Ref-Check VPR

(Voltage Potential Restoration)

Reference Electrode Test Instrument

Farwest Item #04-32052

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User Guide

Background

The majority of the digital multimeters (DMM's) used in the cathodic protection industry have a 10 MΩ (10,000,000 ohm) input resistance, meaning that whenever the meter is connected to a circuit, it imposes a load resistance of 10MΩ onto the circuit being measured. Depending on the total circuit resistance, the 10MΩ may load down the circuit to the extent that the actual voltage reading is lower than it was before connecting the DMM. This condition is known as "Meter Loading".

Most cathodic protection professionals have attempted to measure a structure-to-soil potential in dry soil by utilizing a cathodic protection reference electrode (CPRE). In this scenario, the potential measurement obtained in the test is usually lower (more electropositive) than expected. To combat this, water is typically added to the soil and as a result, the potential measurement increases (goes more electronegative). The reason for the increase in the potential is that the dry soil created a high resistance interface between the CPRE and the soil. Therefore, a large percentage of the actual voltage was lost across the high resistance interface between the CPRE and the soil. The voltage was always there but the low reading is a result of the DMM imposing a load or "current drain" on the high resistance circuit. The introduction of water reduced the contact resistance, thus reducing the voltage drop at the CPRE and soil interface. By adding water, the resistance to earth/electrolyte is reduced, thus reducing the voltage drop and the resultant error caused by the meter loading.

The original Farwest Ref-Check was designed to verify the serviceability of stationary or portable CPRE's. When a CPRE has a high electrical contact resistance to earth/electrolyte, it will provide a false, low reading when measured using a standard DMM. This high resistance issue is caused by factors such as; dry soil, contamination, or simply a high internal electrode resistance due to age.

The original Ref-Check and Ref-Check PLUS provided the ability to vary the input resistance (meter loading) of a DMM in five increments. By noting the relative change in measured potential as the load is increased, the physical condition/serviceability of the CPRE can be determined. A healthy CPRE will maintain a near constant voltage potential reading throughout the five test ranges of the Ref-Check. An unhealthy CPRE will be revealed by the decreasing potential measurements during the test.

The Ref-Check product line DOES NOT confirm that a CPRE under test is within factory or industry tolerance. It provides an indication of reference electrode

health or serviceability by providing a true voltage reading by virtually eliminating meter loading.

Introducing the Ref-Check VPR

The Ref-Check VPR instrument provides improved accuracy and sensitivity well above a standard DMM. The Ref-Check VPR, when used in conjunction with a typical DMM, effectively increases the meter input resistance to **5 billion ohms**. This is an increase to input resistance, or sensitivity, of 500 times more than the typical DMM. Therefore, the Ref-Check VPR enables a standard DMM to operate with virtually zero meter loading.

The Ref-Check VPR is a rugged and compact electronic instrument that connects with a standard DMM. Included with the Ref-Check VPR is a professional grade, stacking, dual banana plug test cord to provide necessary interconnect to a DMM. Customer provided CPRE and structure cable leads that normally plug into the DMM now plug into the Ref-Check VPR.

The Ref-Check VPR can provide an accurate reading from a compromised CPRE, one that has an error factor as high as 90% when using a typical DMM. All of the following tests can be completed without changing test lead cables or the DMM scale or function.

In the default "OFF" condition, the Ref-Check VPR has a hardwired "by-pass" through the instrument. In this condition, the Ref-Check VPR is electrically out of the circuit even while connected to the DMM. This allows the technician the ability to obtain normal pipe-to-soil potential (PSP) readings. However, if a lower than expected PSP reading is obtained or to simply check the "health" of the CPRE, engage the "Press to Read" button on the Ref-Check VPR to display the accurate or "restored" PSP.

Example: If a pipeline utilizing a stationary CPRE has historically provided a reading of –1.000 volts, there would be no reason to suspect a different reading during a repeat survey. However, if the reading is now –0.350 volts, this is likely an indicator that the stationary CPRE has dried and has very high contact-to-earth resistance. In this example, the Ref-Check VPR can provide the actual and accurate reading of –1.000 volts with the touch of a single button.

Ref-Check VPR Features & Specifications

- Response time from "OFF" to a stable corrected reading in less than 3 seconds.
- The Ref-Check VPR will measure DC PSPs within a +/- 5 volt range, with a typical resolution of +/- 2 millivolts.
    - Note: Ref-Check VPR cannot measure AC voltages.
- Includes fully solid state, medical grade electronics. Printed circuit boards are conformal coated to protect the electronic components from moisture and contamination.
- Maximum allowable voltage on the input = 50 volts DC or AC.
- Rugged, lightweight, flame-retardant ABS enclosure with silicone rubber protective boot.
- Built in functionality/accuracy and "Battery Check" circuit. Actual accuracy is dependent on the "calibrated" DMM used with the Ref- Check VPR**.** Therefore, there is no third party calibration required for the Ref-Check VPR
- Battery life provides in excess of 50,000 (3 second) "ON" cycles.

Ref-Check VPR Benefits

- The Ref-Check VPR is designed to verify the serviceability of stationary CPREs as well as CP coupons. It can also confirm good contact to earth of a portable CPRE during routine surveys.
- With the Ref-Check VPR, you will be able to confirm that a CPRE is providing a false low reading due to meter loading.
- The Ref-Check VPR will provide confidence in the accuracy of the PSP you measure. Additionally, you can extend the service life of compromised CPREs and lower your operating costs.
- The Ref-Check VPR can pay for itself on the first day if you are able to obtain an accurate reading from a compromised CPRE, which no longer needs to be replaced.

Ref-Check VPR Operational Guide

Prior to performing any tests with the Ref-Check VPR, it is important that you verify the following:

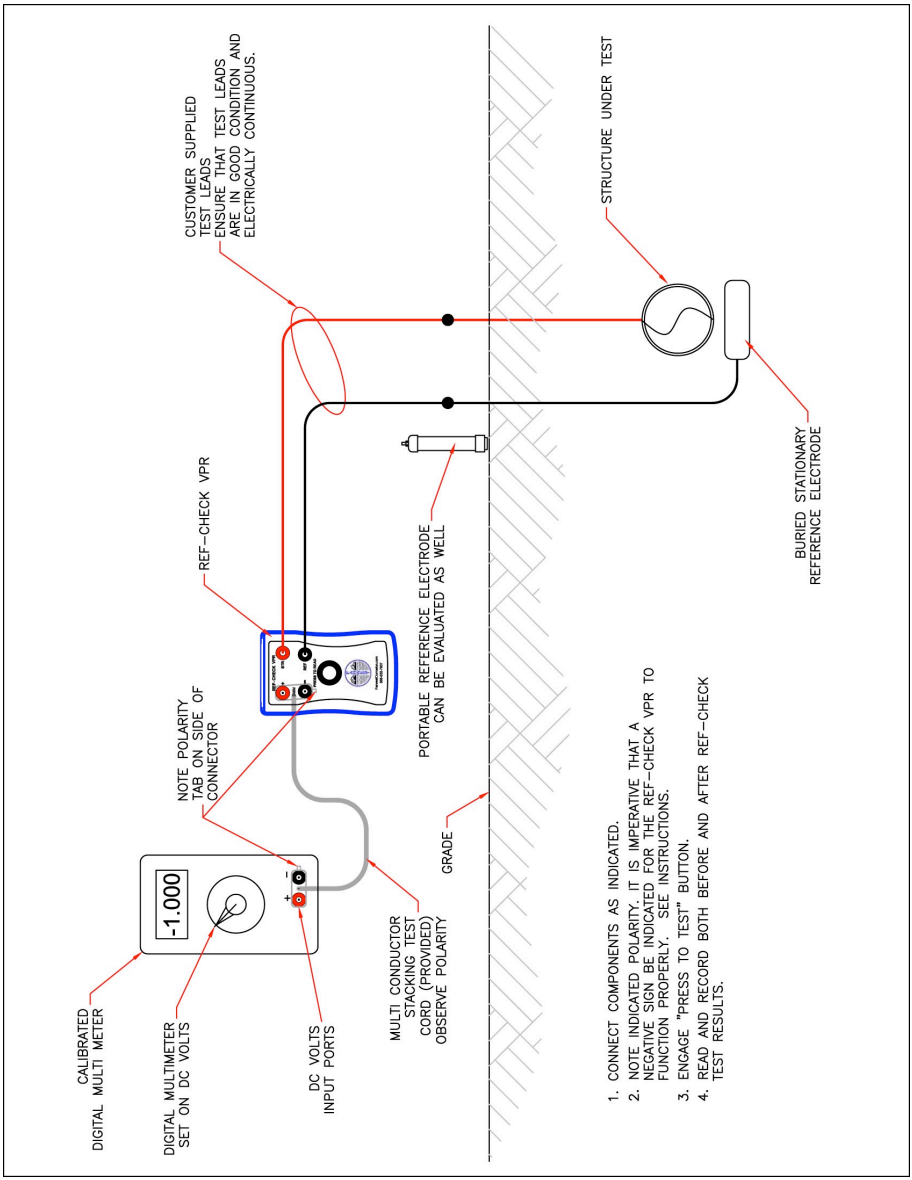
1. The DMM is properly calibrated and fully functional.
2. The meter test leads are in good electrical condition, i.e., no broken wires or dirty/intermittent connectors.
3. The structure and CPRE cable leads are in good electrical condition. A broken or high resistance cable lead will give an indication of a defective CPRE.

Ref-Check VPR & DMM Set-Up

(Refer to the connection diagram on next page)

1. Using the provided dual banana plug test cord, connect one end of the cord to the DMM voltage ports and the other end of the cord to the Ref-Check VPR **"**DMM" input ports on the left side of the instrument.
    a. **Note Polarity! The test cord has a small tab labeled "GND" protruding from the negative terminals at both ends.**
2. Connect the Pipe/Structure cable lead and the CPRE cable leads to the Ref-Check VPR in the ports labeled "STR." and "REF."

Ref-Check VPR Set-Up Diagram



Standard Ref-Check VPR Tests

1. After the cable leads are connected to the structure under test, a negative voltage reading should be displayed on the DMM. If reading displayed is not negative, either the test cable leads are incorrectly connected or the structure under test has shifted to positive. (This would require further investigation).

   NOTE: In order for the Ref-Check VPR to operate properly, the cable leads must be installed correctly.
2. The initial voltage displayed is a direct reading from the DMM as the Ref-Check VPR provides an electrical by-pass until the "PRESS TO READ" button is pressed.
3. To check the quality of CPRE contact resistance, press the "PRESS TO READ" button. If there is any appreciable contact-to-earth resistance from the CPRE, **the DMM will now display the corrected potential**. If the contact-to-earth resistance of the CPRE is good/sufficiently low, little if any change in the displayed voltage will be evident.
4. As noted above, the Ref-Check VPR can be used to confirm good contact-to-earth of a portable CPRE as well as coupons during routine surveys.

Important Notes

- When used with a portable CPRE**, it is important that the plastic body of the CPRE is dry and nothing is touching the top cable connection point of the CPRE, including your hand**. Any moisture or conductive paths, other than the contact to the earth can result in reading errors.
- The Ref-Check VPR can be used on structures with induced AC voltage, up to 50 VAC, without harm to the instrument. However, AC voltages above 15 volts may introduce some errors to the Ref-Check VPR corrected reading. The Ref-Check VPR cannot capture corrected induced AC PSPs. NOTE: AC voltages above 15 volts can present a shock hazard. Extra caution should be exercised.
- The Ref-Check VPR does NOT calibrate CPREs. The CPRE manufacturer, prior to delivery, certifies the accuracy or calibration of the CPRE. The accuracy of the reading you obtain

from any CPRE, while using a standard DMM, is dependent on two factors:

- The CPRE's ability to provide an accurate reference voltage.
- Adequately low contact-to-earth resistance to provide the current required to operate/display an accurate reading on the standard DMM. If the CPRE is drying, this eventually results in high contact-to-earth resistance. In this case, "meter loading" is the root cause of the initial low (inaccurate) reading. However, in the vast majority of cases, the Ref-Check VPR will be able to provide an accurate reading from a compromised CPRE.

Testing Tip

Carry the Ref-Check VPR and DMM in a small utility tray with the test cables connected. Because the Ref-Check VPR has a default "OFF" condition, you can conduct other testing with the DMM such as normal PSPs, shunt current reads, as well as rectifier voltage and current readings. This is accomplished without changing test leads or the meter function.

Calibration

The Ref-Check VPR has a built-in functionality, accuracy verification and "Battery Check" feature.

NOTE: The accuracy of the voltage levels displayed is dependent on the **calibration/accuracy of the DMM** used with the Ref-Check VPR. There is no need to send the Ref-Check VPR for third-party calibration.

Battery Check & Accuracy Tests

Ensure that the Ref-Check VPR is connected to the DMM with the provided dual banana test cord as shown in the provided drawing. Set the DMM to measure "DC Volts". No Structure or Reference connections are required

Note: There are two small buttons on the end-cap of the enclosure used to conduct the following tests. These buttons are labeled: "#1 BAT." and "#2 SIM"

Battery Test: To test the internal battery condition, simultaneously press and hold the "PRESS TO READ" and the "#1 BAT" button. Record the voltage value displayed on the DMM. A serviceable battery should read 2.8 volts DC or greater.

Simulated Compromised CPRE: Press only the "#2 SIM" button and note the reading. It should be approximately half the reading obtained in Battery Test mode.

Accuracy Test: Simultaneously press and hold the "PRESS TO READ" and the "#2 SIM" button. The voltage displayed should be within 5

millivolts (0.005 V) of the voltage measured in the Battery Test. This test simulates a high resistance CPRE with a corrected reading.

Changing Batteries

1. Remove the silicone rubber boot.
2. Remove the four screws on the back of the instrument enclosure and remove the cover.
3. Slide the two coin batteries out of their mounting frame.
4. Install two new CR-2032 coin cells. Be sure to observe polarity as the "+" should be facing up on **both** coin cells.
5. Replace the cover, the four screws and the silicone rubber boot.
6. Perform the function and accuracy tests described above.

Trouble Shooting Guide

Issue	Possible Solution
Reading is unstable in the "Default Mode", i.e., no buttons pressed	Check cable leads and connectors for breaks or intermittent connections.
Corrected Ref-Check VPR reading is unstable	Check cable leads and connectors for breaks or intermittent connections. Test for induced AC on the structure. AC voltages above 15 volts may cause stability and accuracy issues.

Lifetime Warranty

The Farwest Corrosion Control Company Ref-Check VPR is warrantied against defects in material and workmanship for the lifetime of the device. The warranty does not apply to any product that has been subject to obvious physical damage, misuse, neglect, or abnormal conditions of operations.

If you have a warranty issue, return the Ref-Check VPR to Farwest. Upon examination by Farwest Corrosion, and to our satisfaction that the product is defective, we will replace or repair the Ref-Check VPR at our discretion, without charge to the customer. The customer is responsible for all shipping charges to and from Farwest Corrosion.

Appendix

Meter Loading Explained

Once connected to the circuit under test, in this case the CPRE to structure, the current required to operate the DMM changes the conditions in the circuit compared to what it was before the meter was connected. The DMM automatically imposes a load on the CPRE circuit. If the CPRE has a high contact-to-earth resistance, i.e., dried out, this compromised, or weak, galvanic cell cannot provide adequate energy to operate the DMM properly. The DMM is loading down the weak galvanic CPRE/pipeline cell, thus the voltage displayed on the DMM will be lower than normal.

As an analogy, you may have experienced a similar scenario when the batteries in your flashlight become weak and the light intensity dims. Why? The light bulb is not getting the required voltage to operate properly. In cathodic protection, the light bulb would be the DMM and the weak flashlight batteries become the “cell” created between the CPRE and the pipeline.

In the example presented in the Introduction, where physical conditions are changed by adding water, this is a classic case of correcting meter loading. Meter loading will affect the ability to obtain an accurate reading from any CPRE even under the best conditions. Fortunately, in many instances, the effect from meter loading may be minimal and the resultant error is acceptable.

In instances where a lower than expected reading is indicated with a stationary CPRE, the question is, "Now what?" Once a stationary CPRE is tested and found to be compromised, the technician has four choices:

1. Accept the lower PSP with the understanding that it may be inaccurate.
2. Purchase a specialty DMM with a higher input resistance to obtain a more accurate reading. Such instruments can cost $850.00 to $3,000.00 and these instruments will still impose some level of meter loading on the CPRE.

3. Retire the CPRE and use a portable CPRE for future testing but this may present issues with unacceptable IR drop errors.
4. Install a new stationary CPRE. This of course would be very expensive.

How and why copper-sulfate reference electrodes become unserviceable

The most common problem with stationary soil-type CPREs is that they simply dry out. Once they are dehydrated, the contact-to-earth resistance will increase and be affected by meter loading.

Even if installed in permanent moisture, the CPRE still has a finite life. In order for a copper sulfate CPRE to function, there must be an adequate amount of internal copper sulfate to permeate the porous end-plug and migrate into the soil. Eventually, the volume of copper sulfate will deplete and when this occurs, the CPRE will become unreliable. There is no answer as to how long this will take to occur. The physical size of the CPRE, the volume of copper sulfate reserves, the soil composition and relative moisture all play a role in affecting the service life of the CPRE.

Ref-Check VPR Theory of Operation

The Ref-Check VPR utilizes a high efficiency electronic device developed for modern medical Electrocardiogram (ECG) machines. As you may know, an ECG machine uses numerous electrodes placed on the body to measure small voltage signals created by the human heart. The inconsistency in contact resistance to the body from patient-to-patient requires very advanced electronics to capture the correct voltage values. This same technology is used in the Ref-Check VPR. The solid-state device used is referred to as a “unity gain buffer” amplifier, which is also known as a “voltage follower”, because the output voltage follows or tracks the input voltage.

The electronics in the Ref-Check VPR converts the voltage from the CPRE and structure circuit that has a high circuit resistance to an identical voltage level with relatively low impedance required by the DMM. The interposed buffer amplifier prevents the DMM circuit from “loading” the CPRE circuit and interfering with its calibrated voltage.