Challenges Providers Face with Grounding Electrode Systems at Remote Sites

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Challenges

- Definitions
- Testing/Repairs/Solutions
- Calculations
- New build calculated value vs. 3 pin test result

What is a ground grounding electrode system?

ATIS-0600333.2013 5.1

1. Ground rods interconnected with bare plated conductors forming a continuous ring around the building.
2. A counterpoise system with ground rods connected to bare plated conductors that form radials extended from the building.
3. Concrete-encased electrodes.
4. Well casings.
5. Ground grids under the building.
6. Continuous metallic water pipe.
7. Building structural steel.

What is a ground grounding electrode system?

NEC 250.53 (B)

Two or more grounding electrodes that are bonded together shall be considered a single grounding electrode system.

What is a grounding electrode?

NEC 250.52

(A) Electrodes Permitted for Grounding

(1) Metal Underground Water Pipe.

(2) Metal Frame of the Building or Structure.

(3) Concrete-Encased Electrode.

(4) Ground Ring.

(5) Rod and Pipe Electrodes.

(6) Other Listed Electrodes.

What is a grounding electrode?

(7) Plate Electrodes.

(8) Other Local Metal Underground Systems or Structures.

(B) Not Permitted for Use as Grounding Electrodes.

(1) Metal underground gas piping systems

(2) Aluminum

What is a ground ring?

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1. Ground rods interconnected with bare plated conductors forming a continuous ring around the building.

What is a ground ring?

NEC 250.52 (A)(4)

A ground ring encircling the building or structure, in direct contact with the earth, consisting of at least 6.0 m (20 ft) of bare copper conductor not smaller than 2 AWG.

NEC 250.53 (F)

The ground ring shall be buried at a depth below the earth’s surface of not less than 750 mm (30 in).

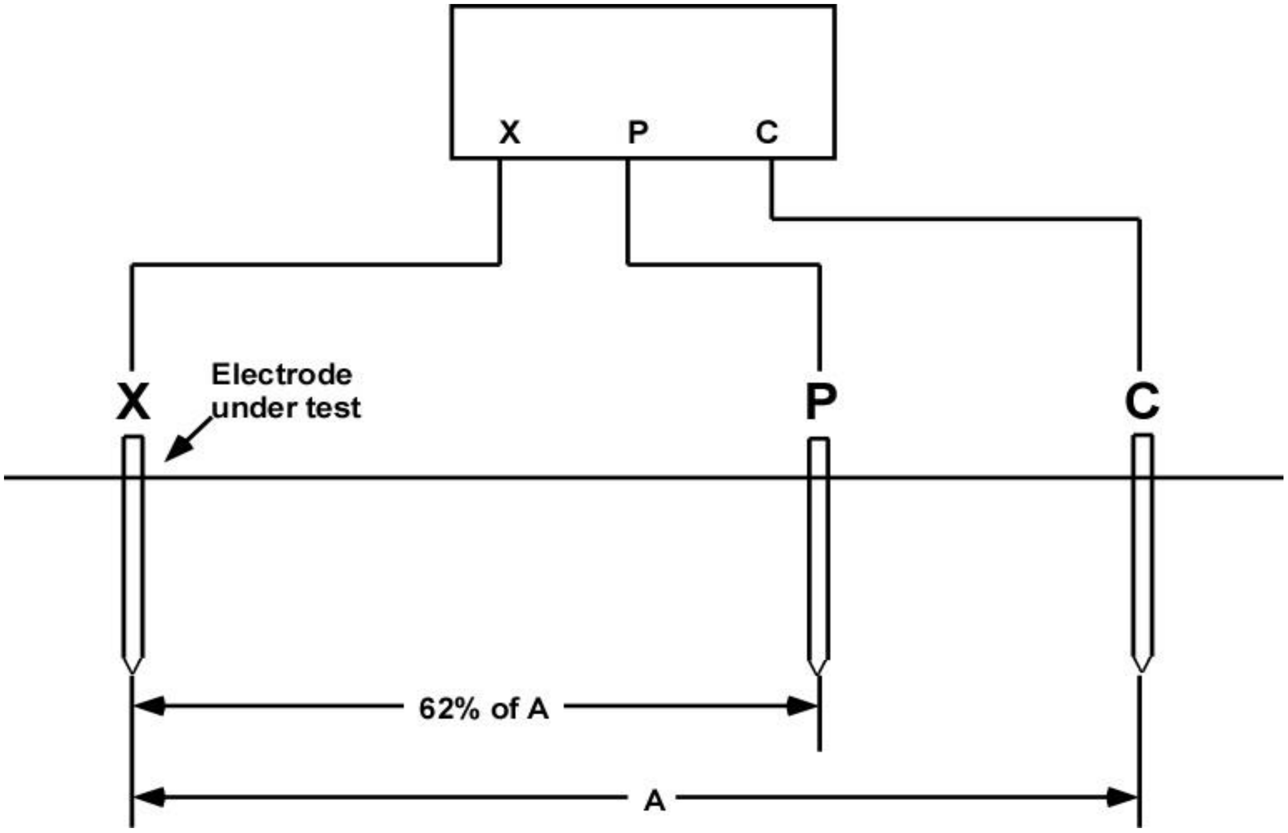
3 pin test

- Method for testing existing ground electrode.

- Total bar should be taken on grounding electrode system prior to isolating ground electrode under test.

- Potential and current probes must be sufficiently spaced for accurate test results.

3 pin test



3 pin test

"Getting down to earth" ©2010 Megger

Approximate location of reference probes

Max Dimension, Ft.	Distance to P, Ft.	Distance to C, Ft.
2	40	70
4	60	100
6	80	125
8	90	140
10	100	160
12	105	170
14	120	190
16	125	200
18	130	210
20	140	220
40	200	320
60	240	390
80	280	450
100	310	500
120	340	550
140	365	590
160	400	640
180	420	680
200	440	710

Repairs

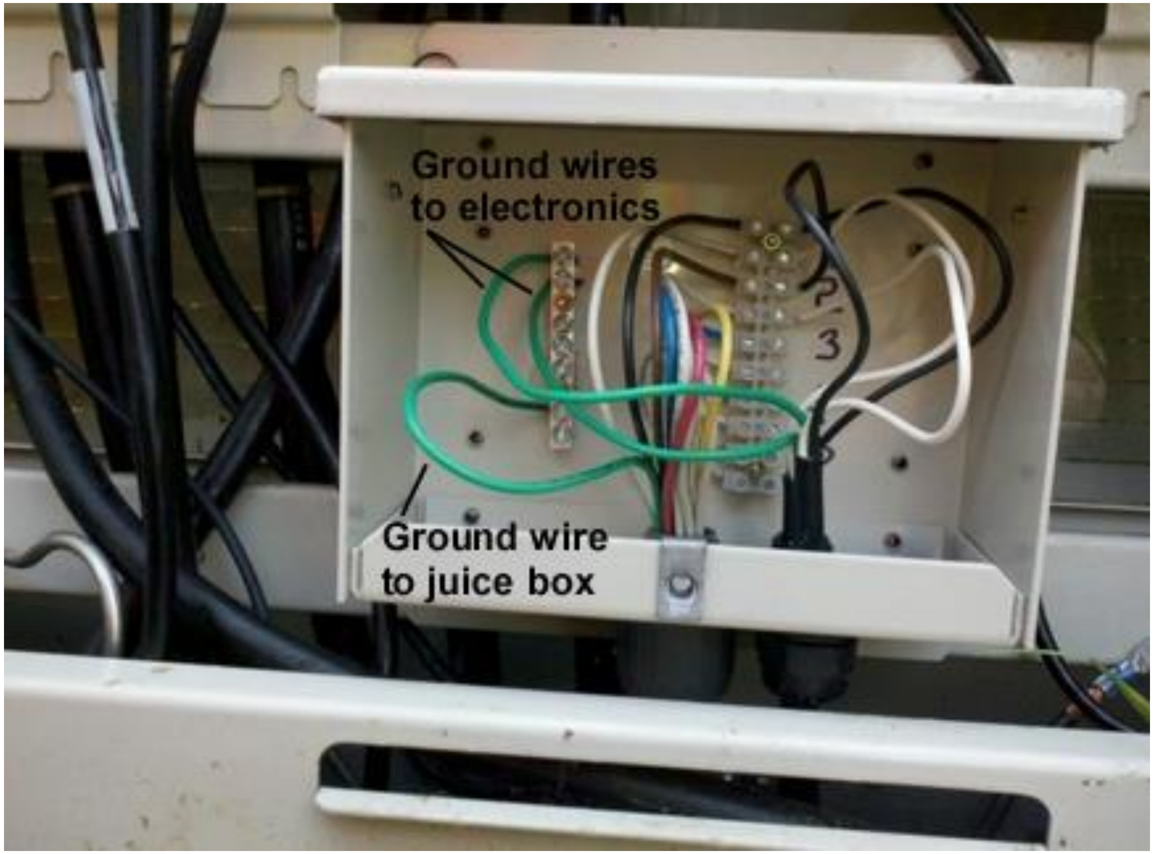
Scenario 1. Improperly built grounding electrode system. Allowed shielding current to pass through remote electronics, causing repeat outages.

Fix: Repaired grounding electrode system

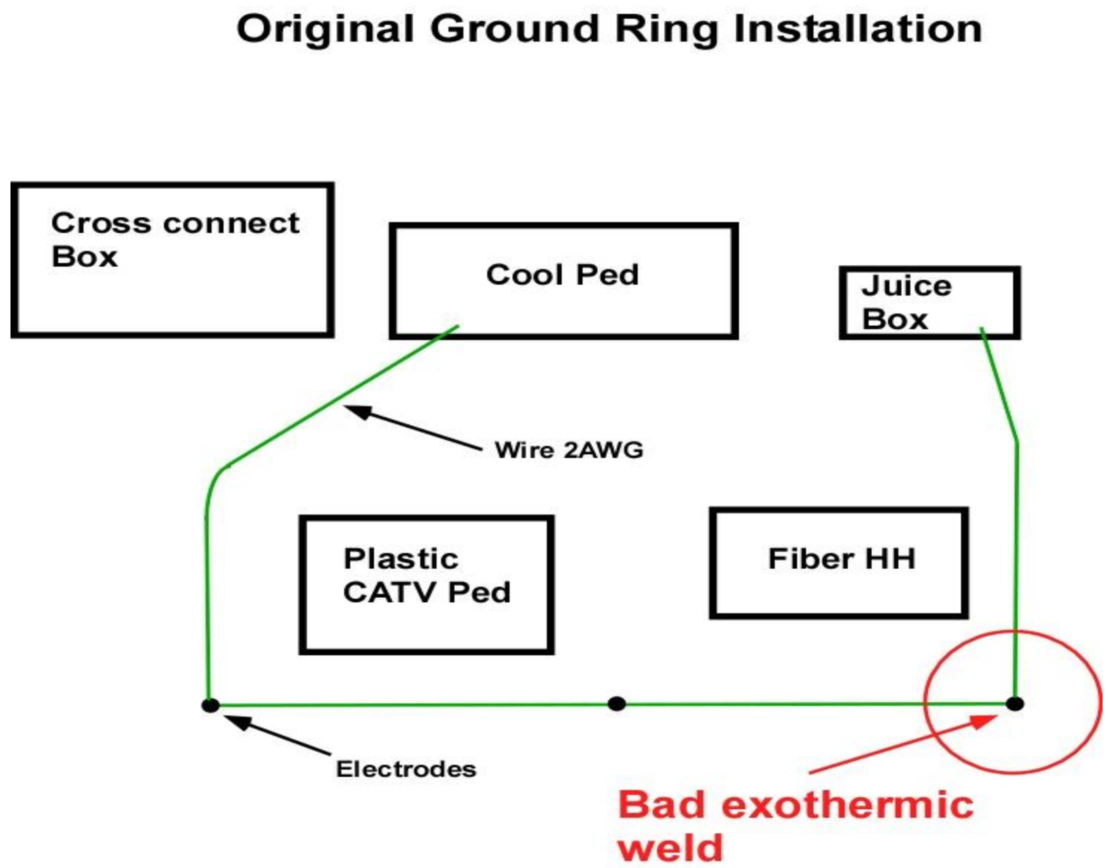
Scenario 2. Existing remote site overbuilt by transmission line. Damage to remote electronics from transient voltage and physical damage to equipment from falling ice.

Fix: Installed SensorGuard system.

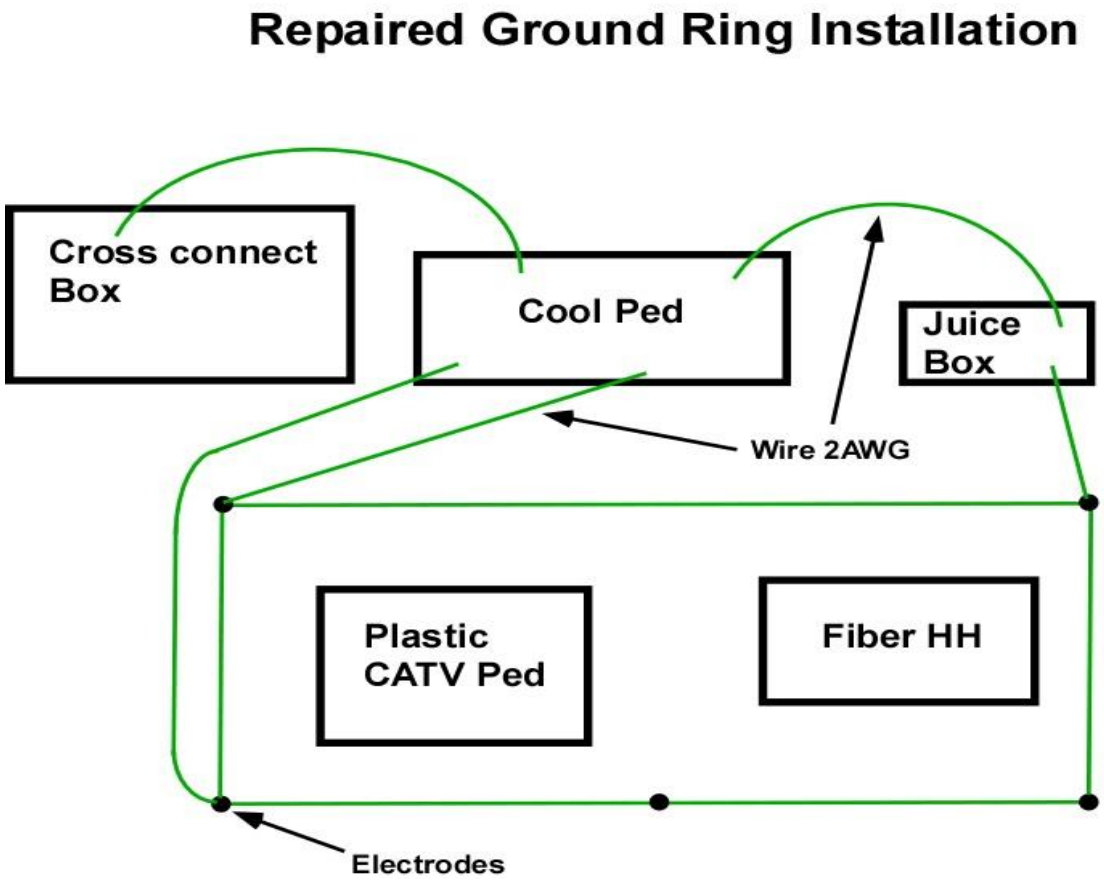
Repairs, scenario 1



Repairs, scenario 1



Repairs, scenario 1

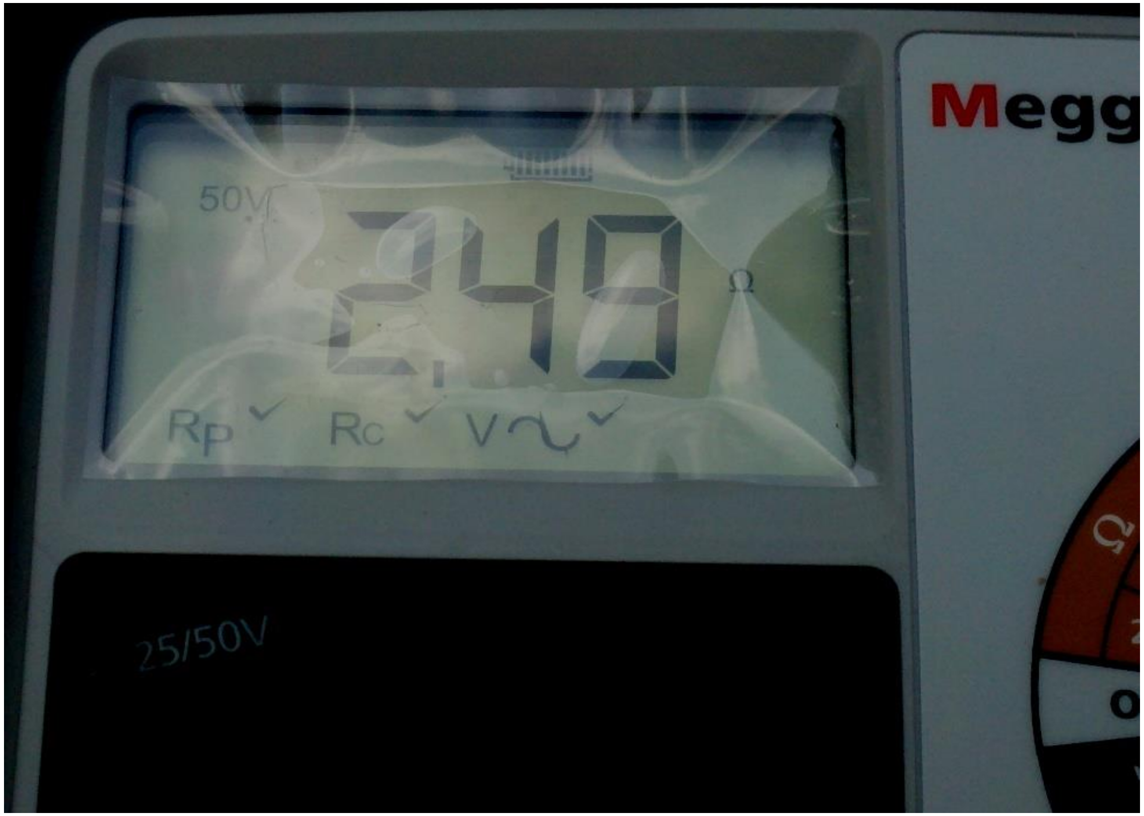


Repairs, scenario 1

Exothermic welds

Repairs, scenario 1

Three pin test results after repairs completed



Repairs, scenario 2

Existing site overbuilt by transmission line

Repairs, scenario 2

Existing site overbuilt by transmission line

4 pin soil resistivity test

Frank Wenner developed the method for measuring the resistivity of earth. This method is commonly referred to as the 4 pin test.

- 4 small probes of equal length and diameter are placed in a straight line at equal spacing.

- 2 probes as current and 2 probes as potential.

- The probes are connected to the test instrument and resistance between the probes is calculated.

- The effective resistivity of the soil can calculated.

- Easier and more cost effective than 3 pin method for new sites.

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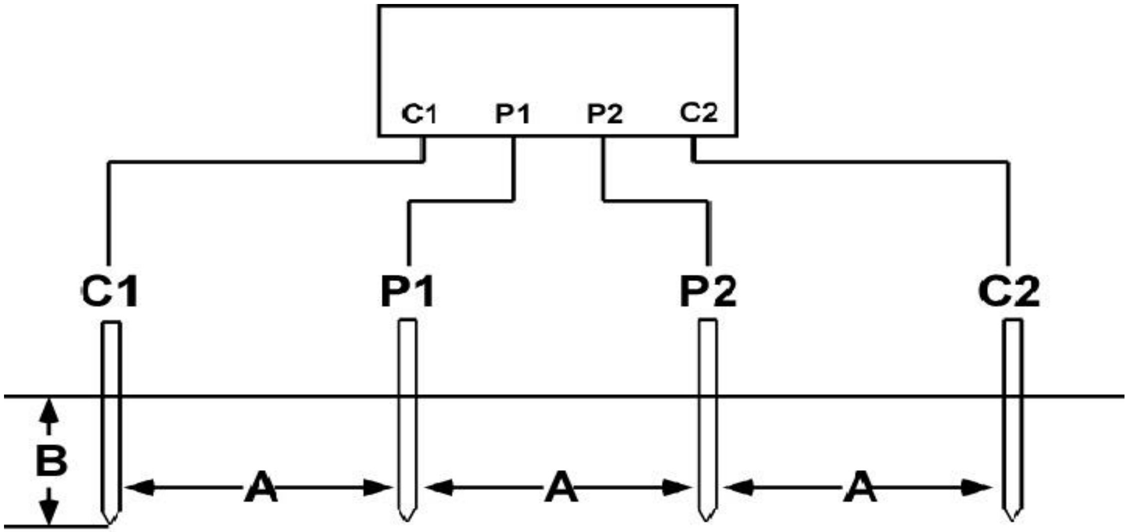
4 pin soil resistivity test



Note: Depth (B) of probes should equal 1/20th of probe spacing (A)

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Calculations

Frank Wenner, Bulletin of the Bureau of Standard

Approximate soil resistivity.

$$\rho = 2\pi a R$$

ρ = the apparent resistivity of soil in Ω-m
π = pi (3.1416)
a = the distance between adjacent electrodes in m
R = the measured resistance in Ω

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Calculations

REA Bulletin 1751F-802 App. B 2.1

Approximate resistance of single vertical electrode.

$$R_r = \frac{\rho}{2\pi L_r}\left[ln\frac{294.3L_r}{d_r}\right]$$

ρ = Earth resistivity in ohmmeters
L_r = Electrode length in meters
ln = Natural logarithm
d_r = Electrode diameter in centimeters

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Calculations

REA Bulletin 1751F-802 App. B 2.2.2

Approximate resistance of multiple vertical electrodes in a ring.

$$R_R = \frac{\rho}{2\pi n L_r}\left[ln\frac{294.3L_r}{d_r} + \frac{2L_r}{S} + ln\frac{2n}{\pi}\right]$$

ρ = Earth resistivity in ohmmeters

n = Number of electrodes

L_r = Electrode length in meters

d_r = Electrode diameter in centimeters

S = Electrode spacing in meters

Calculations

REA Bulletin 1751F-802 App. B 3.2.1

Approximate resistance of buried wire in a ring.

$$R_W = \frac{\rho}{\pi L_W}\left[ln \frac{12.732 L_W}{\sqrt{d_W h}}\right]$$

ρ = Earth resistivity in ohmmeters
L_W = Wire length in meters
d_W = Wire diameter in centimeters
h = Wire depth in meters

Calculations

REA Bulletin 1751F-802 App. B 4.3

Approximate mutual resistance between multiple vertical electrodes and a interconnected buried wire in a ring.

$$R_{WR} = \frac{\rho}{\pi L_w}\left[ln\frac{3.461L_w}{L_r}\right]$$

ρ = Earth resistivity in ohmmeters
L_w = Interconnecting wire length in meters
L_r = Electrode length in meters

Calculations

REA Bulletin 1751F-802 App. B 5.1

Approximate combined resistance of a grounding system with multiple vertical electrodes and a interconnected buried wire in a ring.

$$R_T = \frac{R_W R_R - R_{WR}^2}{R_w + R_R}$$

R_R = Parallel electrode resistance to ground
R_W= Bare wire resistance to ground
R_{WR} Mutual resistance between electrode and wire

Approximate soil resistivity Ω-m

Soil Description	Median	Minimum	Maximum
Topsoil, loam	26	1	50
Inorganic clays of high plasticity	33	10	55
Fills – ashes, cinders, brine wastes	38	6	70
Gravelly clays, sandy clays, silty clays, lean clays	43	25	60
Slates, shales	55	10	100
Silty or clayey fine sands with slight plasticity	55	30	80
Clayey sands, poorly graded sand-clay mixtures	125	50	200
Fine sandy or silty clays, lean clays	190	80	300
Decomposed gneisses	275	50	500
Silty sands, poorly graded sand-silt mixtures	300	100	500
Clayey gravel, poorly graded gravel, sand-clay mixture	300	200	400
Well graded gravel, gravel-sand mixtures	800	600	1,000
Granites, basalts, etc.	1,000	---	---
Sandstone	1,010	20	2,000
Poorly graded gravel, gravel-sand mixtures	1,750	1,000	2,500
Gravel, sand, stones, little clay or loam	2,585	590	4,580
Surface limestone	5,050	100	10,000

Calculations

Calculations

Optimal spacing between poles for testing.	Inches		Feet		
Enter Megger Pole Depth in Inches.	0				
Optimal Distances between poles in feet.			0.00		
Obtain Earth Resistivity, Meter Ohms.	Feet	Inches		cm	Meters
A= Enter Distance between poles.	0	0		0	0
R= Enter Value from Megger.	0				
*Formula is 2*Pi*A*R*		*Pi*	*A*	*R*	**Meter-Ohms**
	2	3.1416	0	0	0
Obtain the spacing between Electrodes.	Feet	Inches		cm	Meters
Enter Distances between (Electrodes) Rods.	0	0		0	0
Obtain the wire length.					
Enter # of (Electrodes) Rods.	0	Inches	Feet	cm	Meters
Enter Distance between (Electrodes) Rods in Feet.	0	0	0	0	0
Obtain Wire depth.	Feet	Inches		cm	Meter
Enter depth in feet that wire will be installed at.	0	0		0	0
Obtain Resistance in Parallel.					
Formula = (1/R1) +(1/R2)=(1/R x)		Result	(R1+R2)		(Rx)

Calculations

Soil resistivity L	53.508
Soil resistivity U	137.888
pi	3.14
Number of rods	4
Electrode legth in m	2.43
Electrode diameter in cm	1.588
Electrode spacing	3.04
Wire length in m	12.192
Wire depth in m	0.762
Wire diameter in cm	0.742
RW calculated value	19.19772
RR calculated value	7.577108
RWR calculated value	3.989661
RT calculated value	**5.358233**

Calculations

3 pin test result compared to calculated value

Questions?