AUCSC

Appalachian Underground Corrosion Short Course

Fundamentals Course

Soil Resistivity

Presented By: John Block

Corrosion Cell

Anode

Cathode

Metallic Path

Electrolyte

(Soil / Water)

Electrolyte

Designing a successful cathodic protection system requires an understanding of the resistivity of the environment (electrolyte) surrounding a pipeline.

Electrolyte

Soil resistivity is an electrical characteristic of the soil / groundwater which affects the ability of corrosion currents to flow through the electrolyte. Resistivity is a function of soil moisture and the concentrations of ionic soluble salts and is considered to be the most comprehensive indicator of a soils corrosivity

Soil Resistivity Measurements

- Determine the character and physical properties of soil deposits
- Indicate to some degree the level of corrosion that might be expected in underground pipelines
- Identify best location and depth for low-resistance electrodes (ground rods and anodes)

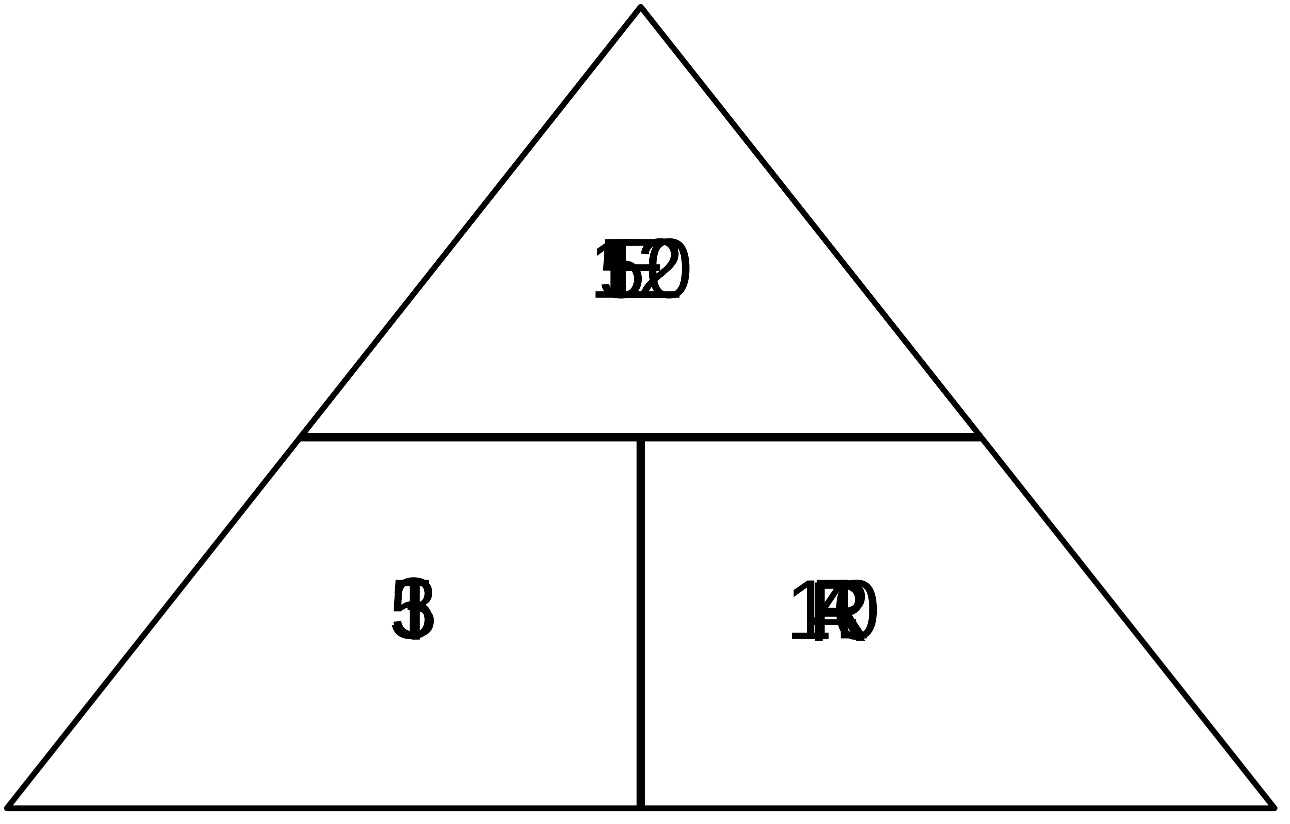
Soil Resistivity Measurements

- Soil Resistivity tests determine the reciprocal of conductivity for a particular soil
- Soil moisture plays a large part in resistivity.
- Low resistivity indicates a soil will be a good electrolyte.

Classification of Soil Resistivity

Resistivity (ohm-cm)	**Category**
Below 500 ohm-cm	Very Corrosive
500 to 1000 ohm-cm	Corrosive
1000 to 2000 ohm-cm	Moderate Corrosive
2000 to 10,000 ohm-cm	Mildly Corrosive
10,000 ohm-cm and above	Progressively less Corrosive

Ohm’s Law

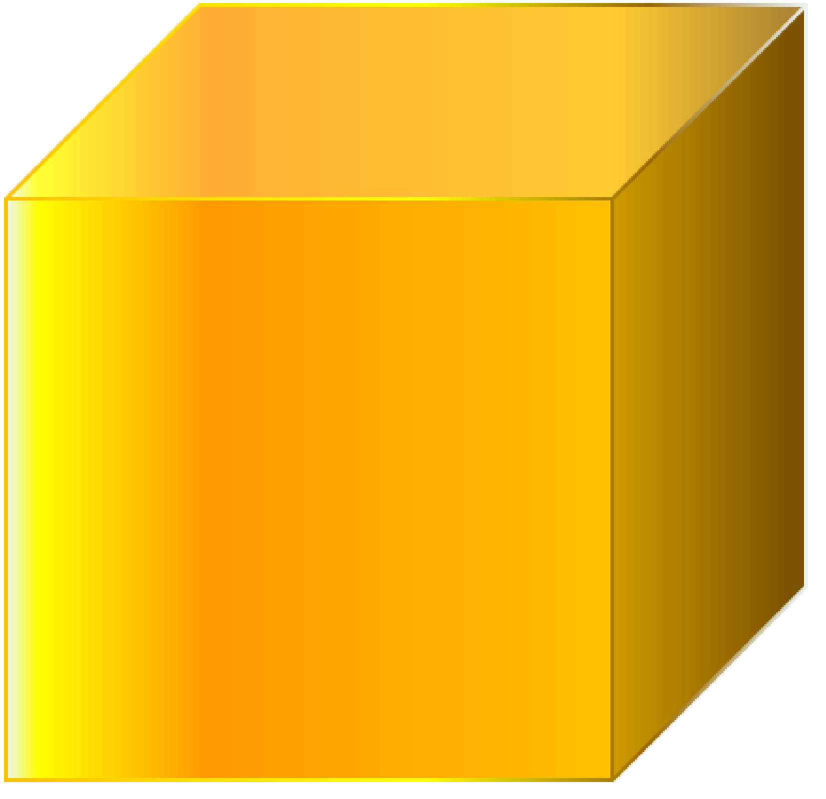


Resistance vs. Resistivity

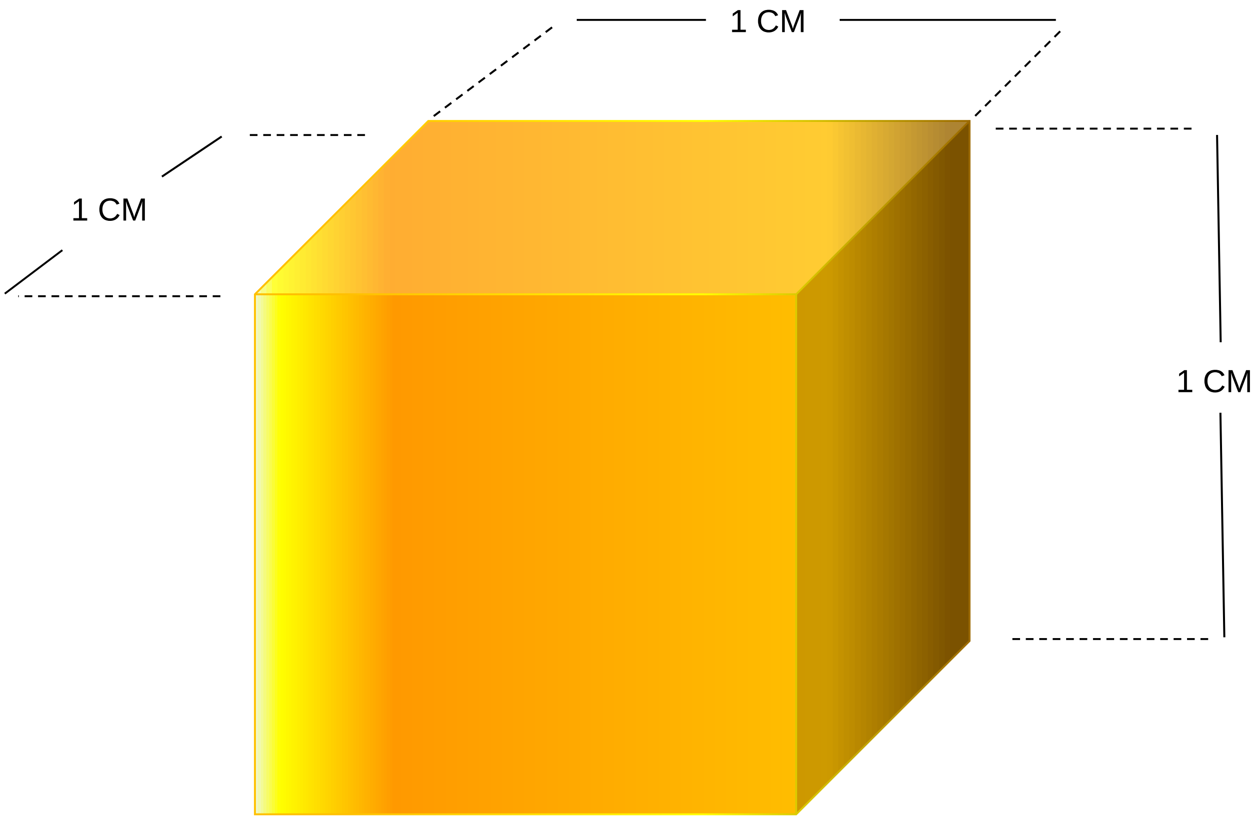
R = *P*

Resistance = Resistivity

(ohms) (ohm-cm)

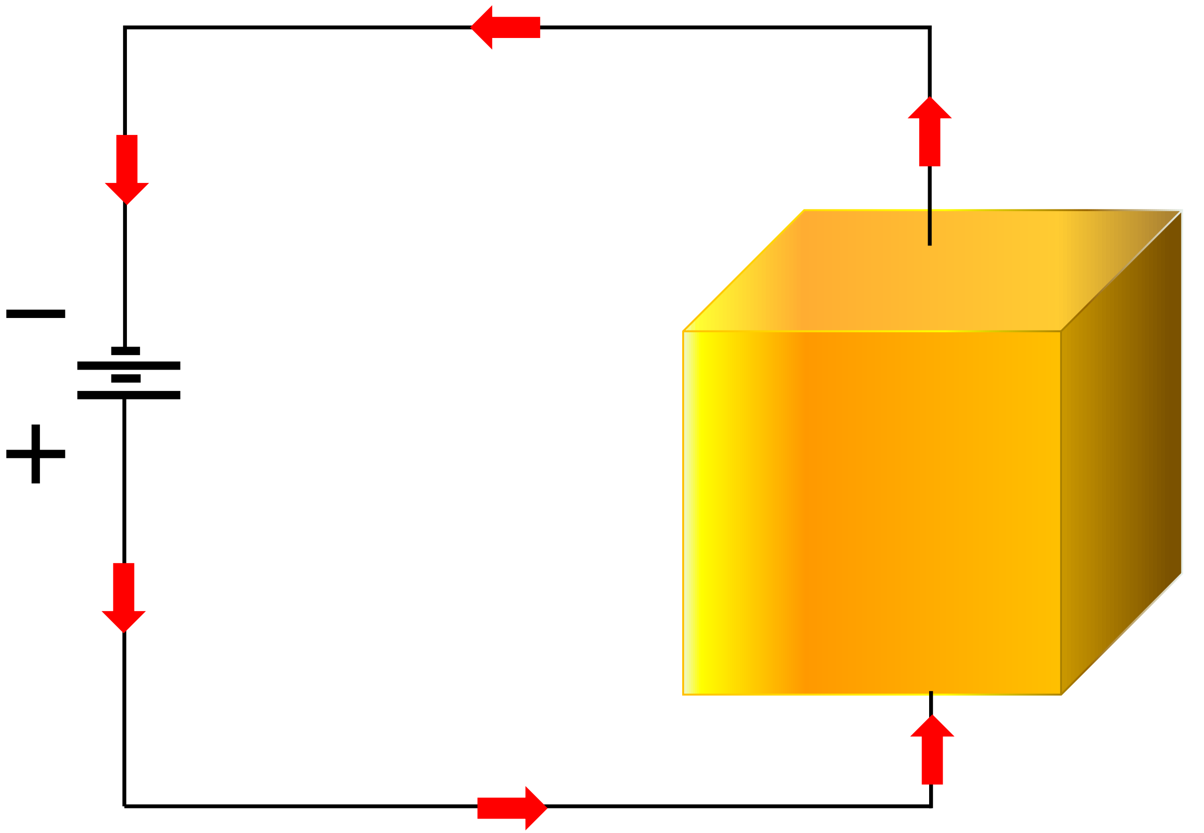


Resistance of Metal

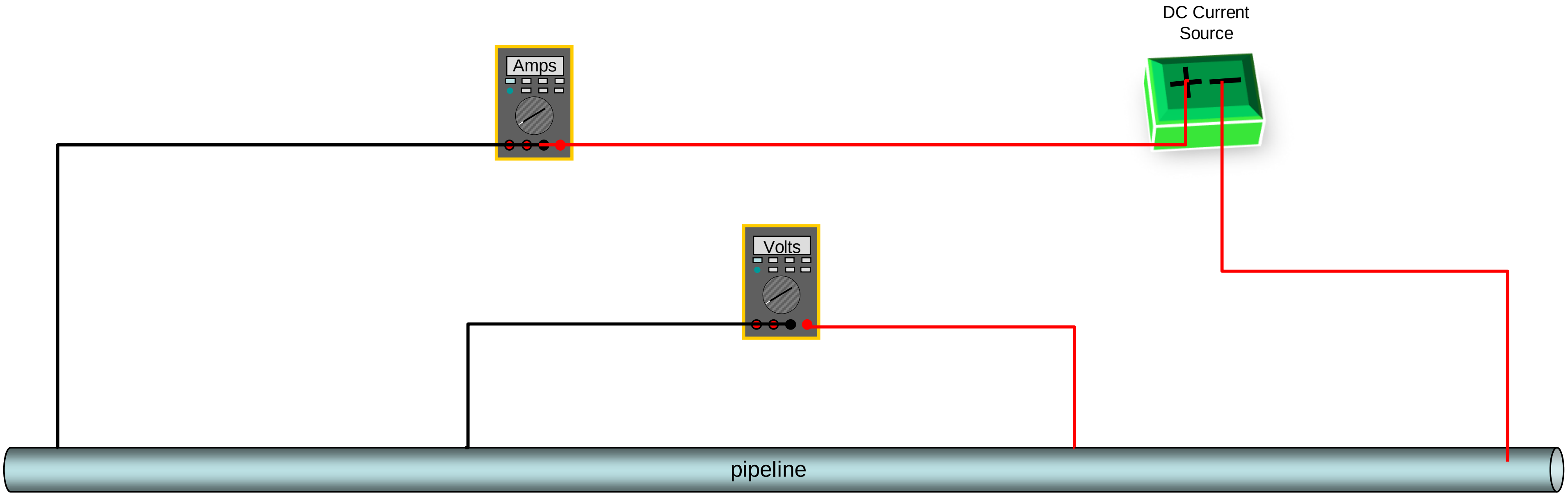


A **1-centimeter cube** is the standard size that is used to test the resistance of metals. Different metals offer different resistance to the flow of electrons.

Resistance of Metal



Pipeline Resistance



$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

Soil Resistivity Instruments

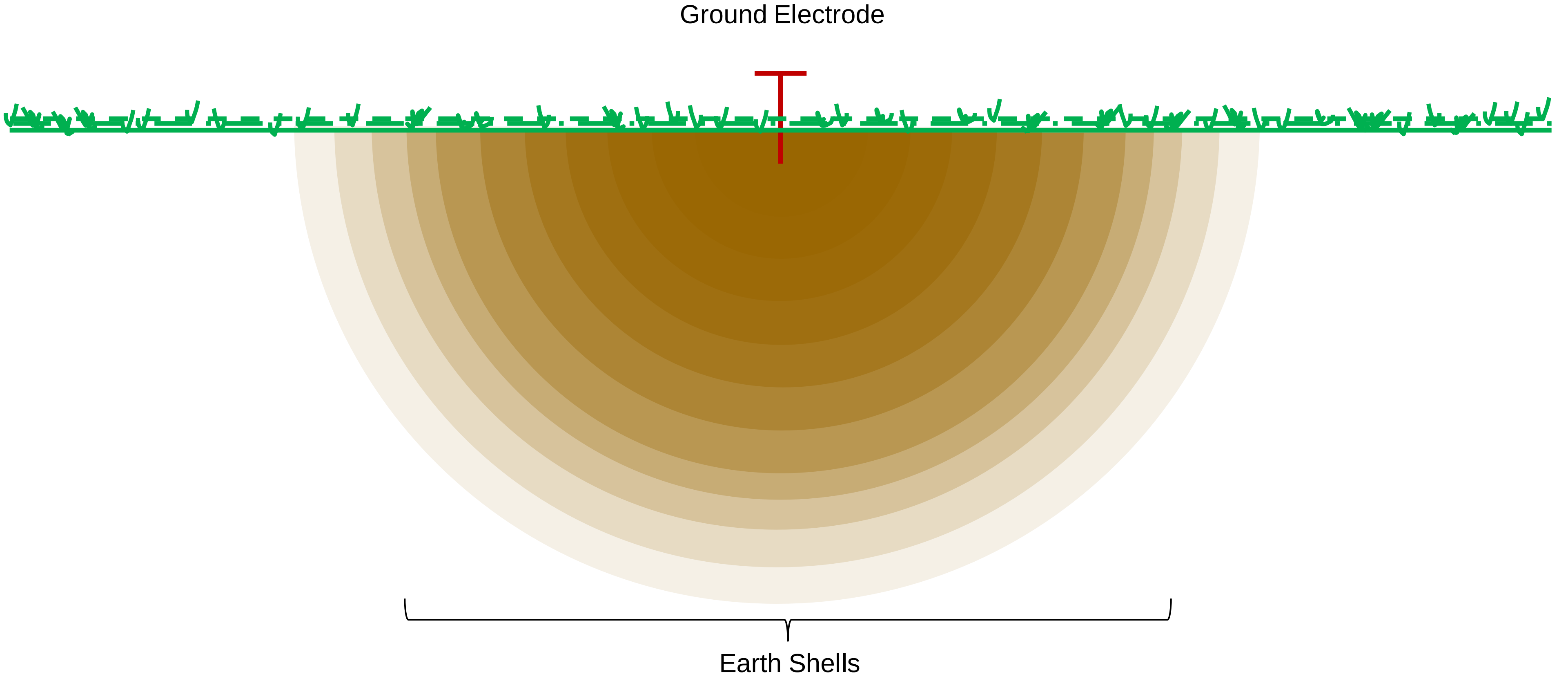
Shepard Canes

AC Soil Rod

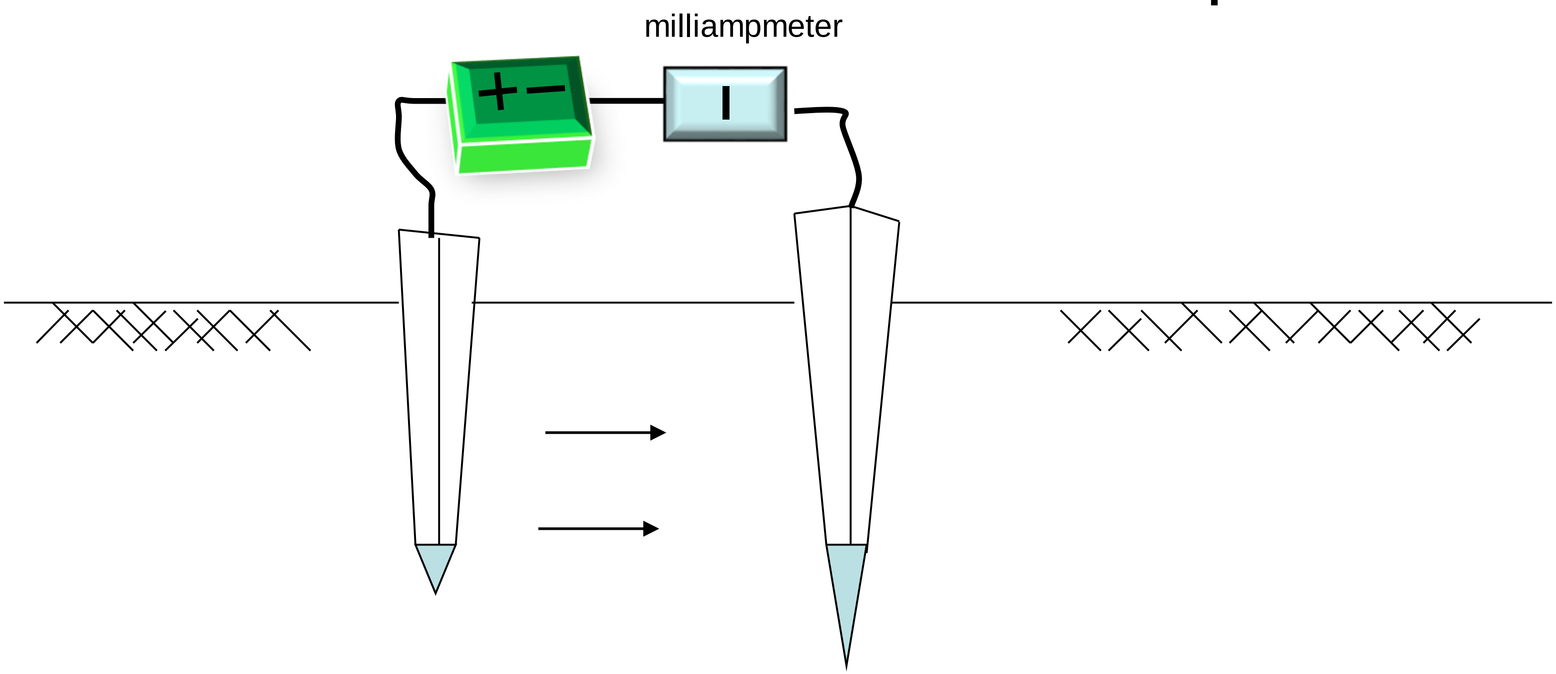
Soil Box

4 Pin Soil Resistivity Meter

Concentric Earth Shells Around an Earth Electrode



Shepard Canes

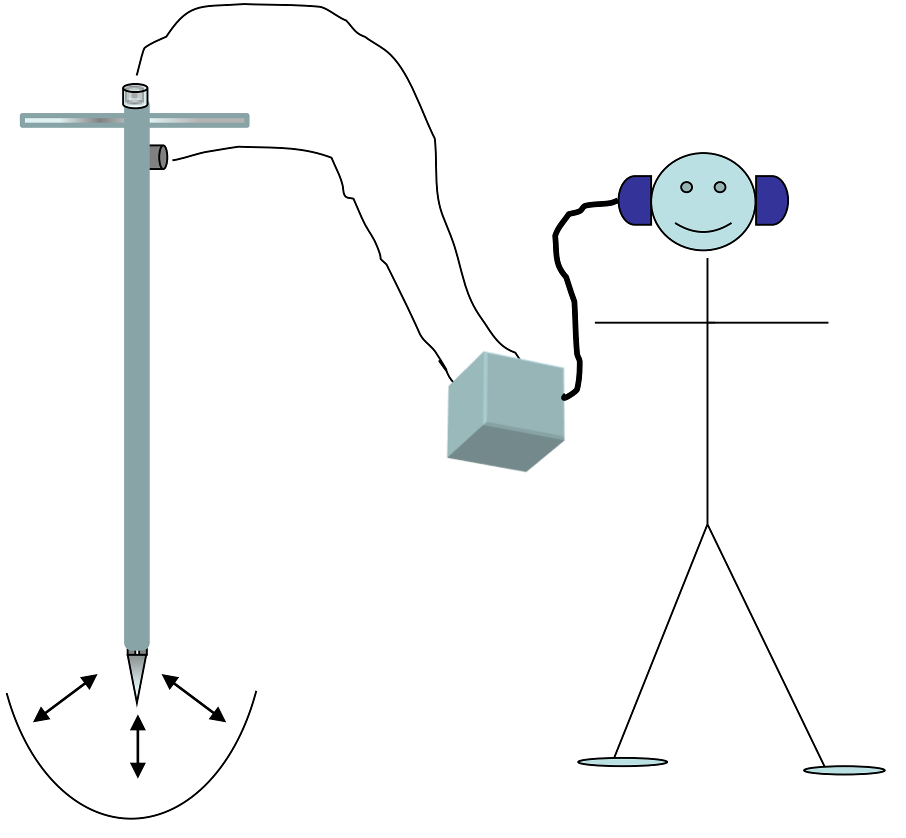


Current passed through the soil between two iron electrodes.

Cathode is larger than anode to avoid polarization

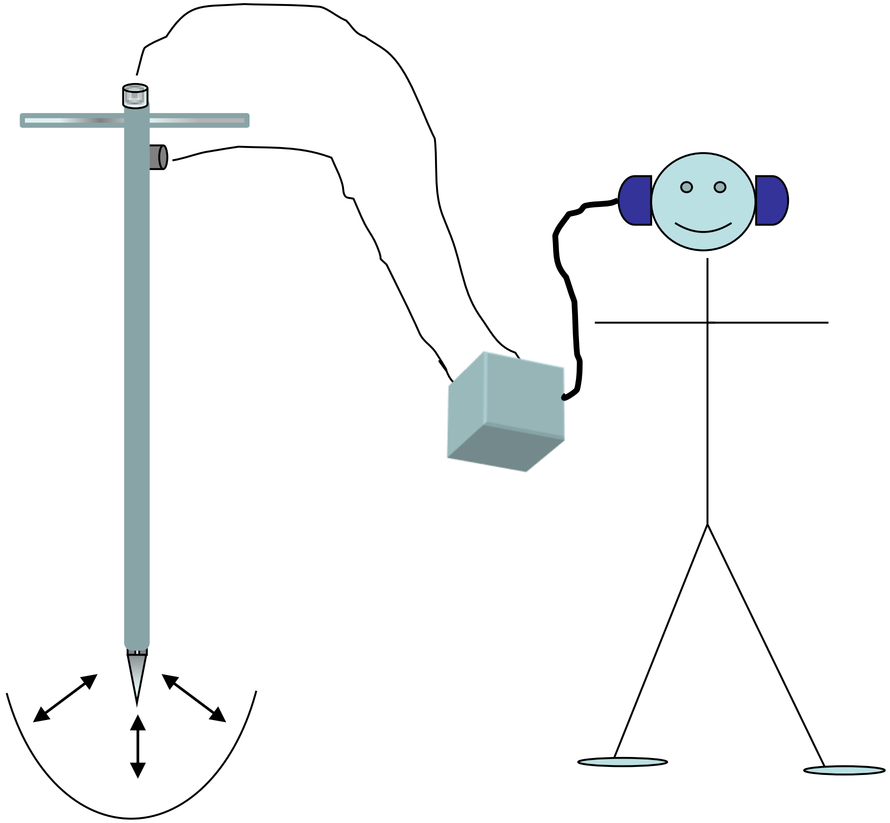
AC Soil Rod
(Collins Rod)

Current from an AC source is passed through the soil between a steel rod and an insulating tip. The slide wire in the AC Bridge is adjusted until balanced and there is no longer an audible, or a "null" is produced. The scale on the instrument is read in Ω-cm



AC Soil Rod
(Collins Rod)

Soil Resistivity in Ω-cm is measured within an inch or two around the tip of the AC Rod. The rod is calibrated hexagonal steel with a hardened steel tip insulated by a nylon washer. The connecting lead from the tip is brought up through the body of the 40’ rod to the insulated terminal. The other terminal is grounded to the body of the rod.

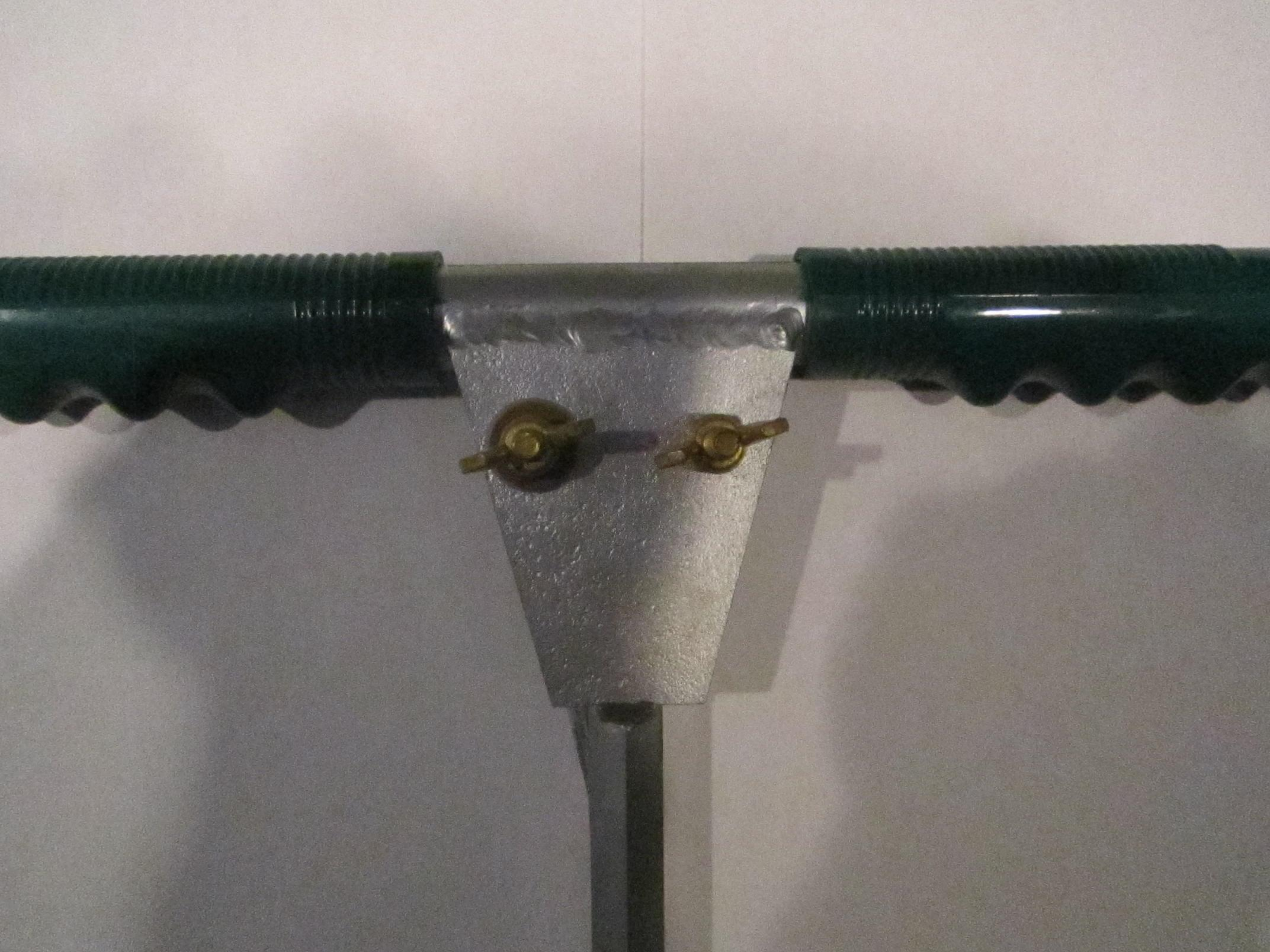



LEADS
0
100
250
500
1K
OHM-C.C.
TEST
1K
20K
POWER
PHONES
COLLINS INSTRUMENT CO., INC.
Angleton, Texas


LEADS
2K
2.5K
3K
4K
5K
6K
7K
8.5K
10K
12.5K
15K
17.5K
20K
25K
33K
40K
47K
75K
100K
220K
POWER
ON

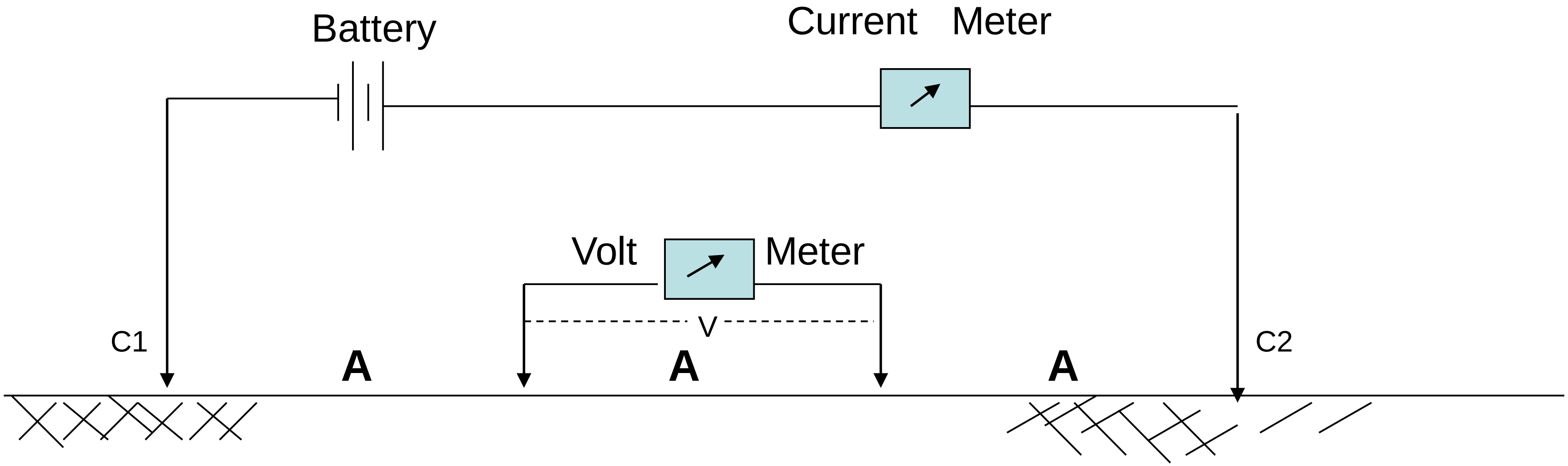

LEADS
1K
1.5K
2K
2.5K
3K
500
250
100
0
OHM-C.C.
TEST
POWER


TEST
1K
POWER
ON
OFF
PHONES
COLLINS INSTRUMENT CO., INC.
Angleton, Texas

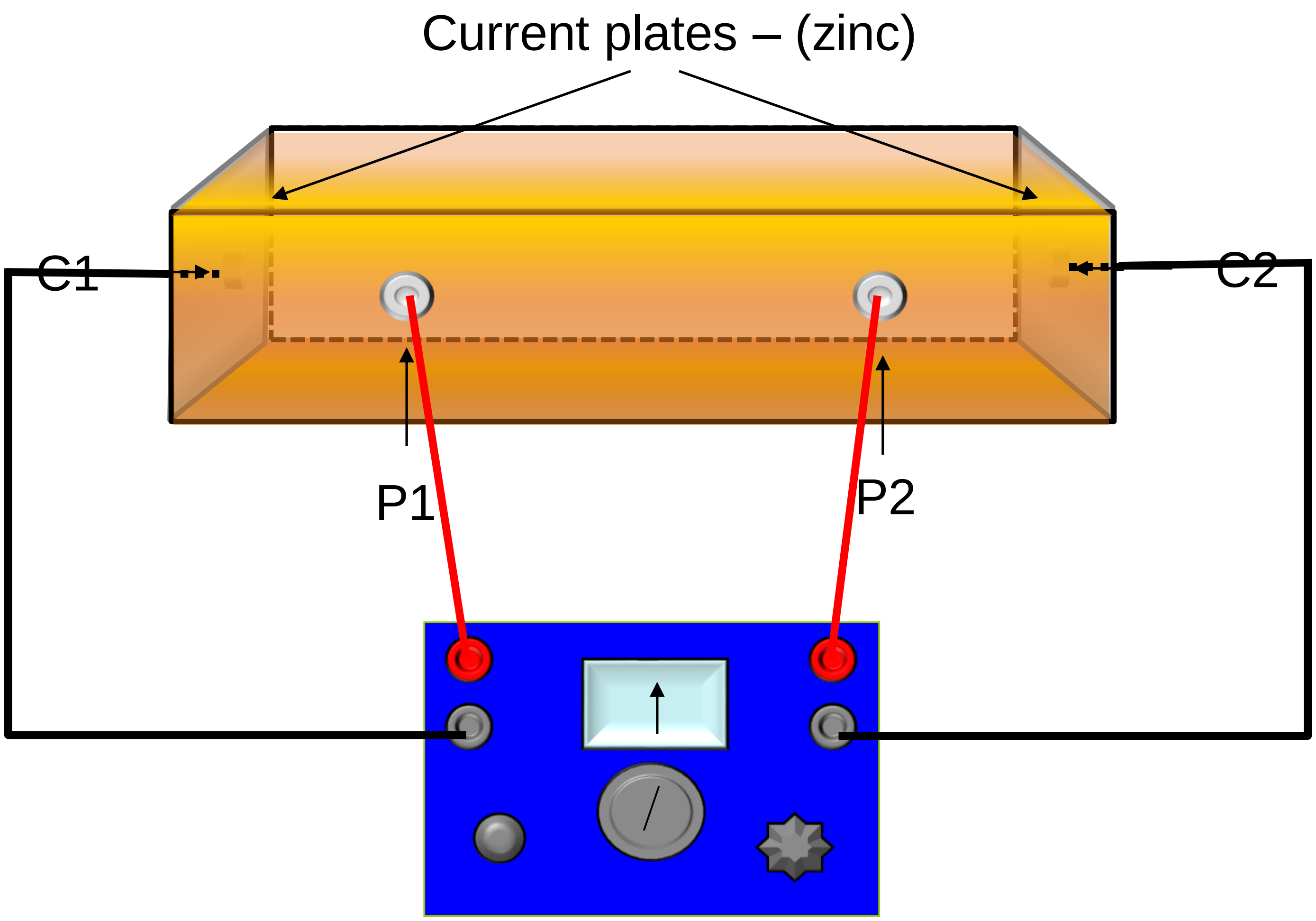



P/N 117-0002-50

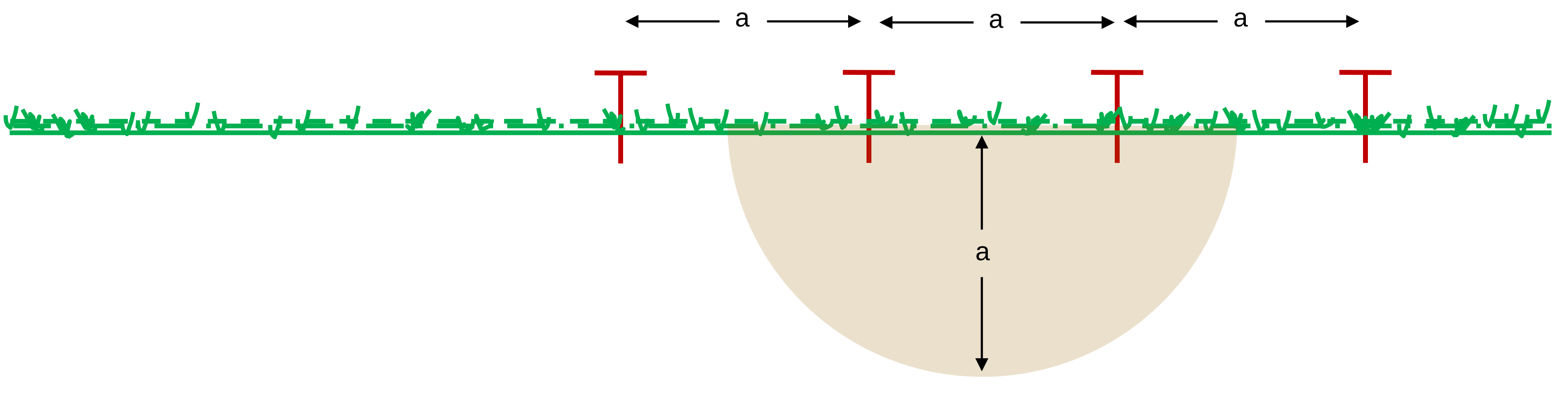
Wenner 4 pin Arrangement



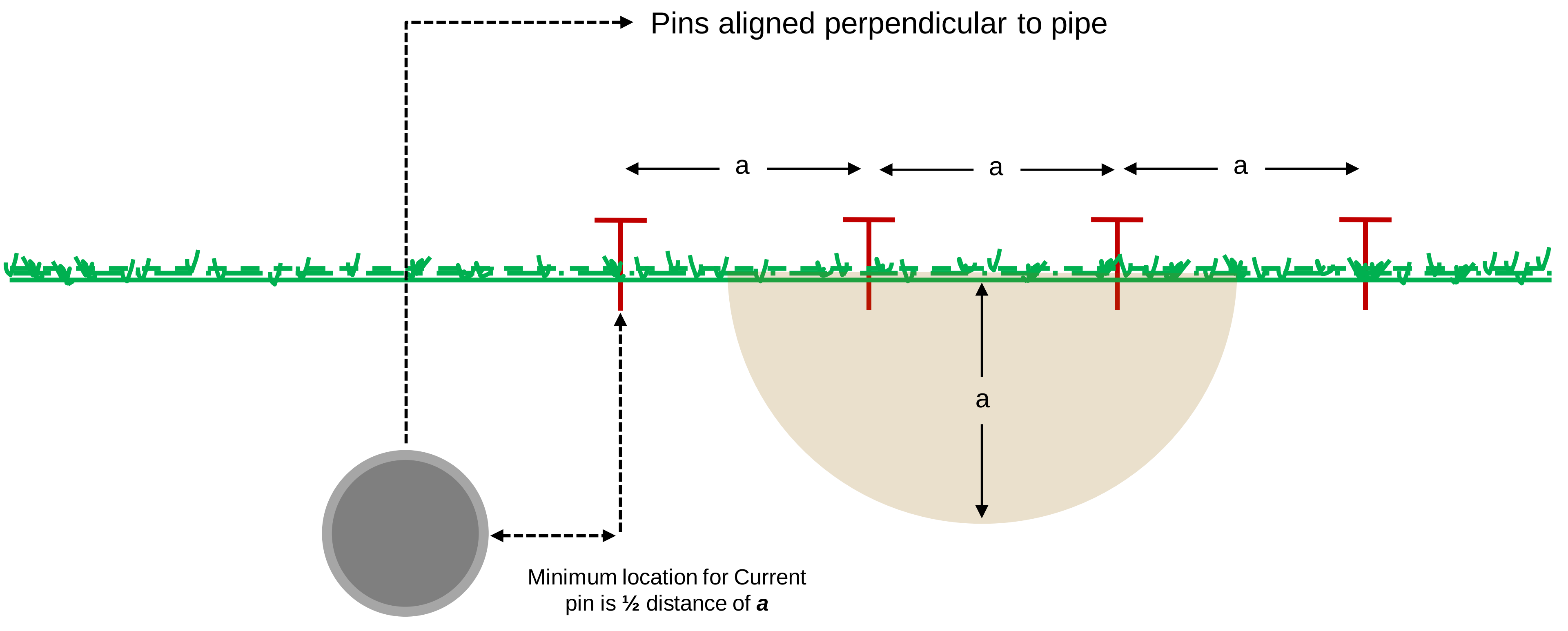
Soil Box



Pin Alignment for Soil Resistivity



Pin Alignment for Soil Resistivity



Wenner 4 Terminal Soil Test Formula:

$$\boldsymbol{p} = \mathbf{2}\,\pi\,\boldsymbol{AR}$$

p = average soil resistivity to depth ***A*** in ohm-cm

π = constant 3.1416

A = distance between electrodes in cm

R = instrument reading in ohms

Example A: measure soil resistivity to depth of five (5) feet

1 - Set distance between electrodes to five (5) feet

2 - Convert feet to centimeters to obtain ***A*** in the formula:

$$\mathbf{5} \times \mathbf{12} \times \mathbf{2.54}\ \text{cm} = \mathbf{152}\ \text{cm}$$

3 - Multiply **2** *x* **π** *x* ***A*** to obtain a constant for a given test set-up:

$$\mathbf{2} \times \mathbf{3.14} \times \mathbf{152} = \mathbf{955}$$

4 - Multiply instrument reading (**ohms**) by constant (**955)** to obtain soil resistivity in ohm-cm

If, for example, your instrument reading was **55** ohms, the average earth resistivity would be **55** *x* **955** = **52,525** ohm-cm at **5**' depth.

Example A: measure soil resistivity to depth of four (4) feet

1 - Set distance between electrodes to four (4) feet

2 - Convert feet to centimeters to obtain ***A*** in the formula:

4 *x* **12** *x* **2.54** cm = **122** cm

3 - Multiply **2** *x* **π** *x* ***A*** to obtain a constant for a given test set-up:

2 *x* **3.14** *x* **122** = **766**

4 - Multiply instrument reading (**ohms**) by constant (**766)** to obtain soil resistivity in ohm-cm

If, for example, your instrument reading was **26** ohms, the average earth resistivity would be **26** *x* **766** = **19,916** ohm-cm at **4**' depth.

Simplify Formula: $p = 2\pi$ AR

$$\mathbf{2} \times \mathbf{3.14} \times \mathbf{12} \times \mathbf{2.54} = \mathbf{191.5}$$

Multiply **191.5** *x* pin spacing in feet *x* instrument reading (ohms) = average earth resistivity depth ***A***.


SOIL RESISTIVITY METER
DL-1
Datalogger Connector
BATTERY
CHARGE
CHARGING
INDICATOR
Y
B
C1
C2
2 PIN METHOD
P1
P2
O
R
4 PIN METHOD
x1
x1
x1,000
x1,000
x1,000
x1,000,000
OHMS
KILOHMS
MEGOHMS
Start Here
RANGE SELECTOR
2 PIN
4 PIN
METHOD
FLASHING INDICATES LOW BATTERY
PUSH AND HOLD TO TEST
PUSH TEST
TINKER & RASOR
SR-2
T&R
www.tinker-rasor.com
OF METER IF PINS ARE DISCONNECTED OR IF RESULTS ARE NOT IN RANGE


ESISTIVITY METER
CHARGING
INDICATOR
Y
C1
C2
B
2 PIN METHOD
P1
P2
O
R
4 PIN METHOD
x1,000,000
2 PIN
4 PIN
METHOD
FLASHING INDICATES LOW BATTERY


CHARGE
Datalogger
Connector
x1
x1
x1,000
x1,000
x1,000
x1,000,000
OHMS
KILOHMS
MEGOHMS
Start Here
RANGE SELECTOR
TINKER & RASOR

TEST PROCEDURE (4 PIN METHOD):

Place four pins into the ground in a straight line. Connect all four cables from pins to RED and BLACK terminals on the SR-2 (spade or banana connection).
Move the Range Selector Switch counter-clockwise to the ***Start Here*** line.
Press and HOLD the ***PUSH TEST*** button.
Move the Range Selector Switch clockwise, pausing briefly (3 seconds) at each position of the switch.
When the LCD meter changes from 1_ _ _ ., you have found the correct range. Do not continue moving the Range Selector switch.
View the range the Range Selector Switch is in, Ohms, Kilohms or Megohms.
Use the conversion chart below to find the multiplier based on the Pin separation.

COLUMN A		COLUMN B		
PIN SEPARATION (m)	MULTIPLIER	PIN SEPARATION (m)	MULTIPLIER	RESULT
5 ft. (1.52m)	957.5	5.2 ft. (1.58m)	1000	(Range Selector) x (Display)
10 ft. (3.05m)	1915	10.4 ft. (3.17m)	2000	(Range Selector) x (Display)
15 ft. (4.57m)	2872.5	15.7 ft. (4.79m)	3000	(Range Selector) x (Display)
20 ft. (6.10m)	3830	20.9 ft. (6.37m)	4000	(Range Selector) x (Display)
25 ft. (7.62m)	4787.5	26.1 ft. (7.96m)	5000	(Range Selector) x (Display)
SOILBOX	1	SOILBOX	1	(Range Selector) x (Display)

(Multiplier)x(Range Selector)x(Display)=Ohm-cm

Example Formula COLUMN A:
Using 5 ft. Pin Separation
Meter shows 37.9
Range Selector Switch is in Ohm range
(957.5)x(1)x(37.9)= 36,289.25 Ohm-cm
or 36.289 K ohm-cm

Example Formula COLUMN B:
Using 10.4 ft. Pin Separation
Meter shows 0.39
Range Selector Switch is in Kilohm range
(2000)x(1000)x(0.39)= 780,000 Ohm-cm
or 780K Ohm-cm

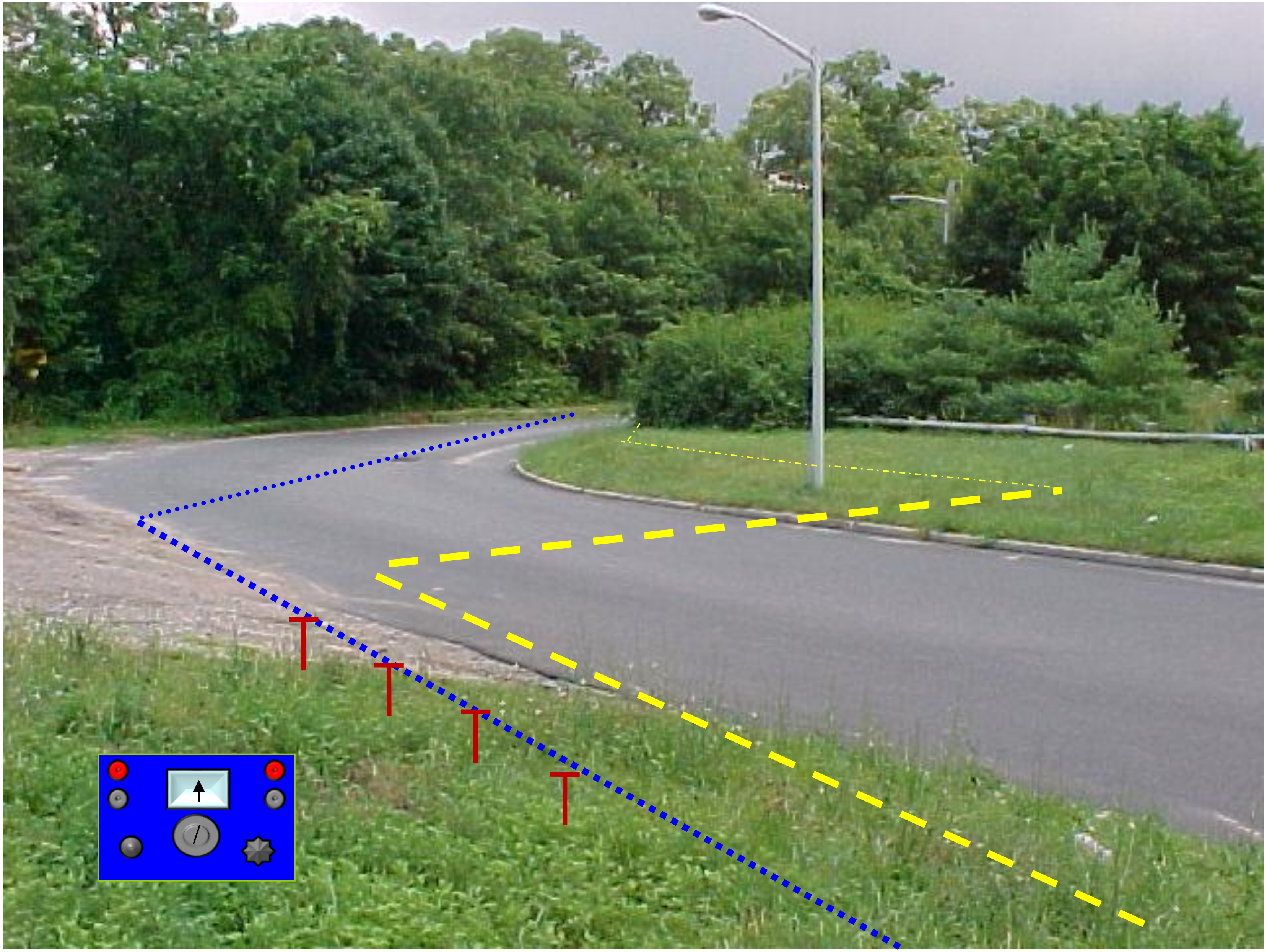
Formula =
ρ, Ω x cm =
$2 \pi a R$ (a in cm) =
$191.5 a R$ (a in ft)

This formula is in accordance with:
- ASTM G57-95a (www.astm.org)
- Peabody's Control of Pipeline Corrosion 2nd ed. pg. 84, 105

Quick Troubleshooting:
Display shows all zeros and/or a negative number:
P1 and/or P2 have a bad connection with soil under test. Re-seat P1 and P2 pins a few inches away and repeat the test. It might be recommended to add a small amount of water around the pin to ensure good contact with soil. Problem may also be with cables.

MANUFACTURED BY
TINKER & RASOR
SAN GABRIEL, CALIF
MODEL NO. SR-2

Property of



Soil Resistivity Field Survey

- Avoid proximity to metallic structures
- If metallic structure in area of survey, no electrode should be closer than the total distance between the current electrodes
- If unable to keep distance, survey should be made perpendicular to metallic structure and as far away as possible