, Zero-Adjust.
1	Range-Selector Switch for right-hand meter, wired, with resistors.
1	Toggle Switch, Polarity.
1	Input Resistance Selector Switch, wired, with resistors.
Left-Hand Meter & Circuit	
1	Meter, complete with calibration board. Calibrated.
1	Amplifier Assembly for left-hand meter, complete.
1	Control, Zero-Adjust.
1	Push-Button Switch, Zero-Adjust.
1	Range-Selector Switch for left-hand meter, wired, with resistors.
1	Toggle Switch, Polarity.
1	Range-Selector Switch & Ammeter Shunt Assembly, wired. Calibrated.
1	Toggle Switch, Amps/Volts.

QUAN.	DESCRIPTION

Contact Check Control & Circuit

1	Toggle Switch, On/Off.
1	Control, 50 ohms, Adjust.
1	Resistor, 5 ohms (located on battery platform).

Battery Platform Assembly

1	Battery Platform Assembly, complete with Battery Holders and wiring, but less Batteries.

Replacement Parts for Battery Platform

Battery Holders (specify "C", or "AA" size).
Mounting Posts with necessary hardware.
Contact Check Circuit 5 ohm resistor (see Contact Check Circuit section).

Please Specify Serial Number Of Model M3A1 When Ordering Parts.

CALIBRATION OF
MODEL M3A1

Test Equipment Required:

a) DC power supply or calibrator with voltage ranges from 2mV to at least 20V, with accuracy of .1% or better, and output impedance of 2 ohms maximum.

b) DC current supply with ranges of from 2mA to 20A at an accuracy of .1% or better.

c) DC voltmeter with a range of 1.5, 2 or 2.5V at an accuracy of 3% or better.

Calibration Procedure (Left-Hand Meter):

a) With both voltage and current range switches in "Off" position, adjust mechanical zero adjust in center of meter cover as necessary.

b) Using voltmeter check voltage of all four penlite cells located behind left-hand meter. Replace if below 1.4 volts. Make sure all battery contacts are clean and are pressing tightly against the ends of the batteries.

c) Turn voltage range switch to "2mV" position and adjust electronic zero adjust using push-button and control on front of panel. Re-adjust as necessary during calibration procedure. It is suggested that the meter be left on the "2mV" range for at least 15 minutes to allow for normal warmup zero drift.

d) Turn voltage range switch to "1V" range, throw amps toggle switch to the "Volts" position, and connect source of 1 volt to the left hand pair of terminals. Adjust pointer to full scale using the 2K ohm trimpot located on the left side of the circuit board which is mounted on the back of the meter movement.

e) Turn voltage range switch to "20mV" range and connect source of 20 millivolts to the left hand pair of terminals. Adjust pointer to full scale using the 10 ohm trimpot which is also located on the circuit board on the back of the meter movement.

f) Repeat Steps d.) and e.) until both "20mV" and "1V" ranges are accurate.

g) All mV and voltage ranges should now be within specifications unless there is a faulty range resistor.

h) To check current ranges place voltage range switch in the "Off" position; throw amps toggle switch to "Amps" position; and check all current ranges using the DC current supply. There is no calibration adjustment for the current ranges.

Calibration Procedure (Right-Hand Meter):

a) With voltage range switch in the "Off" position, adjust mechanical zero adjust in the center of meter cover as necessary.

b) Using voltmeter check all four penlite cells located behind right-hand meter. Replace if below 1.4 volts. Make sure all battery contacts are clean and are pressing tightly against the ends of the batteries.

c) Turn voltage range switch to the "2mV" position and adjust the electronic zero after a 15 minute warmup period. Readjust as necessary throughout the calibration procedure.

d) Turn voltage range switch to the "1V" range and connect source of 1 volt to the right hand pair of terminals. Adjust pointer to full scale using the 2K ohm trimpot located on the left side of the circuit board which is located on the back of the meter movement.

e) Turn voltage range switch to the "20mV" range and connect source of 20 millivolts to the right hand pair of terminals. Adjust pointer to full scale using the 10 ohm trimpot which is also located on the circuit board on the back of the meter movement.

f) Repeat Steps d.) and e.) until both "20mV" and "1V" ranges are accurate.

g) All mV and voltage ranges should now be within specifications unless there is a faulty range resistor.