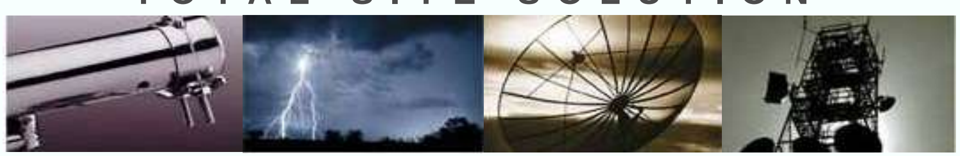
Grounding

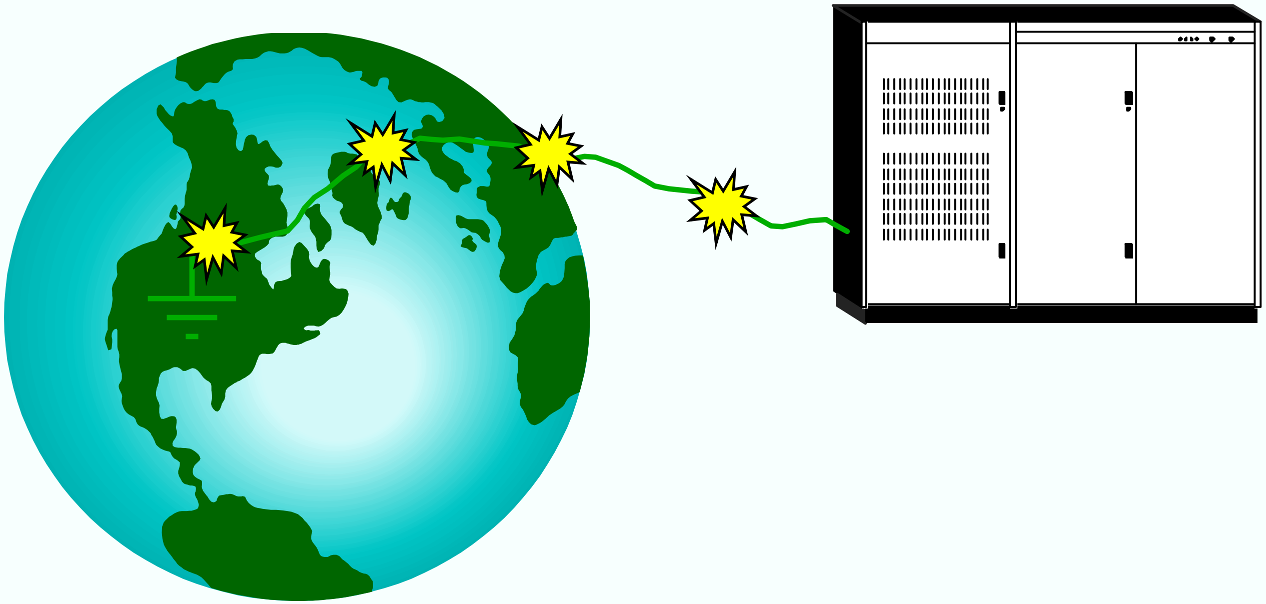
ESD Technical Seminar in San Diego
April 23, 2013

LYNCOLE
XIT GROUNDING
A VFC Company

T O T A L   S I T E   S O L U T I O N



What Is Grounding?



An electrical connection, whether intentional or accidental between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

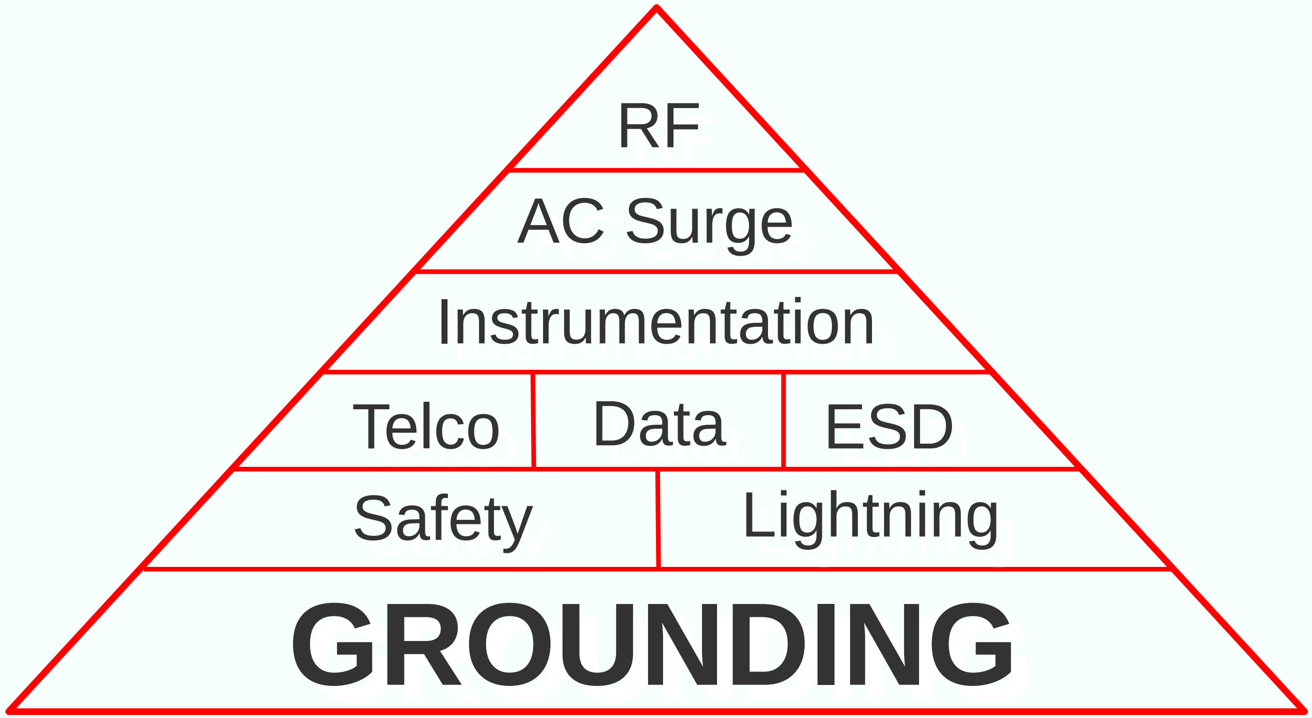
LYNCOLE XIT GROUNDING A VFC Company

Reasons For Grounding

- Personnel safety and equipment protection by providing a path to safely dissipate any unwanted charges or potentials.
- Ensure equipment performance and protection
- Satisfy manufacture's warranty

LYNCOLE XIT GROUNDING A VFC Company

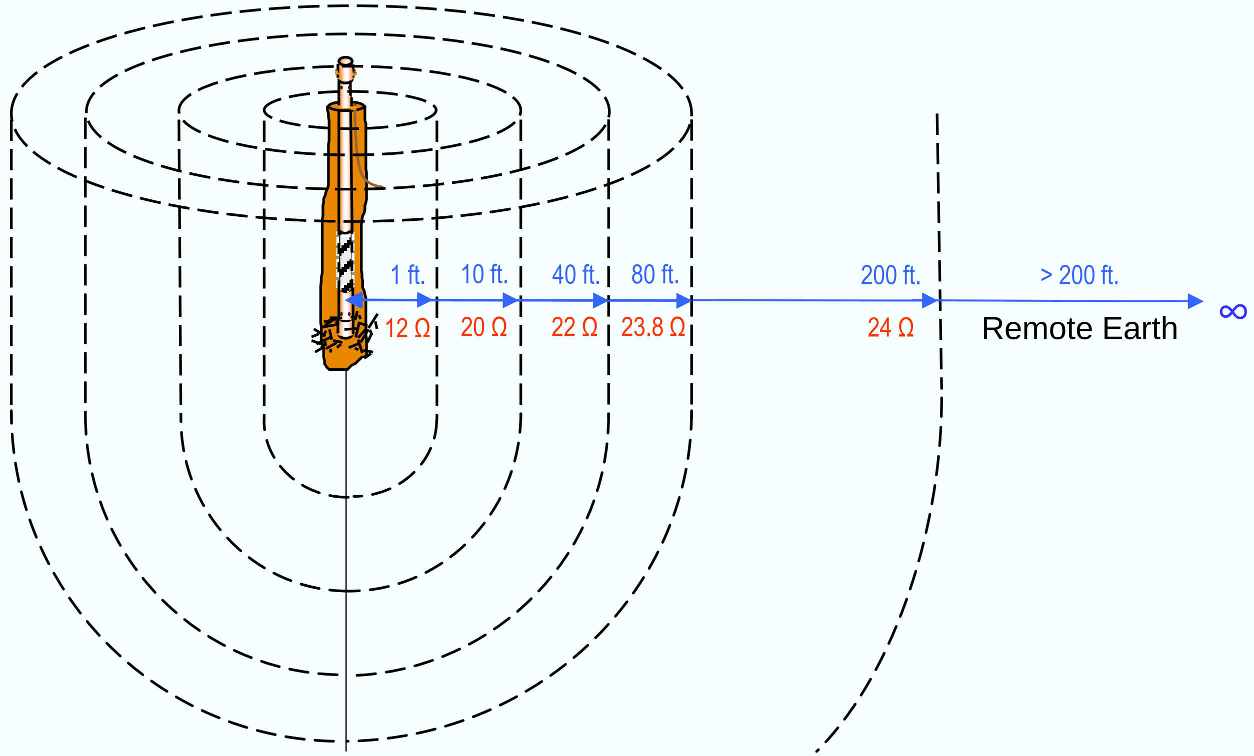
Electrical Protection Pyramid



LYNCOLE XIT GROUNDING
A VFC Company

Earth Resistance

The ohmic resistance between the grounding electrode and a remote earth (remote grounding electrode).

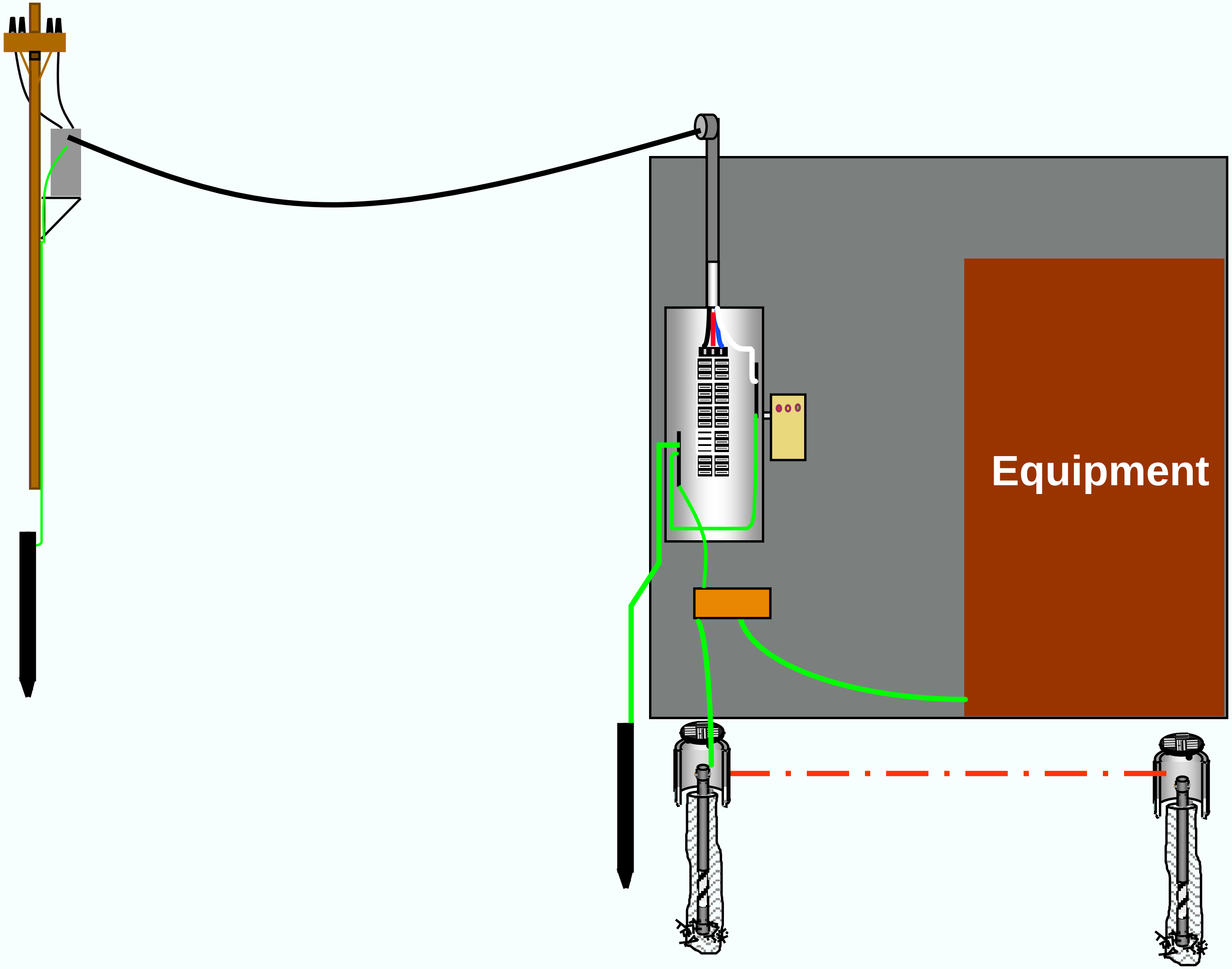


Typical Earth Resistance Requirements

Industry Standard	Target	Upper Target
NFPA 70 NEC	25 Ω	Two rods regardless of resistance
MIL-HDBK-419	10 Ω	
IEEE Standard 142	Equipment Dependent	Equipment Dependent
IEEE Standard 1100	Equipment Dependent	Equipment Dependent
Motorola Standard R-56	5 Ω	10 Ω
Telecommunications	5 Ω	10 Ω
Emerson DeltaV	1 Ω	3 Ω
Essilor	3 Ω	
GE Medical Systems	2 Ω	

LYNCOLE XIT GROUNDING A VFC Company

Grounding System Components



Electrical Noise

Any unwanted electrical signal which produces undesirable effects in the circuits of the control system in which they occur.

Noise Sources	Example
Natural	- Lightning - ESD
Incidental	- Fault - Motors - Power switching devices - Dissimilar metals
Intentional	- Two way radio (mobile, handheld) - Broadcast (AM, FM, Satellite) - Cellphone - WiFi

LYNCOLE XIT GROUNDING A VFC Company

25Ω Grounding

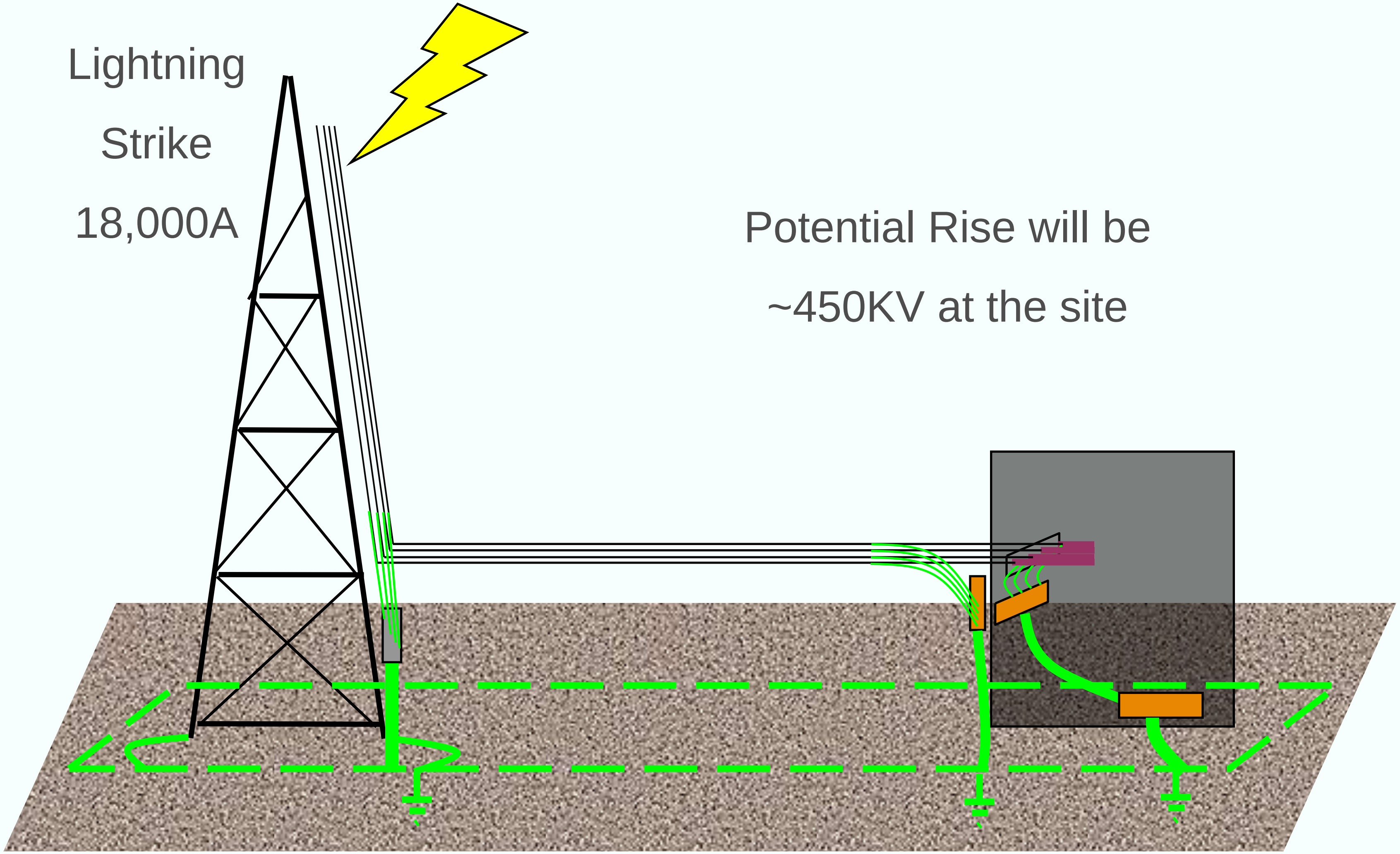
Lightning

Strike

18,000A

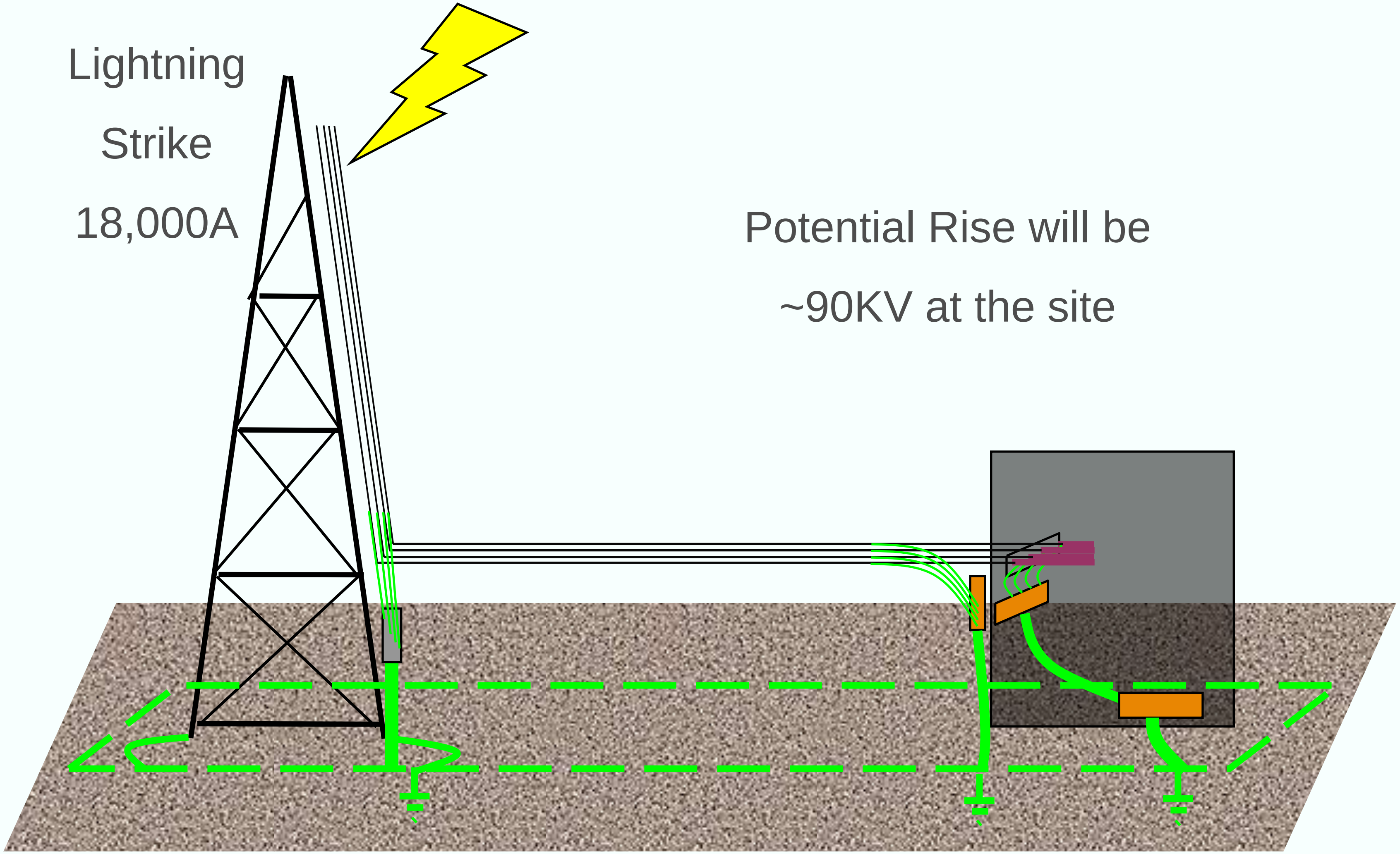
Potential Rise will be

~450KV at the site



3547 Voyager Street Suite 204 • Torrance • CA 90503 • Tel: 800.962.2610 • Email: info@Lyncole.com • Web: www.Lyncole.com

5Ω Grounding



LYNCOLE XIT GROUNDING
A VFC Company

Benefits of a Properly Designed Grounding System

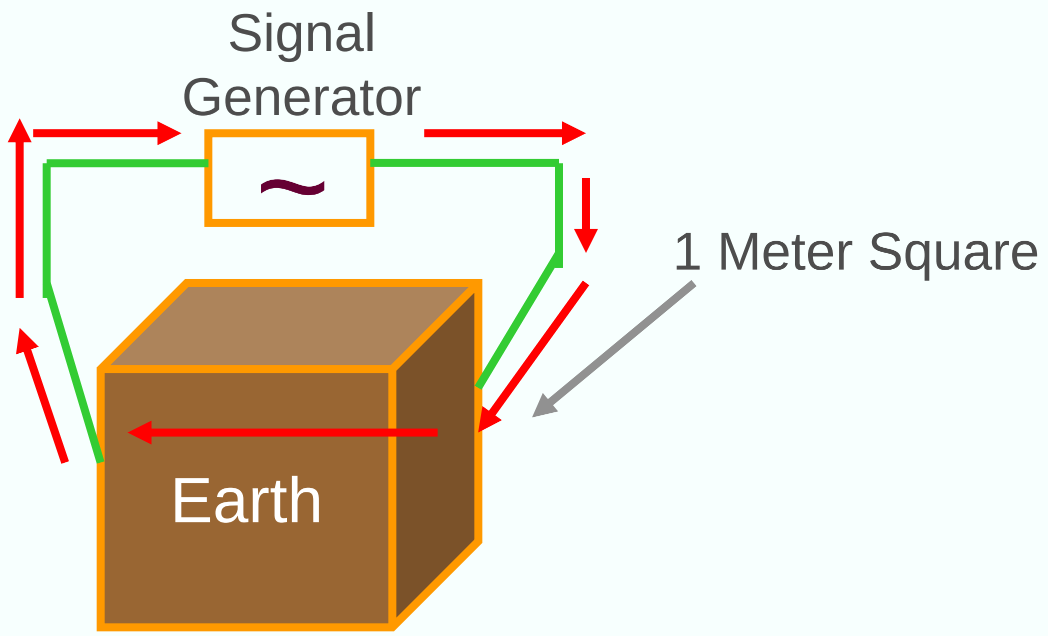
- Predictable Results
- Improved Personnel Safety
- Improved Equipment Reliability
  - Protection from Lightning/Power Surges
- Improved Equipment Performance
  - Less System Noise
  - Less Stress on Equipment and Fewer Operating Errors
- Improved Power Quality
- Meet Mfr's Warranty Requirements

3547 Voyager Street Suite 204 • Torrance • CA 90503 • Tel: 800.962.2610 • Email: info@Lyncole.com • Web: www.Lyncole.com

Soil Resistivity Basics

LYNCOLE XIT GROUNDING
A VFC Company

Soil Resistivity



The resistance of earth to current flow between opposite faces of a cubic earth that is one cubic meter in volume. Measured in Ohms-meter.

LYNCOLE XIT GROUNDING A VFC Company

Soil Resistivity

IS	IT
The key variable in system design	Determines grounding system resistance
Changing from site to site	Depends on: a. Soil type b. Moisture content c. Electrolytes d. Temperature

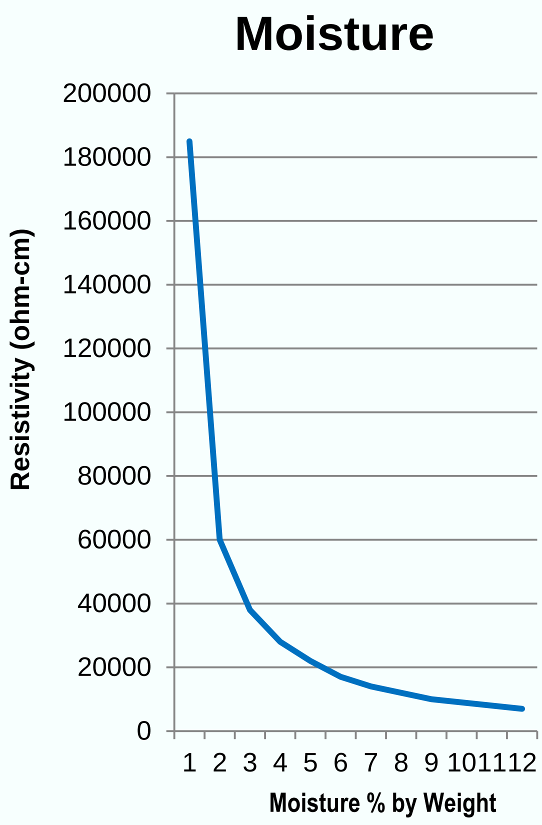
LYNCOLE XIT GROUNDING
A VFC Company

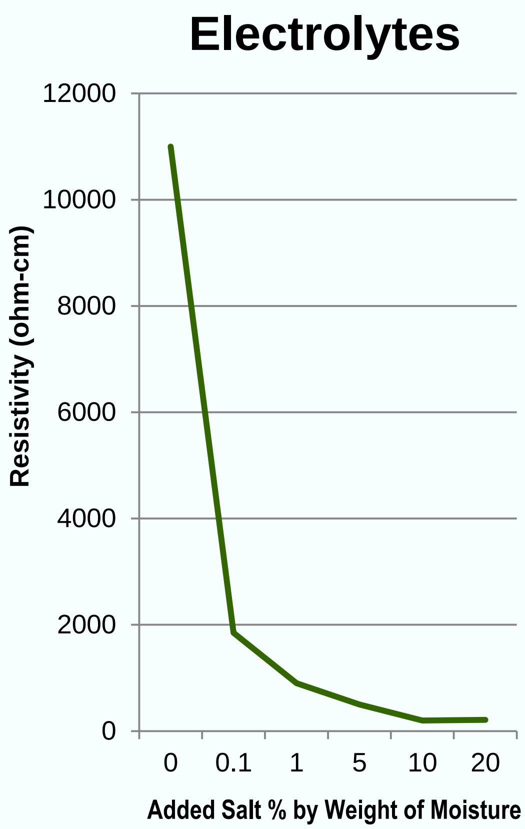
Soil Resistivity Comparison

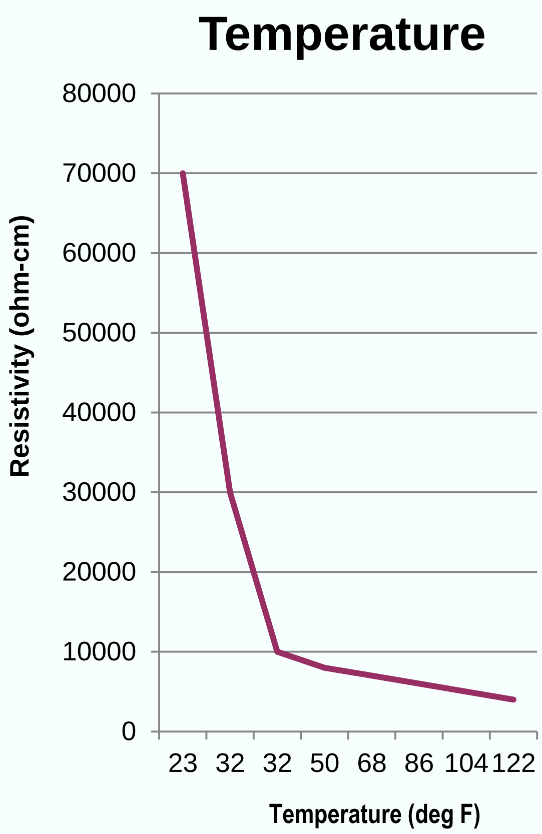
Soil Type	Resistivity (ohms-cm)	
Lynconite II		60
Surface Soil	100	5,000
Clay	200	10,000
Sand and Gravel	5,000	100,000
Surface Limestone	10,000	1,000,000
Limestone	500	400,000
Shales	500	10,000
Sandstone	2,000	200,000
Granites, Basalts, etc		100,000
Decomposed Gneisses	5,000	50,000
Slates, etc	1,000	10,000

3547 Voyager Street Suite 204 • Torrance • CA 90503 • Tel: 800.962.2610 • Email: info@Lyncole.com • Web: www.Lyncole.com

Conditions Affecting Soil Resistivity





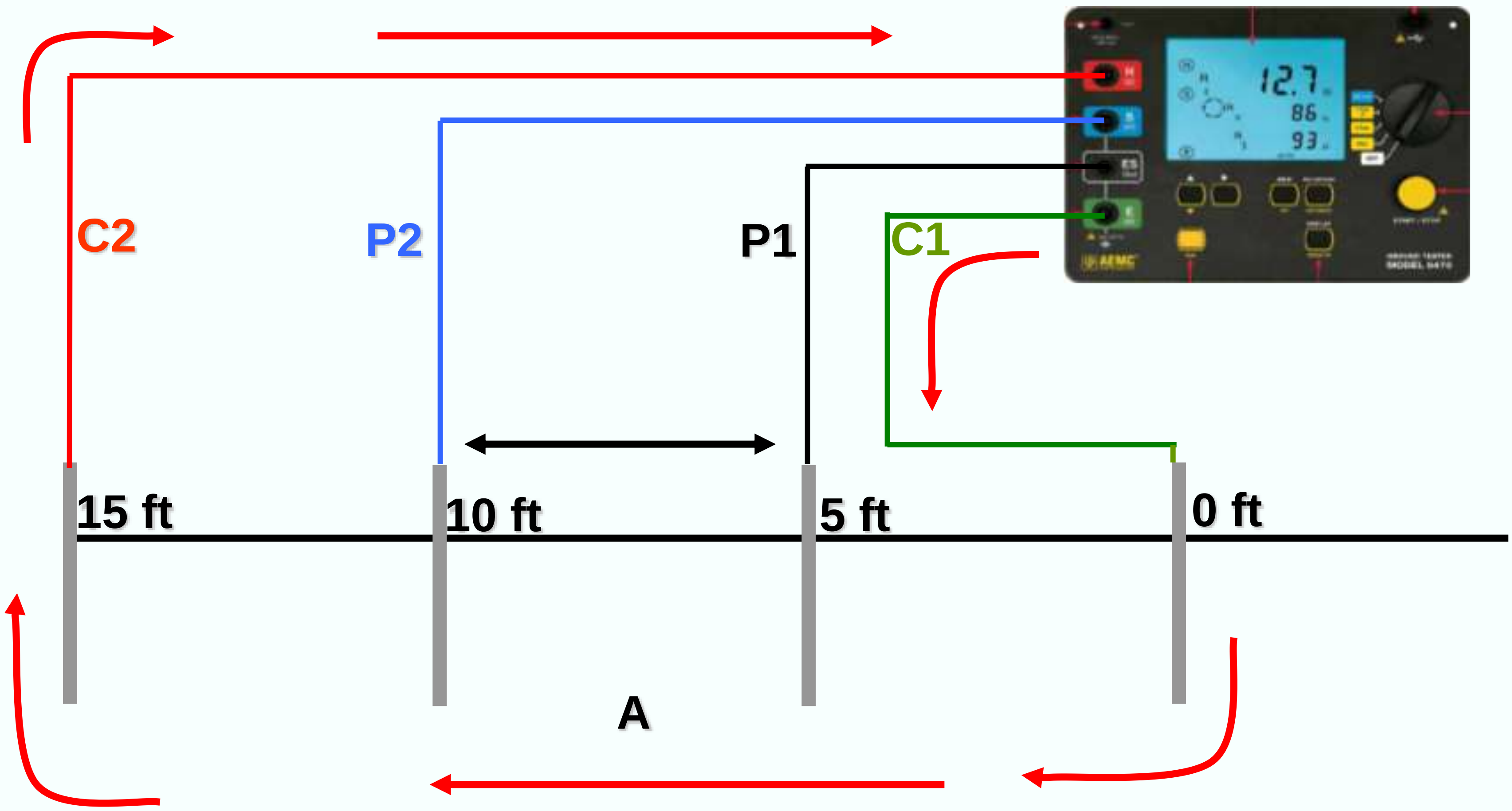


LYNCOLE XIT GROUNDING A VFC Company

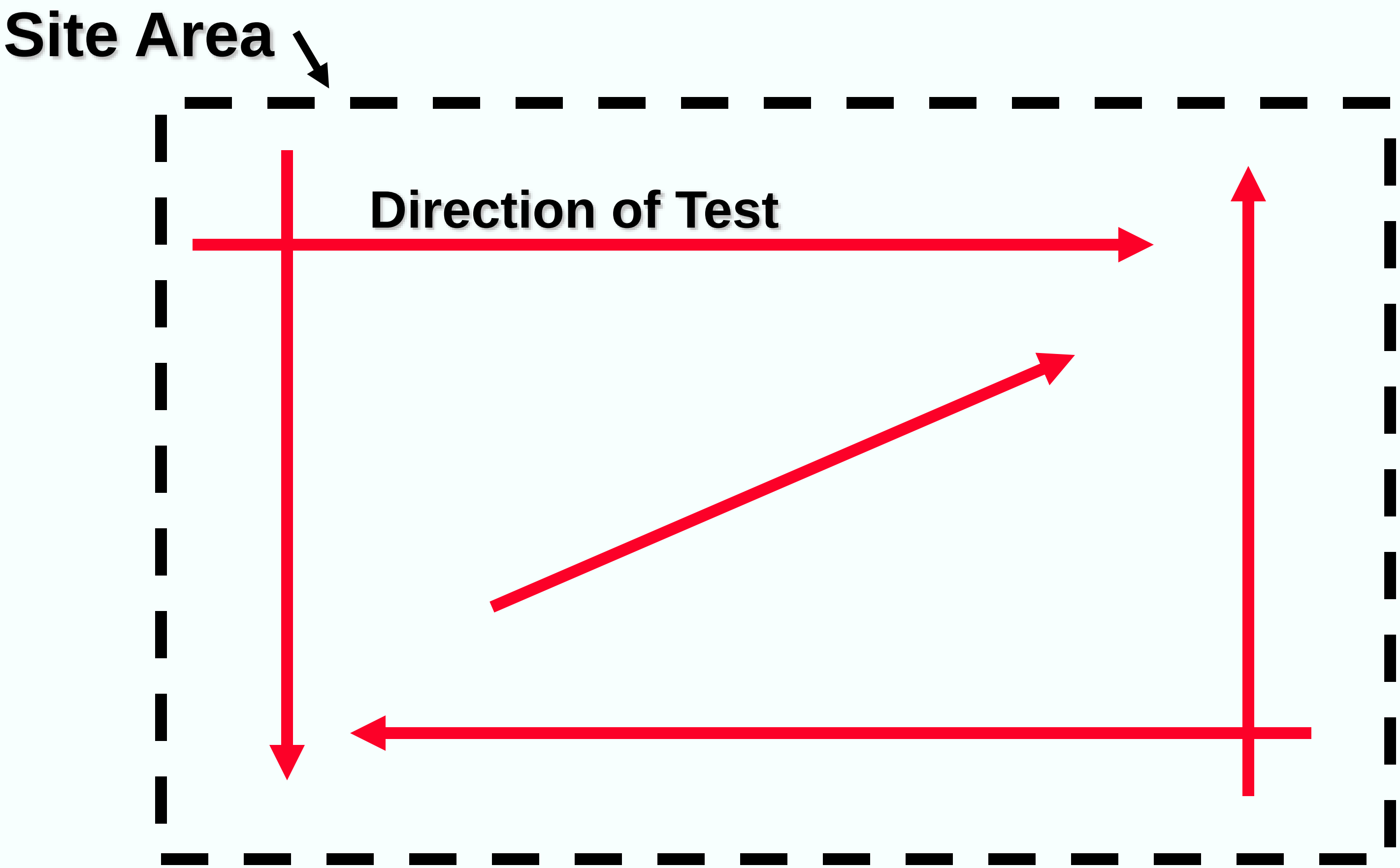
Soil Resistivity Testing

LYNCOLE XIT GROUNDING A VFC Company

4-Pt. Wenner Method



Soil Resistivity Testing
4-Pt. Wenner Method



LYNCOLE XIT GROUNDING
A VFC Company

4-Pt. Wenner Method

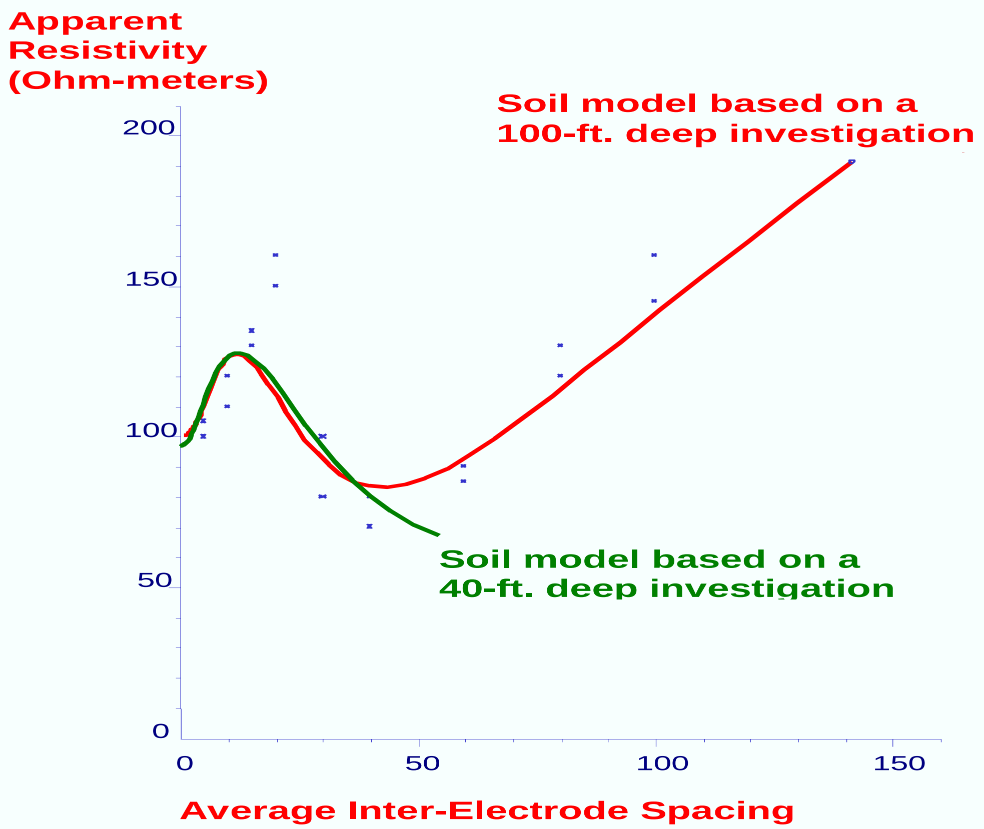
ρ= 1.915 *AR*

Probe Spacing (Feet)	Meter Reading (Ohms)	Calculated Resistivity (Ohm-Meter)
5	52.00	497.90
10	19.68	370.87
15	10.16	292.00
20	6.53	250.10
30	4.30	247.04
40	10.80	827.28
60	7.40	850.26
80	5.58	855.60
100	4.44	850.26

LYNCOLE XIT GROUNDING A VFC Company

Soil Model

100ft Vs 40ft Test



LYNCOLE XIT GROUNDING A VFC Company

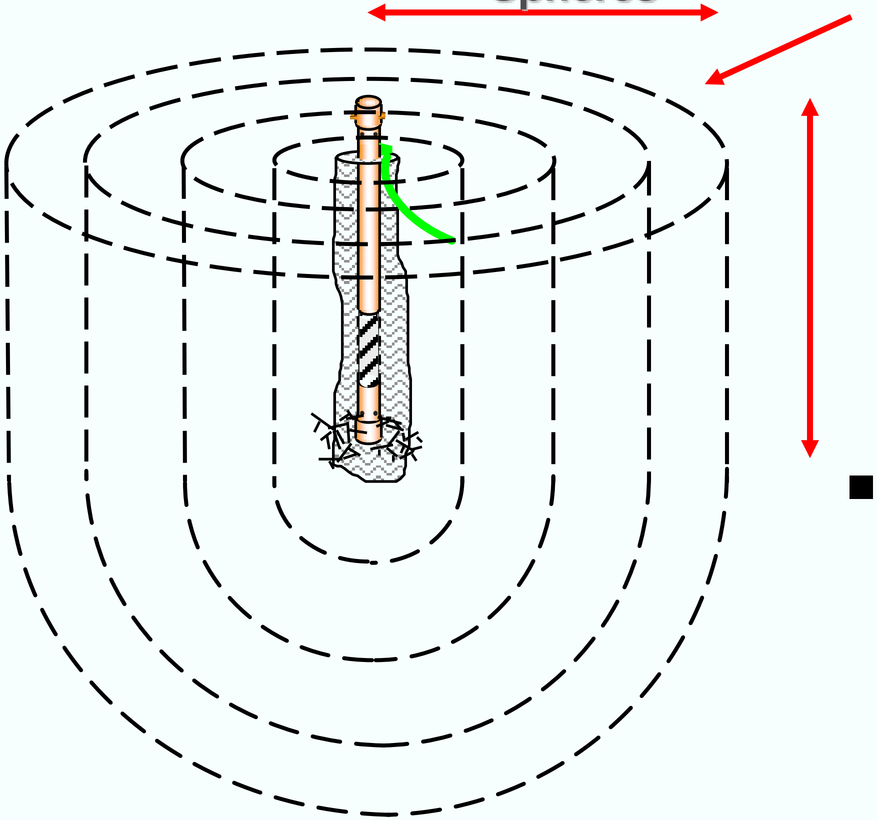
Characteristics of Ground Electrodes

LYNCOLE XIT GROUNDING
A VFC Company

Spheres of influence

Radius [R] or Primary Spheres

Concentric Shells



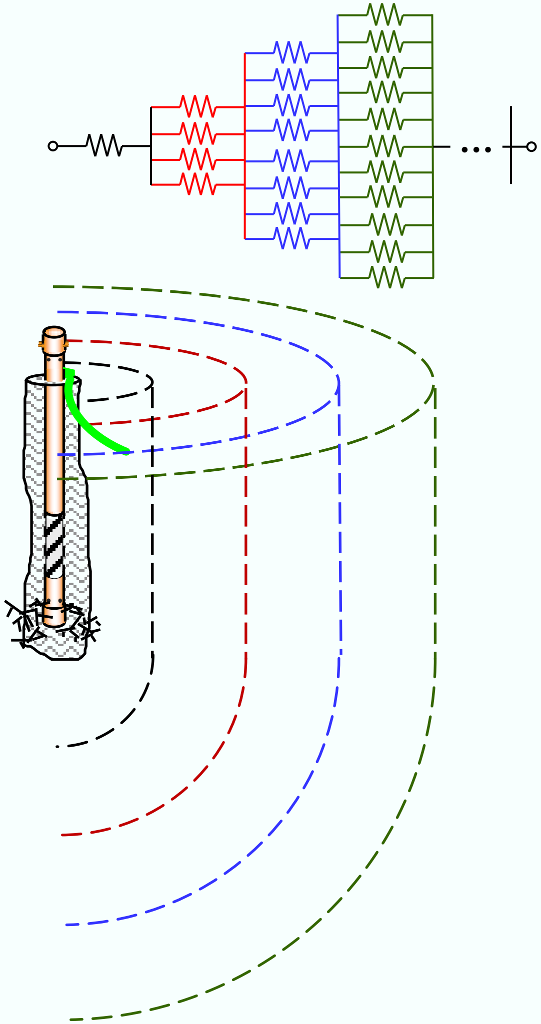
Rod Length (L)

- Electrode Depth (Length) equals the radius of the effective sphere of influence R = L (uniform soil resistivity)

LYNCOLE XIT GROUNDING
A VFC Company

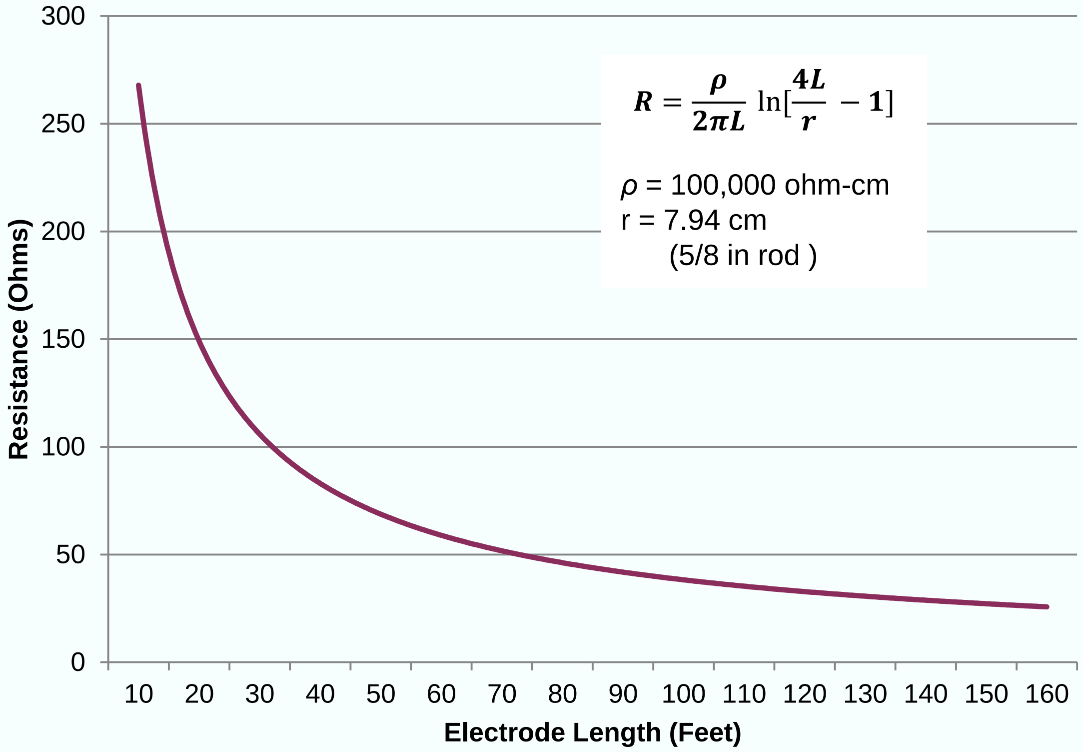
Spheres of influence

- Resistance due to sum of a series of “shells” surrounding the electrode
- Closest “shell” has the smallest circumference. It has the least cross sectional area resulting in higher resistance
- Outer “shells” have larger circumference. It has a larger cross sectional area resulting in lower resistance
- Lower the resistance of closest “shell”, lower the overall resistance



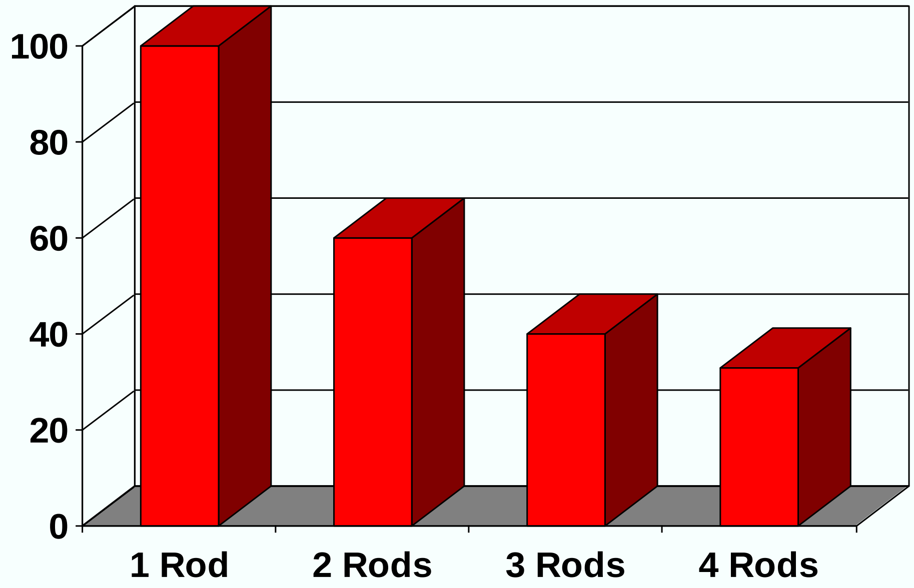
LYNCOLE XIT GROUNDING A VFC Company

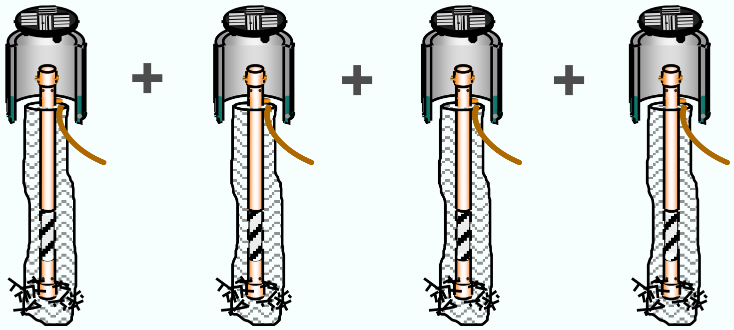
Resistance vs. Electrode Length
(in a defined space)



Resistance vs. Number of Electrodes

(in a defined space)





LYNCOLE XIT GROUNDING A VFC Company

Types of Ground Electrodes

Methods of Grounding and Their Limitations

Driven Rods

– Copper-clad rods driven into the ground

Drawbacks:

– Easily affected by the environment, aging, temperature, and moisture.

– Resistance increases steadily with age.

– Usually damaged during installation.

LYNCOLE XIT GROUNDING A VFC Company

"Driven rods have always worked for us..."

LYNCOLE XIT GROUNDING
A VFC Company

Methods of Grounding and Their Limitations

Water Pipes

– **Large amount of underground metal providing a "theoretically good ground."**

Drawbacks:

– **Difficult to test / impossible to maintain.**

– **Plastic inserts destroy circuit integrity.**

– **Condensation and corrosion are accelerated.**

LYNCOLE XIT GROUNDING A VFC Company

Methods of Grounding and Their Limitations

<u>Ground Plates</u>

– **Thin copper plates placed under poles or supplementing counterpoises.**

Drawbacks:

– **Small sphere of influence, higher resistance reading.**

– **Susceptible to environmental changes and corrosion.**

LYNCOLE XIT GROUNDING A VFC Company

Methods of Grounding and Their Limitations

Building Steel

- Large metallic structure
- Disperses fault current equally over large area

Drawbacks:

- May have little or no connection to earth
- May not be electrically continuous
- Carries large amounts of electrical noise
- Creates multiple “Ground Loops”

LYNCOLE XIT GROUNDING A VFC Company

Methods of Grounding and Their Limitations

Ufer Grounds / Concrete Encased Electrodes

– **Copper wire grid incorporated into building concrete foundation.**

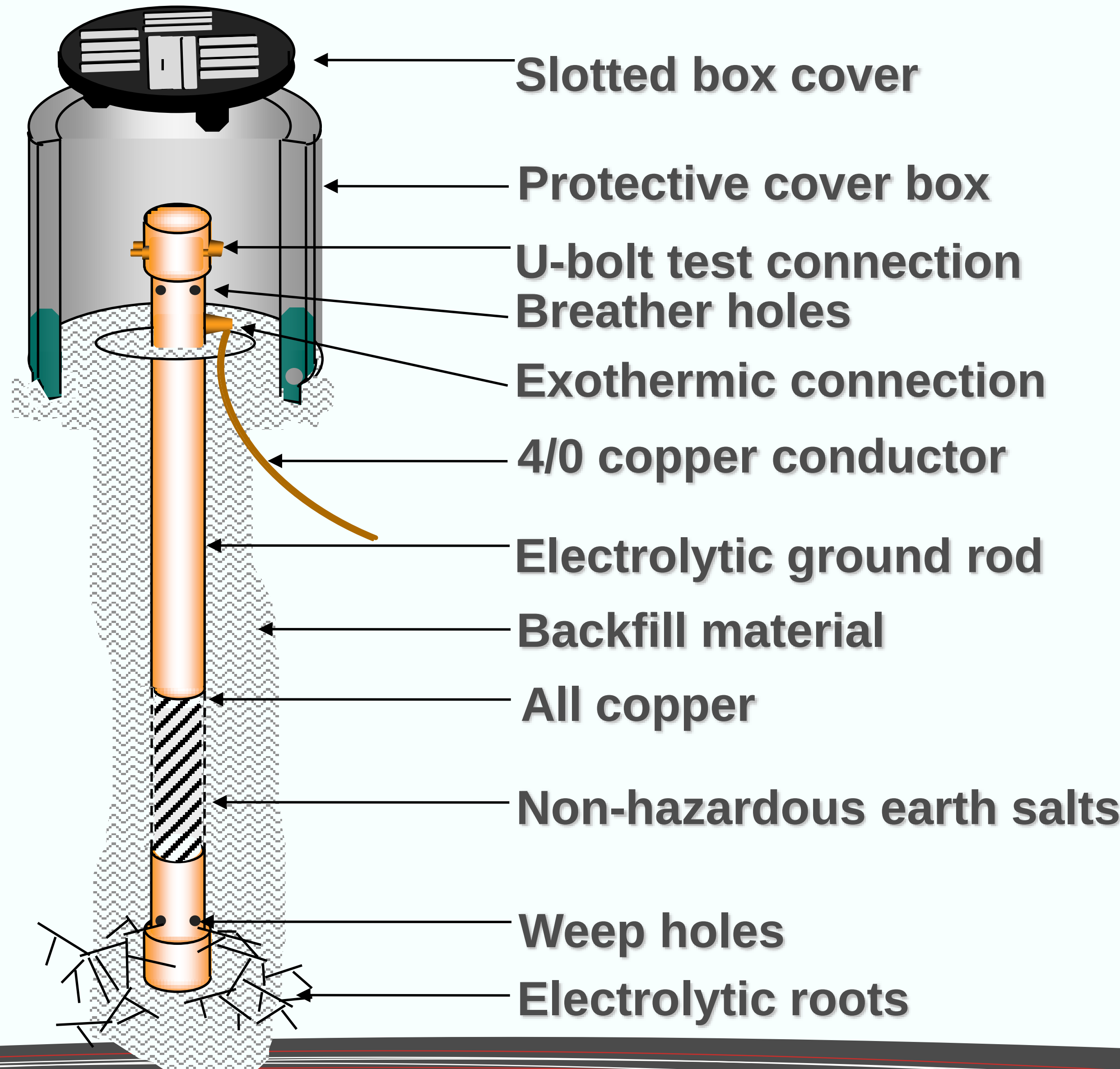
Drawbacks:

– **Impossible to test and maintain.**

– **Time and gradual removal of moisture can cause change in foundation integrity.**

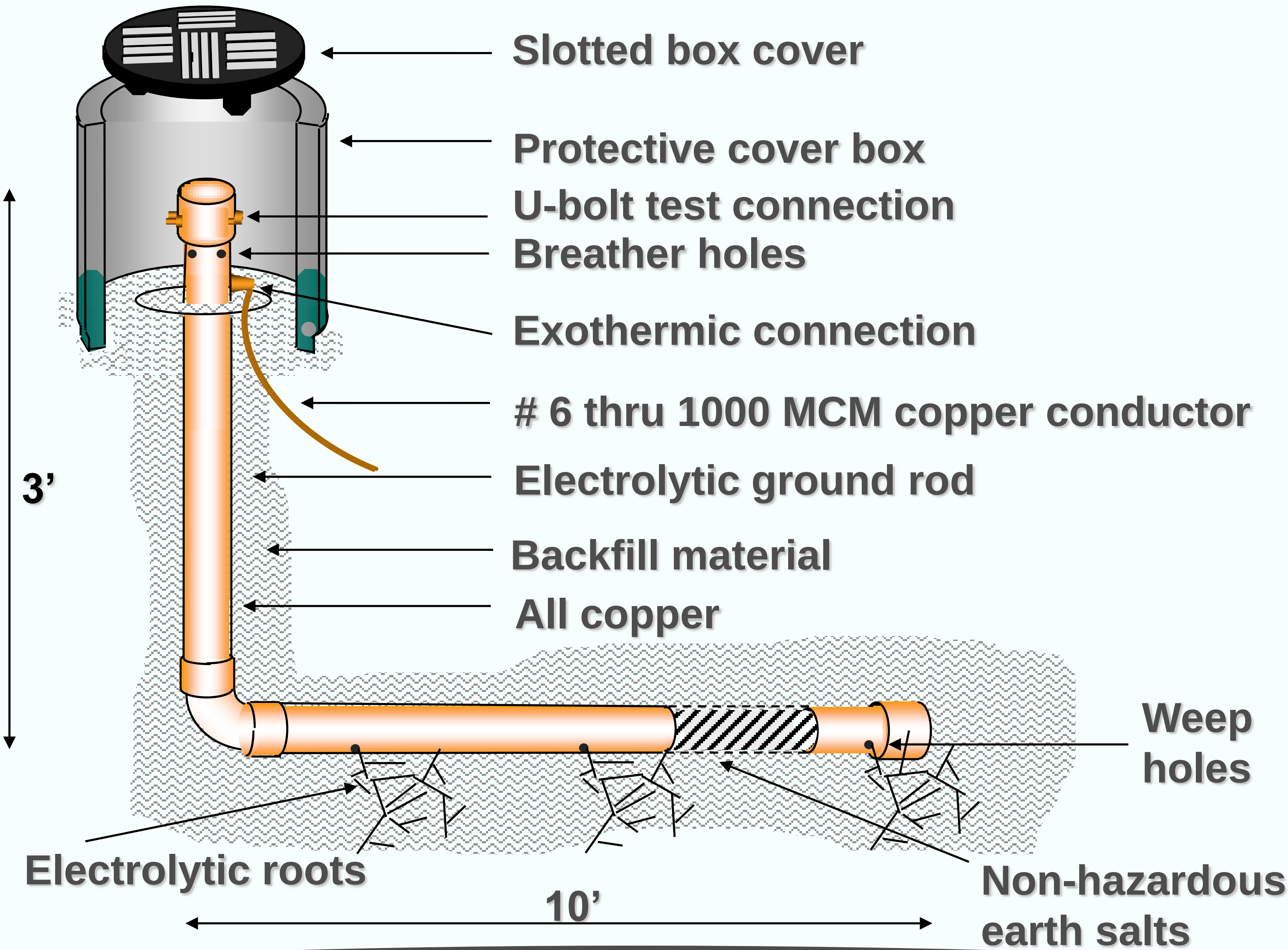
LYNCOLE XIT GROUNDING A VFC Company

Electrolytic Rod: XIT Grounding System



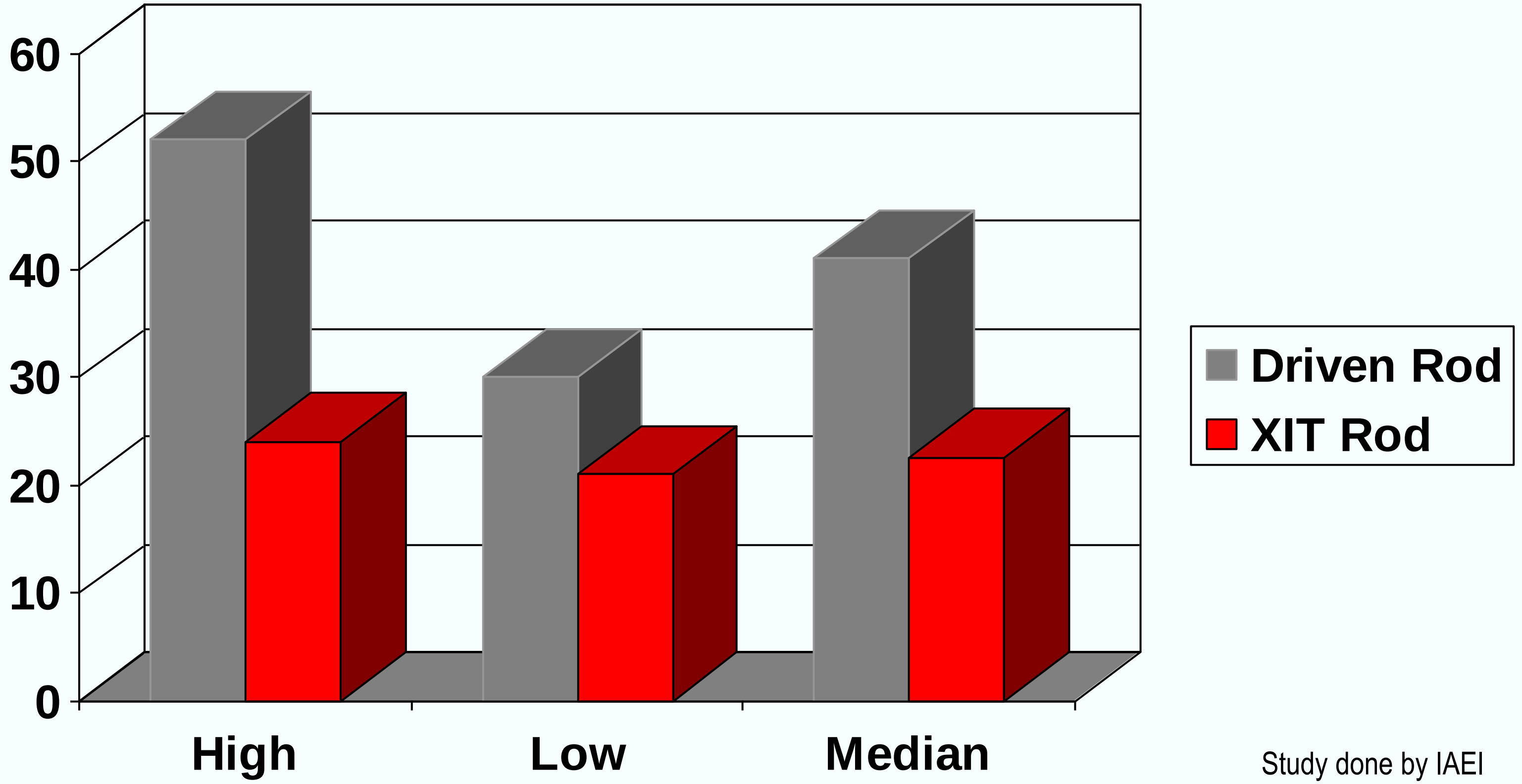
LYNCOLE XIT GROUNDING A VFC Company

The XIT Grounding System (Horizontal Shaft)



LYNCOLE XIT GROUNDING A VFC Company

Resistance Variance Over a Year: XIT Rod -v- Driven Rod



Study done by IAEI

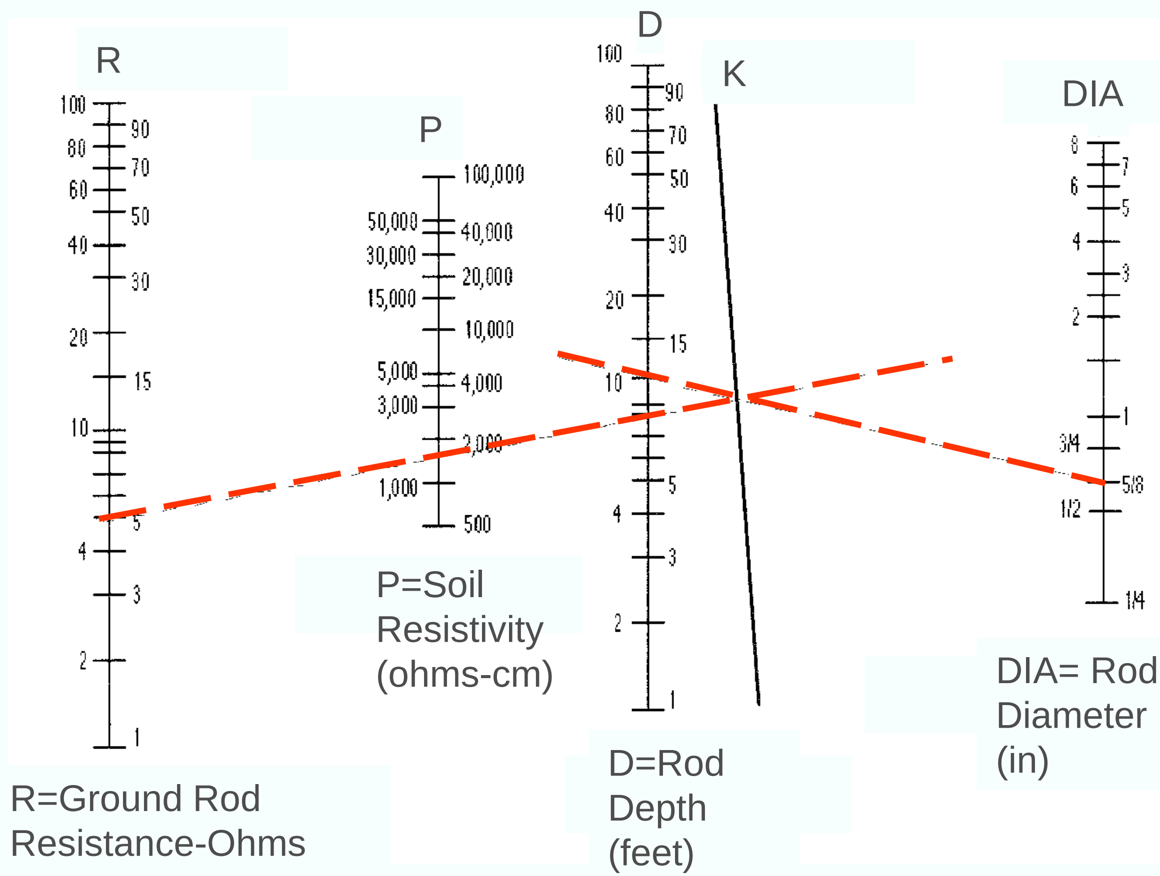
Grounding Calculations

Earth Ground Resisitivity Nomograph

This example reflects a 5 ohm ground resistance with a soil resistivity of 1800 ohms/cm using 5/8 inch diameter copper clad steel rods buried to a 10 ft depth

Directions

1) Select required resistance on R scale
2) Select apparent resistivity on P scale
3) Lay straightedge on R and P scale, and allow to intersect with K scale
4) Mark K scale point
5) Lay straightedge on K scale point and DIA scale and allow to intersect with D scale
6) Point on D scale will be the depth required for resistance on R scale



LYNCOLE XIT GROUNDING A VFC Company

Resistance of Single Rod

Green Book IEEE-142 (Table 13)

$$R = \frac{\rho}{2\pi L}\left(\ln\frac{4L}{a} - 1\right)$$

R = Resistance

L = Length of Rod

ρ = Resistivity

a = Radius of rod

LYNCOLE XIT GROUNDING A VFC Company

Influence of Resistivity

Example:

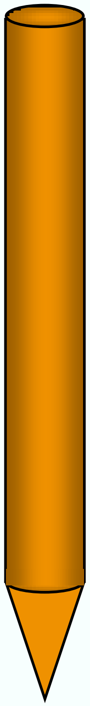
Soil Type: Clay

ρ = 1500 ohm-cm

5/8" x 10' Driven Rod

R = 4.963 ohms

$$R = \frac{1500}{1915.11}\left(\ln\frac{1219.2}{0.794} - 1\right)$$
$$R = 0.7832(7.337 - 1)$$
$$R = 4.963$$



Soil Type: Sand

ρ = 50000 ohm-cm

5/8" x 10' Driven Rod

R = 165.447 ohms

$$R = \frac{50000}{1915.11}\left(\ln\frac{1219.1}{0.794} - 1\right)$$
$$R = 26.108(7.337 - 1)$$
$$R = 165.447$$

LYNCOLE XIT GROUNDING
A VFC Company

3547 Voyager Street Suite 204 • Torrance • CA 90503 • Tel: 800.962.2610 • Email: info@Lyncole.com • Web: www.Lyncole.com

Resistance of Two Rods (Spacing Greater than Length)

$$R = \frac{\rho}{4\pi L}\left(\ln\frac{4L}{a} - 1\right) + \frac{\rho}{4\pi s}\left(1 - \frac{L^2}{3s^2} + \frac{2L^4}{5s^4}\ldots\right)$$

$$R = \frac{1500}{3830.23} \bullet (7.3367 - 1) + 0.19581 \bullet 0.94167$$

$$R = 2.4814 + 0.18439$$

$$R = 2.52122$$

ρ = Resistivity (1500 Ohm-cm)
L = Length of Rod (304.8cm or 10 ft.)
a = Radius of rod (0.794cm or 5/8in.)
s = Spacing between rods (609.6cm or 20 ft.)

LYNCOLE XIT GROUNDING A VFC Company

Resistance of Horizontal Wire

(100 Feet of 4/0 AWG Buried 30 Inches Deep)
(1500 ohm-cm soil)

$$R = \frac{\rho}{4\pi L}\left(\ln\frac{4L}{a} + \ln\frac{4L}{s} - 2 + \frac{s}{2L} - \frac{s^2}{16L^2} + \frac{s^4}{512L^4}\ldots\right)$$

$$R = \frac{1500}{19151.15}(9.114 + 3.689 - 2 + 0.05 - 0.000625 + 0.000000195)$$

$$R = 0.0783 \bullet 10.852$$

$$\boxed{R = 0.8499}$$

ρ = Resistivity (1500 ohm-cm)

2L = Length of Wire (3048cm or 100 ft.)

a = Radius of Wire (0.671cm or 0.264 in.)

s/2 = Depth of conductor (76.2cm or 30 in.)

LYNCOLE XIT GROUNDING A VFC Company

Grounding Design

3547 Voyager Street Suite 204 ● Torrance ● CA 90503 ● Tel: 800.962.2610 ● Email: info@Lyncole.com ● Web: www.Lyncole.com

ABC ENGINEERING
John Smith

Date: November 30, 2008

RE: **Grounding Option**
Site # N/A

Project #: 080020
Acct Mgr.: Zahid Mitha

Yellow Brick Road
Address: #1 Main Street
Anywhere, USA
XYZ Communication

Engineer: Julian Hristov

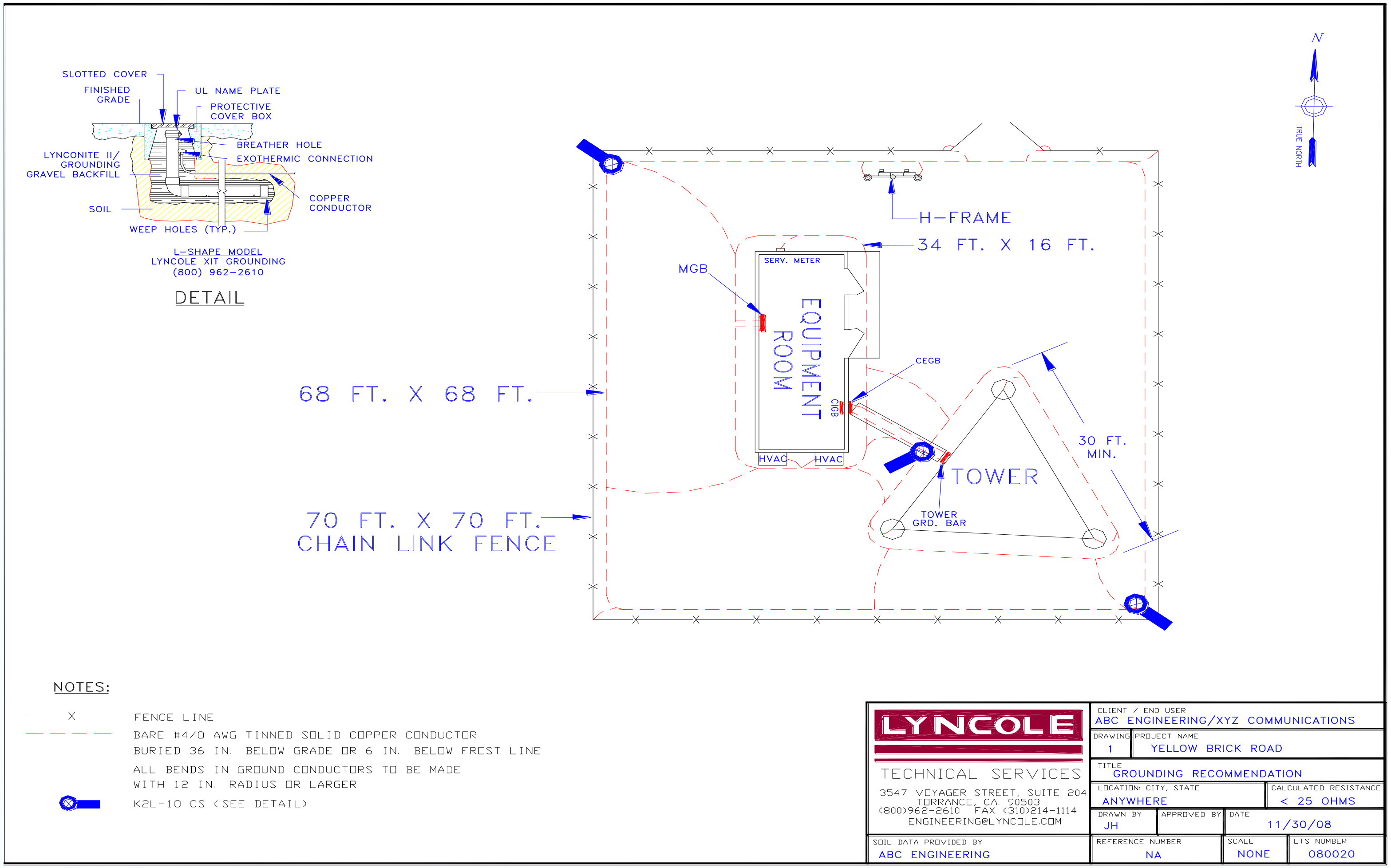
These options are conservative calculations of the grounding system, based on testing data provided by ABC Engineering. These designs will provide a stable, system that will be unsusceptible to environmental variables, such as changes in temperature and precipitation, and may improve with time.

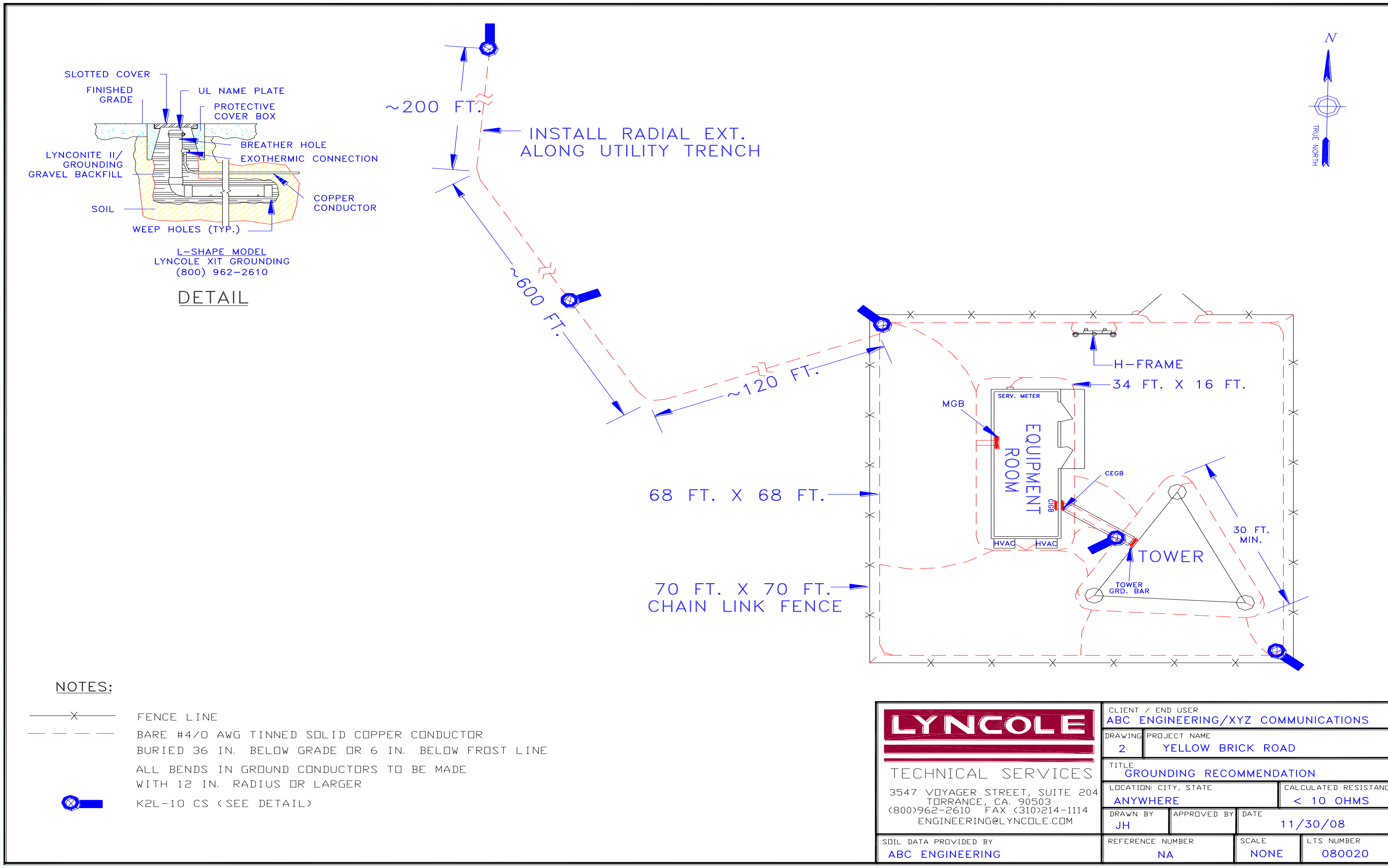
NUMBER OF ELECTRODES	ELECTRODE TYPE	TYPE AND SIZE OF GRID	PLACEMENT OF ELECTRODES	CALCULATED EARTH RESISTANCE
Grounding Option				
3	K2L-10CS	As illustrated (Drawing 1)	As illustrated (Drawing 1)	< 25 ohms
5	K2L-10CS	As illustrated (Drawing 2)	As illustrated (Drawing 2)	< 10 ohms
8	K2L-10CS	As illustrated (Drawing 3)	As illustrated (Drawing 3)	< 5 ohms

- **Note: Lyncole recommends that the copper conductor be covered with Lynconite II™ or Lyncole Grounding Gravel™ to protect from corrosive action of the soil and to promote conductivity.**

LYNCOLE XIT GROUNDING A VFC Company

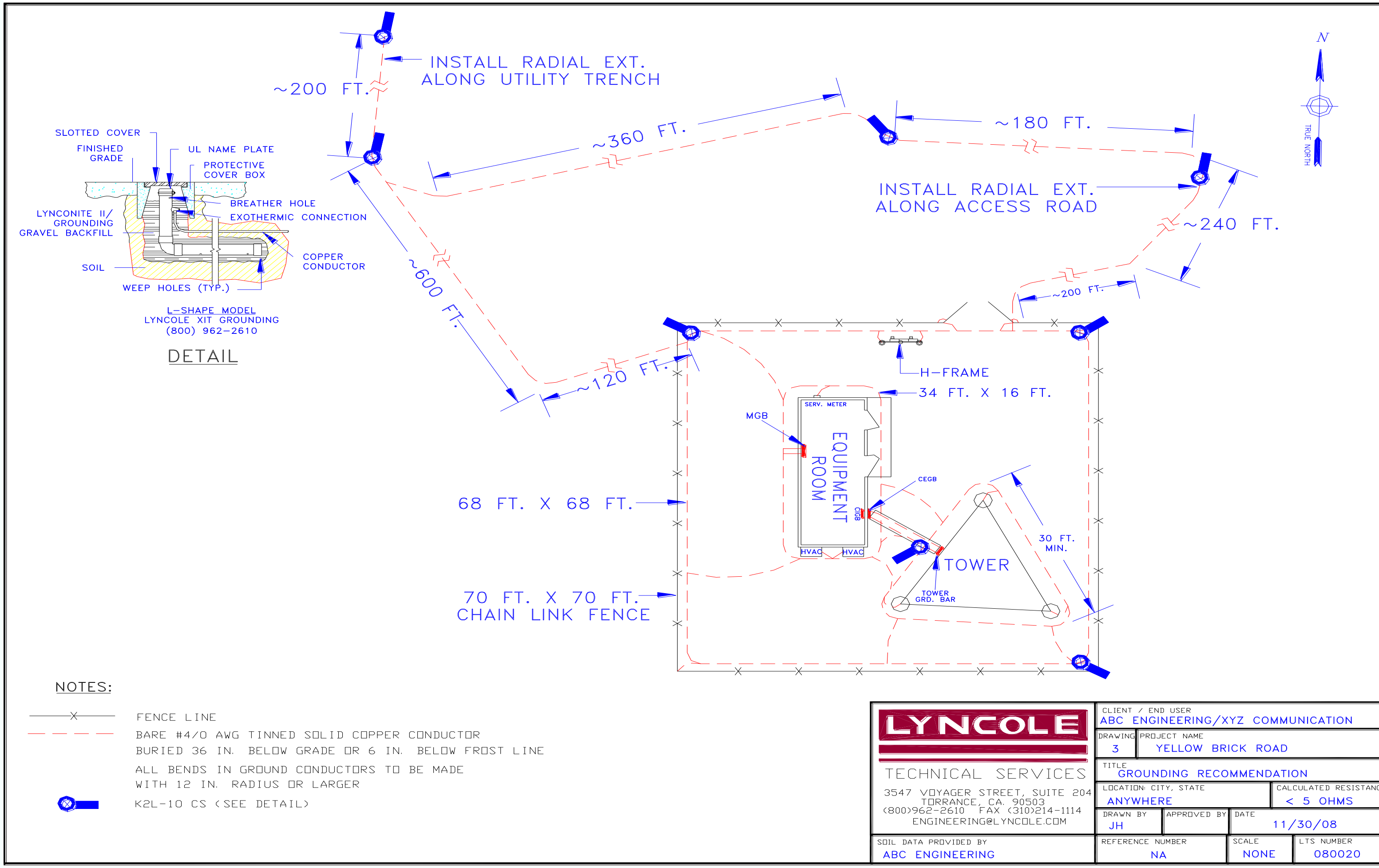
LYNCOLE
XIT GROUNDING
A VFC Company





LYNCOLE
XIT GROUNDING
A VFC Company

LYNCOLE XIT GROUNDING
A VFC Company



Grounding System Resistance Testing

LYNCOLE
XIT GROUNDING
A VFC Company

Ground System Testing

– Why Test Grounds?

– Determine Baseline
– Validate Construction
– Confirm Design Spec Satisfied
– Satisfy Warranty Reqs
– Ensure Equip Protection & Performance

LYNCOLE XIT GROUNDING A VFC Company

Testing Methods

- Two Test Methods
  - Fall Of Potential Test (Three Point/62% Test)
  - Clamp-On Test

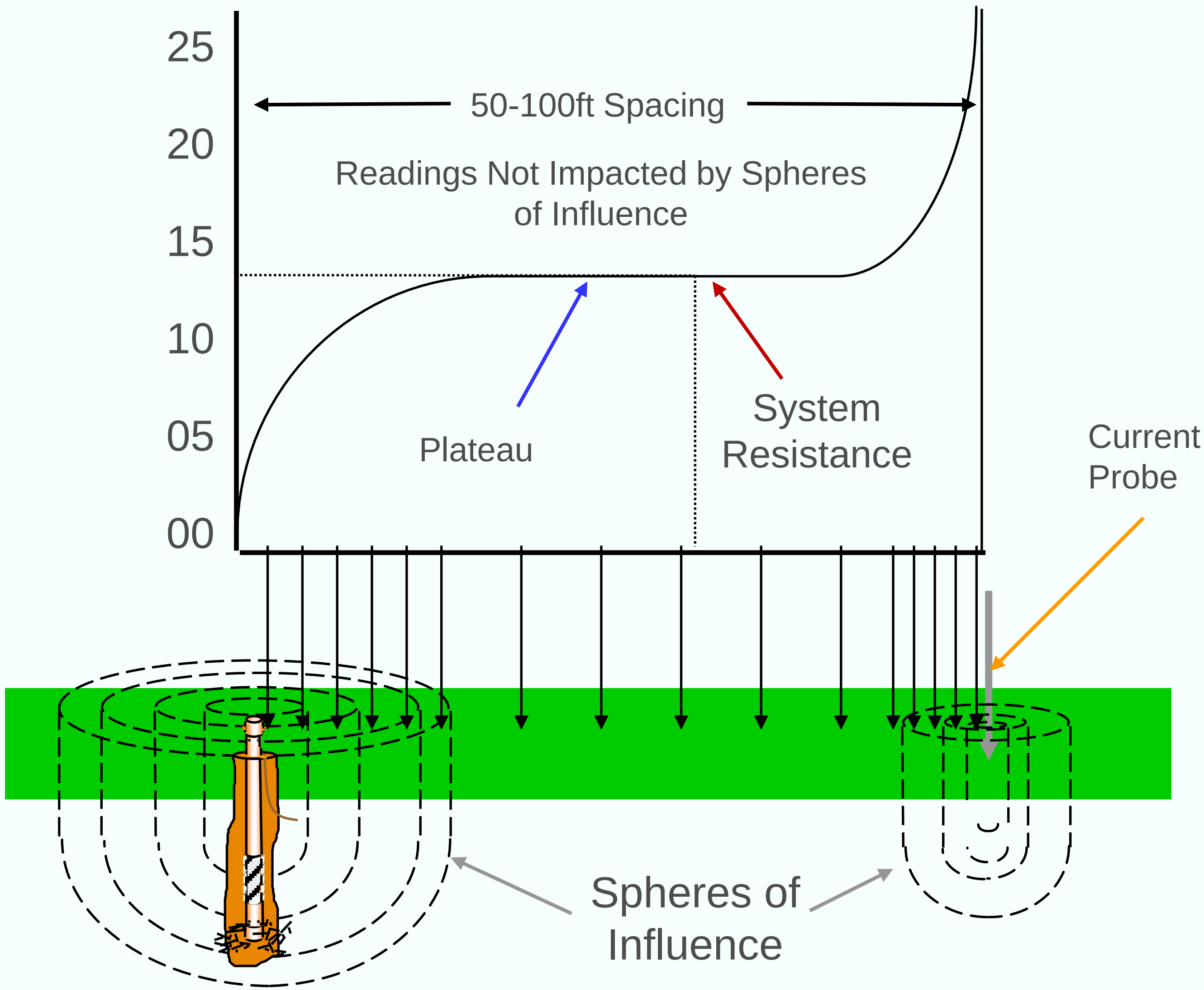
LYNCOLE XIT GROUNDING
A VFC Company

Fall of Potential Test

- **Advantage**
  - Recognized As Accurate
  - Most Commonly Utilized (IEEE 81)
- **Disadvantages**
  - Results are Frequently Invalid
    - Requires Isolated Ground System
    - Requires Large Area; 10X rod length (ideal) or 5X rod length (min)
  - Time Consuming
  - Access To Soil

LYNCOLE XIT GROUNDING A VFC Company

Fall of Potential Test



LYNCOLE XIT GROUNDING A VFC Company

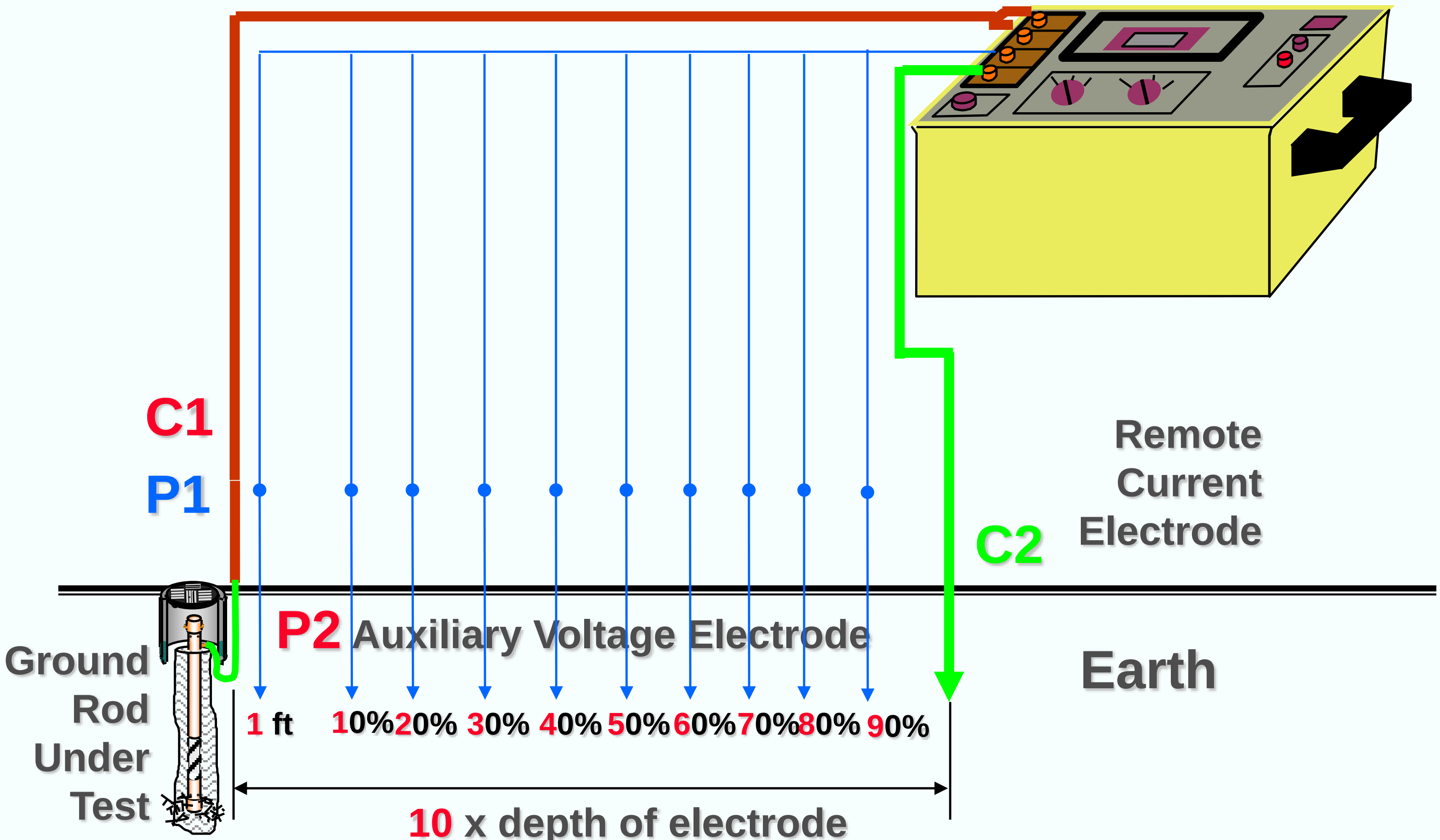
Ground System Testing

Required Equipment
- 3 / 4 Pole Tester
  - AVO / AEMC

- Test Kit
  - Probes
  - Conductor
  - Tape Measure

LYNCOLE
XIT GROUNDING
A VFC Company

Fall-of-Potential Method



3547 Voyager Street Suite 204 • Torrance • CA 90503 • Tel: 800.962.2610 • Email: info@Lyncole.com • Web: www.Lyncole.com

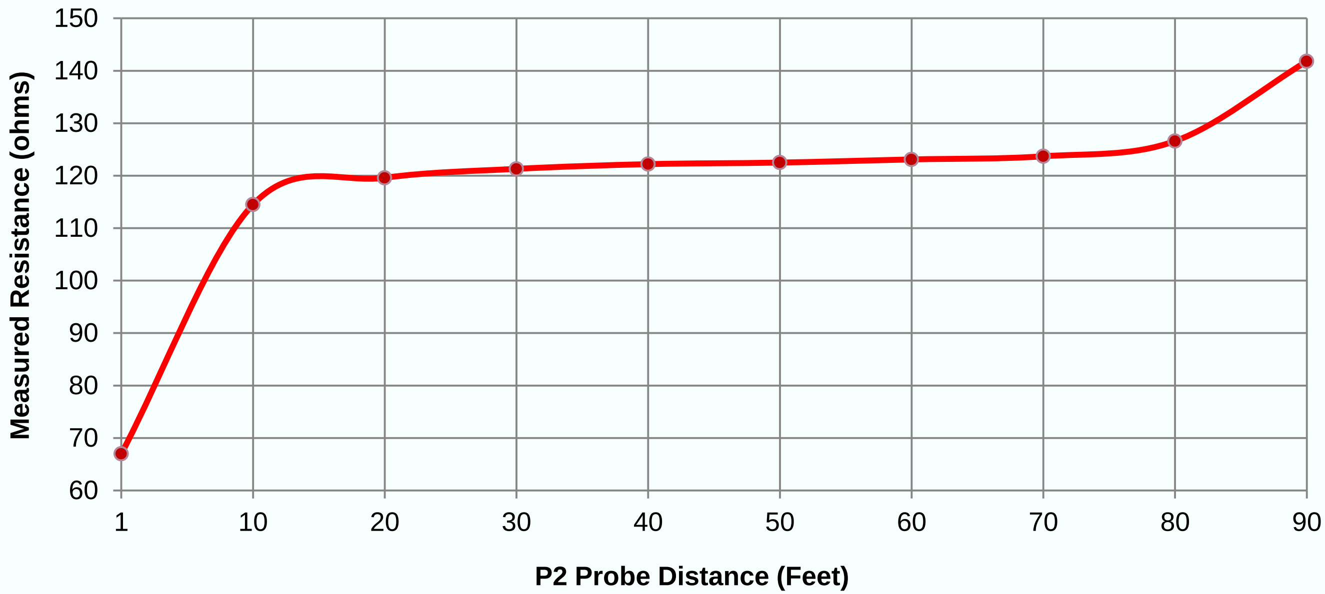
Fall-of-Potential Test Results

P2 Distance (%)	P2 Distance (Feet)	Measured Resistance (ohms)	Resistance Change (ohms)
1	1	67.0	
10	10	114.5	47.5
20	20	119.6	5.1
30	30	121.3	1.7
40	40	122.2	0.9
50	50	122.5	0.3
60	60	123.1	0.6
70	70	123.7	0.6
80	80	126.6	2.9
90	90	141.8	15.2
100	100	C2 probe	

LYNCOLE XIT GROUNDING A VFC Company

Fall of Potential

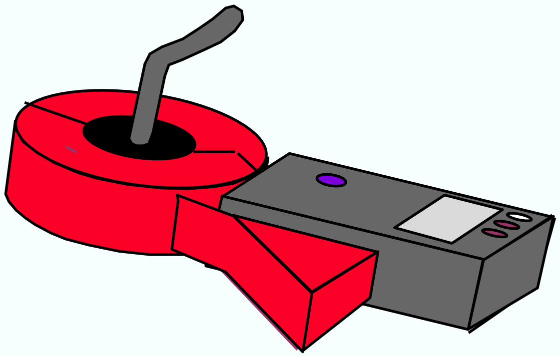
- Why 10+ Samples?
  - Single Point Could Be Misinterpreted
  - Data must be plotted
    - Visual Plateau
    - Confirms Test Validity



Ground Resistance Testing

<u>Clamp-On</u> Resistance Testing

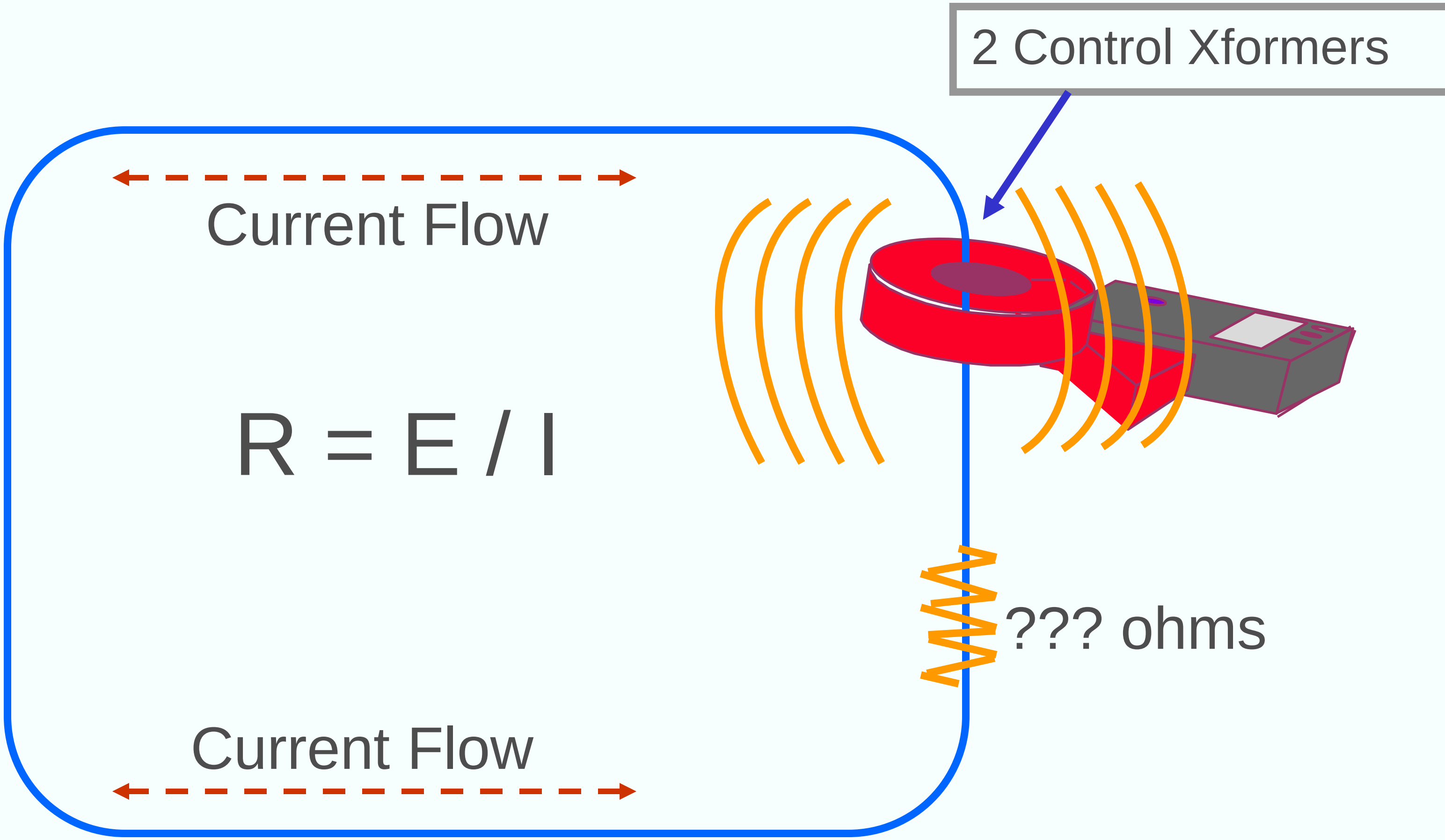
AEMC 3711 Clamp-On <u>Meter</u>



- Convenient, Quick, Easy
- Does Not Require Disconnecting Equipment
- Measures Current on the Ground

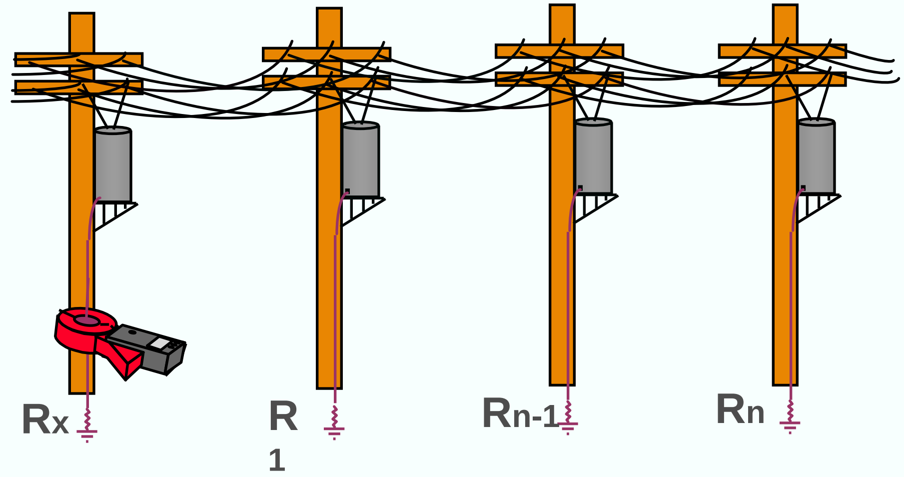
LYNCOLE XIT GROUNDING A VFC Company

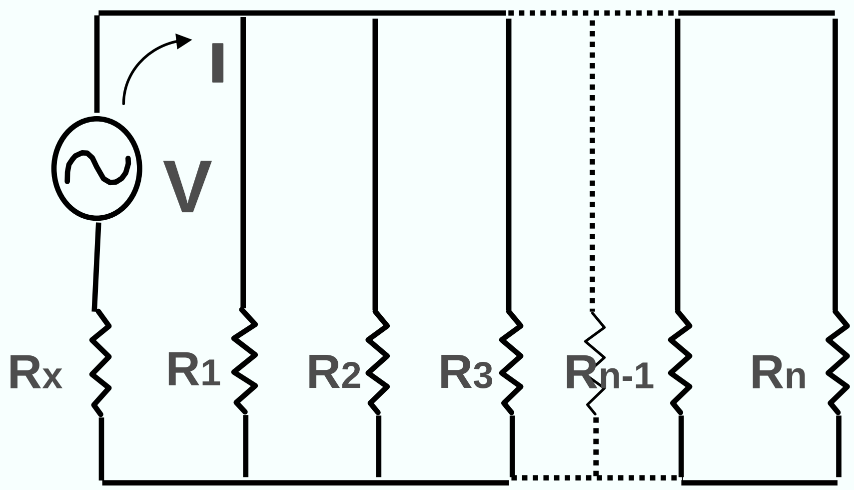
Clamp -On Meter Operation



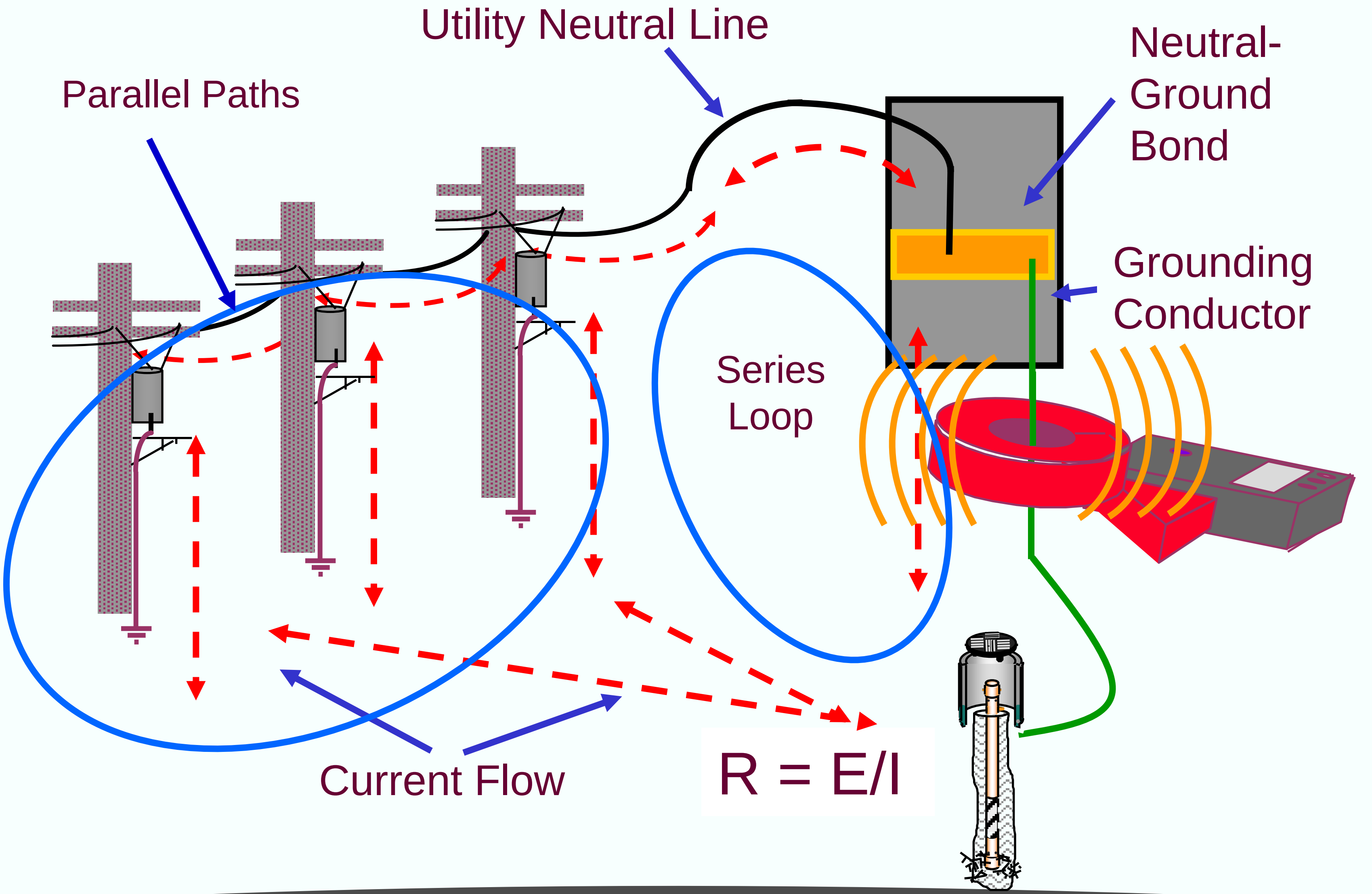
3547 Voyager Street Suite 204 • Torrance • CA 90503 • Tel: 800.962.2610 • Email: info@Lyncole.com • Web: www.Lyncole.com

Clamp-On Resistance Testing Example





Clamp-On Meter Operation



Conclusion

- Grounding is the foundation for personnel safety and system performance.
- Low impedance to earth minimizes potential rise in event of lightning, fault or heavy load switching.
- A good grounding system implementation always starts at the design phase.
- Soil resistivity testing is the key variable for grounding design.
- Effective, pragmatic and economically sound earth resistance targets is engineered using computer aided grounding design software.
- Test the system before commissioning.
- Monitor ground system to ensure system performance.

LYNCOLE

XIT GROUNDING

A VFC Company

Where Grounding Bonds With Science®

LYNCOLE XIT GROUNDING A VFC Company