Requirements for Earthing Enhancement Compounds

Presenter: Rohit Narayan

Author: Dale Boling, PE

March 25, 2014

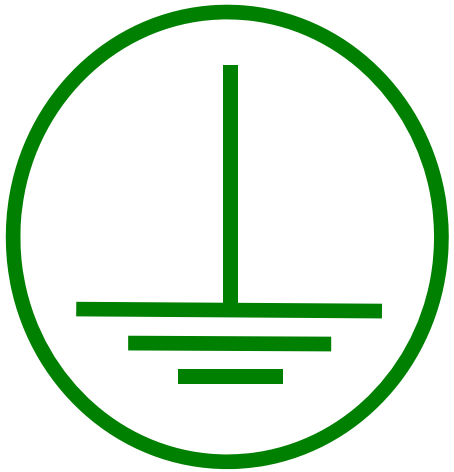
ERICO®

Agenda

- Introduction
- Grounding and Ground Electrode Resistance
- Earthing Enhancement Compounds
- International Electrotechnical Commission (IEC)
- IEC 62561-7 Requirements for Earthing Enhancing Compounds
- Leaching Tests
- Sulfur Tests
- Determination of Resistivity
- Corrosion Tests – Linear Polarization Resistance (LPR)
- Marking and Indications
- Structure and Content of Test Report

Why Ground?

- Personnel Safety
  - Reduce Potential Differences Between Non-current Carrying Parts (Enclosures) and Between Non-current Carrying Parts and Earth
- Equipment Protection
  - Operate Overcurrent Device During a Ground Fault
  - Equalize Voltage Potentials
  - Overvoltage Control
- Lightning Dissipation
- ESD (Electrostatic Discharge)
- Noise Control (Computer Grounding)



Costs of Inadequate Grounding

- Equipment Damage
- Downtime and Loss of Operations
- Loss of Service
- Public Dissatisfaction About Reliability
- Human Safety

Soil Resistivity

Description	Average Resistivity (ohm-meters)
Well-graded gravel, gravel-sand mixtures, little or no fines	600 to 1,000
Poorly-graded gravel, gravel-sand mixtures, little or no fines	1,000 to 2,500
Clayey gravel, poorly graded gravel, sand-clay mixtures	200 to 400
Silty sands, poorly graded sand-silt mixtures	100 to 500
Clayey sands, poorly graded sand-clay mixtures	50 to 200
Silty or clayey fine sands with slight placticity	30 to 80
Fine sandy or silty soils, elastic silts	80 to 300
Gravelly clays, sandy clays, silty clays, lean clays	25 to 60
Inorganic clays of high plasticity	10 to 55
Sea water	1

Resistivities of Different Soil Types

Soil Resistivity

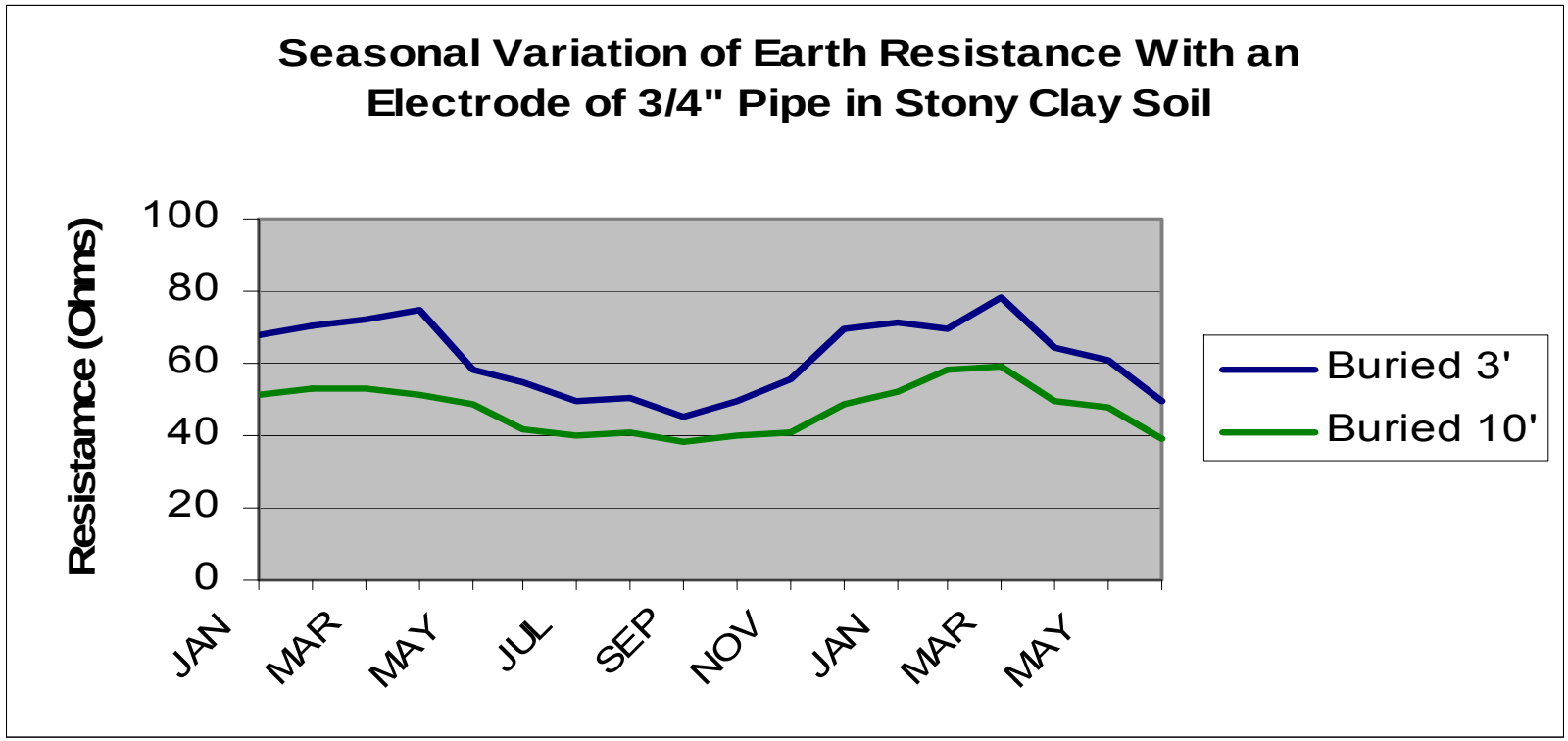
Table 1—Geological Period and Formation

Earth Resistivity Ohmmeters	Quarternary	Cretaceous Tertiary Quarternary	Carboniferous Triassic	Cambrian Ordovician Devonian	Pre-Cambrian and Combinat. with Cambrian
1 Sea water					
10 Unusually low		Loam Clay Chalk			
30 Very low			Chalk		
100 Low			Trap Diabase Shale		
300 Medium				Shale	
1000 High			Limestone Sandstone	Limestone Sandstone	Sandstone
3000 Very High	Coarse Sand and Gravel in surface Layers			Dolomite	Quartyite
10 000 Unusally high					Slate Granite Gneisses

NOTE — Table 1 is from reference [B38] of the Bibliography section.

Soil Types and Resistivity - Geological Period and Formation (IEEE Std 81)

Soil Resistivity



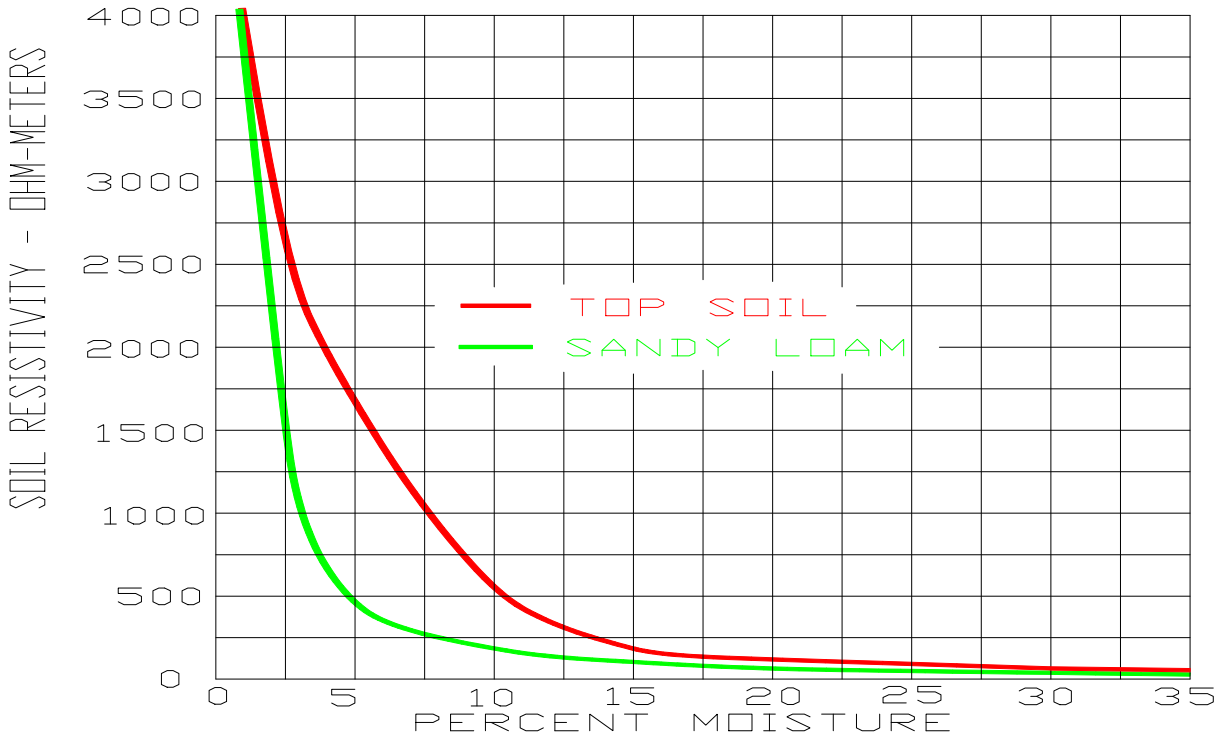
Resistance Variation With Seasons

Soil Resistivity

Moisture content % by weight	Resistivity, Ohm-cm	
	Top soil	Sandy loam
0	$1{,}000 \times 10^6$	$1{,}000 \times 10^6$
2.5	250,000	150,000
5	165,000	43,000
10	53,000	18,500
15	19,000	10,500
20	12,000	6,300
30	6,400	4,200

Effect of Moisture on Earth Resistivity

Soil Resistivity



Effect of Moisture

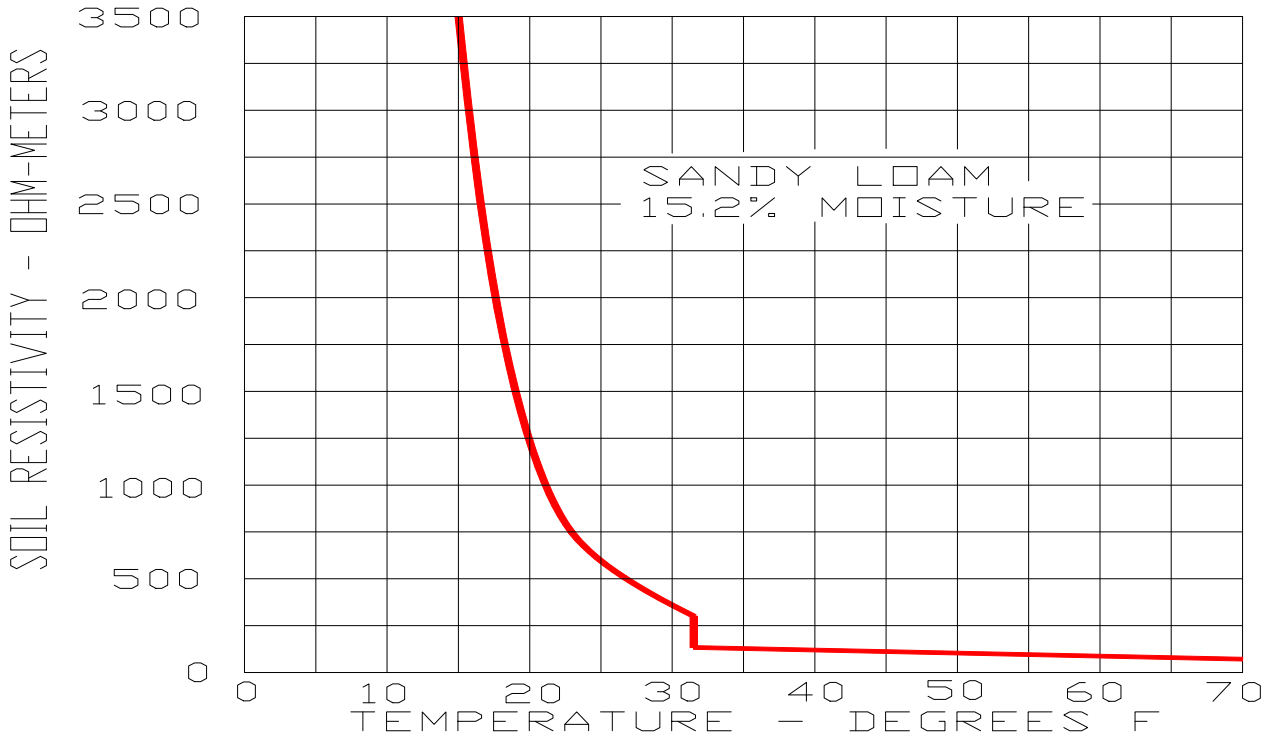
Soil Resistivity

Temperature		Resistivity, ohm-cm
°C	°F	
20	68	7,200
10	50	9,900
0	32 (water)	13,800
0	32 (ice)	30,000
-5	23	79,000
-15	14	330,000
*For sandy loam, 15% moisture		

Effect Of Temperature On Earth Resistivity

A Seasonal Change From 20º C to -5º C Will Decrease Soil Resistivity by a Factor of 10

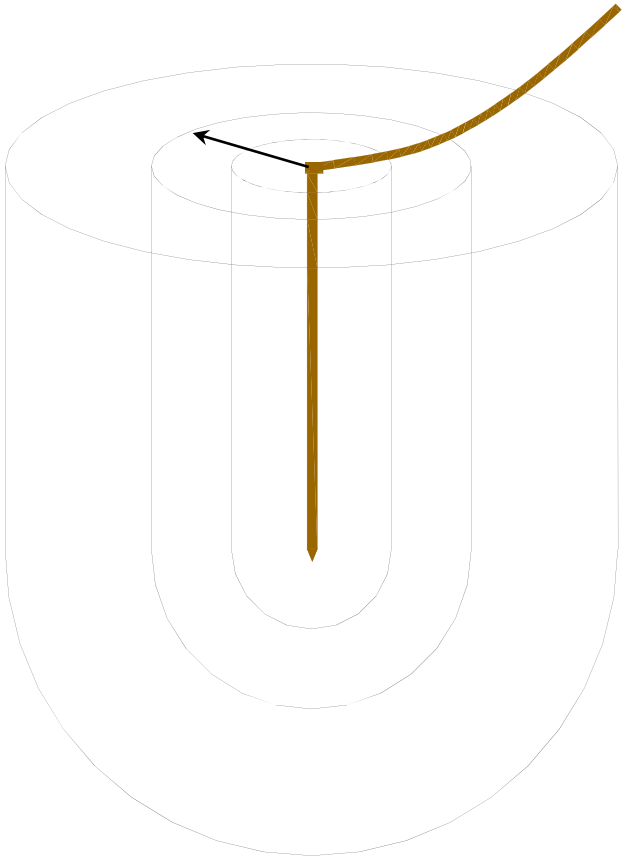
Soil Resistivity



Effect of Temperature

Ground Electrode Resistance

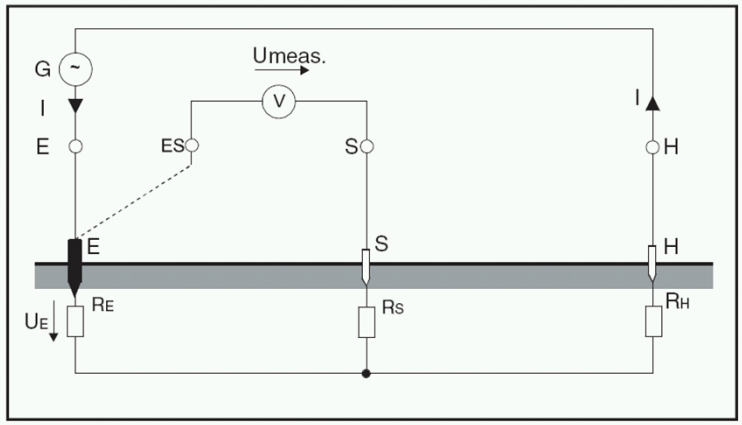
- Resistance Between Round Electrode System and Remote Earth
- Comprised of:
  - Resistance of Electrode
  - Contact Resistance Between the Electrode and Soil
  - Resistance of Soil, from the Electrode Surface Outward
  - Flow of current outward from the electrode to infinite earth



Ground Electrode Resistance

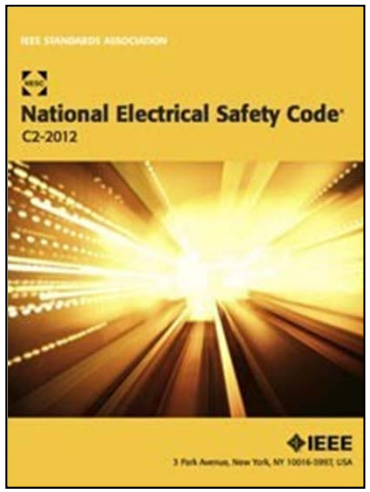
- Measurement of Ground Electrode Resistance

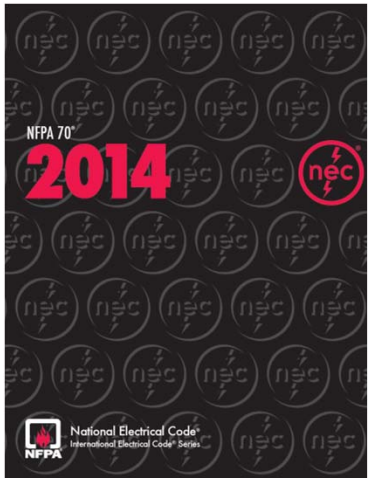
3-Point Fall-of-Potential Method

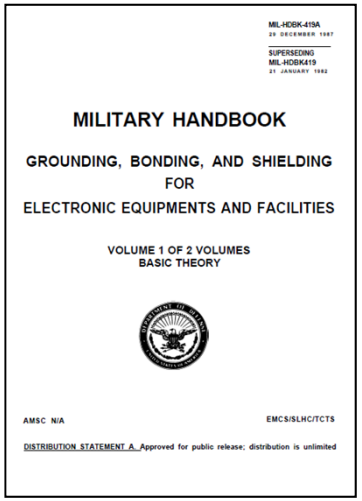


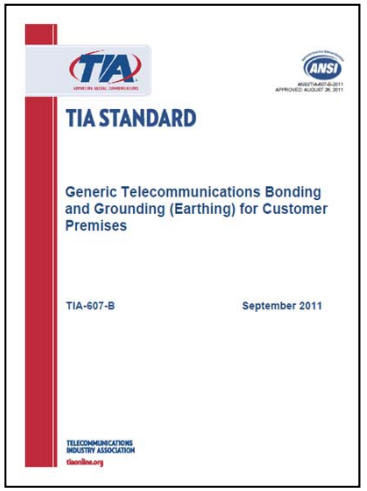
Ground Electrode Resistance

- Requirements
  - NEC and NESC
    25 ohms
  - Military Standards
    10 ohms
  - Telecom Industry
    5 ohms





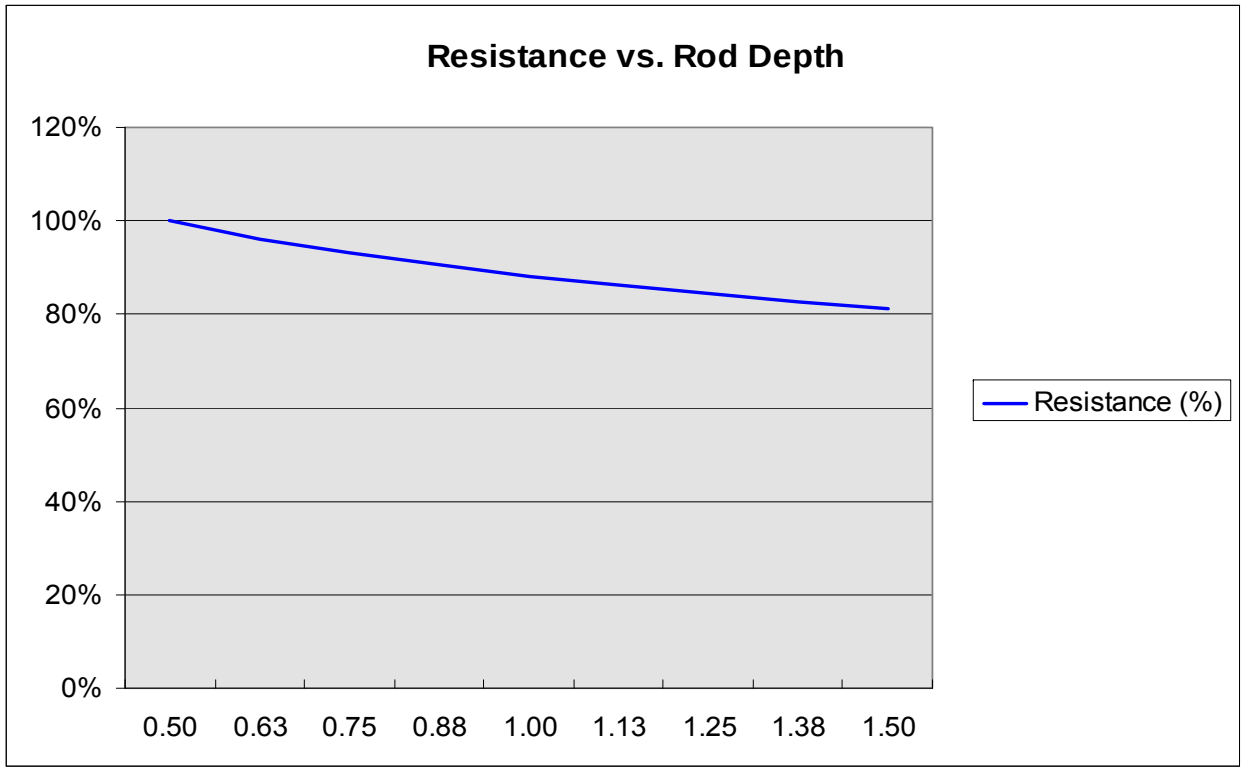




Lowering Ground Resistance

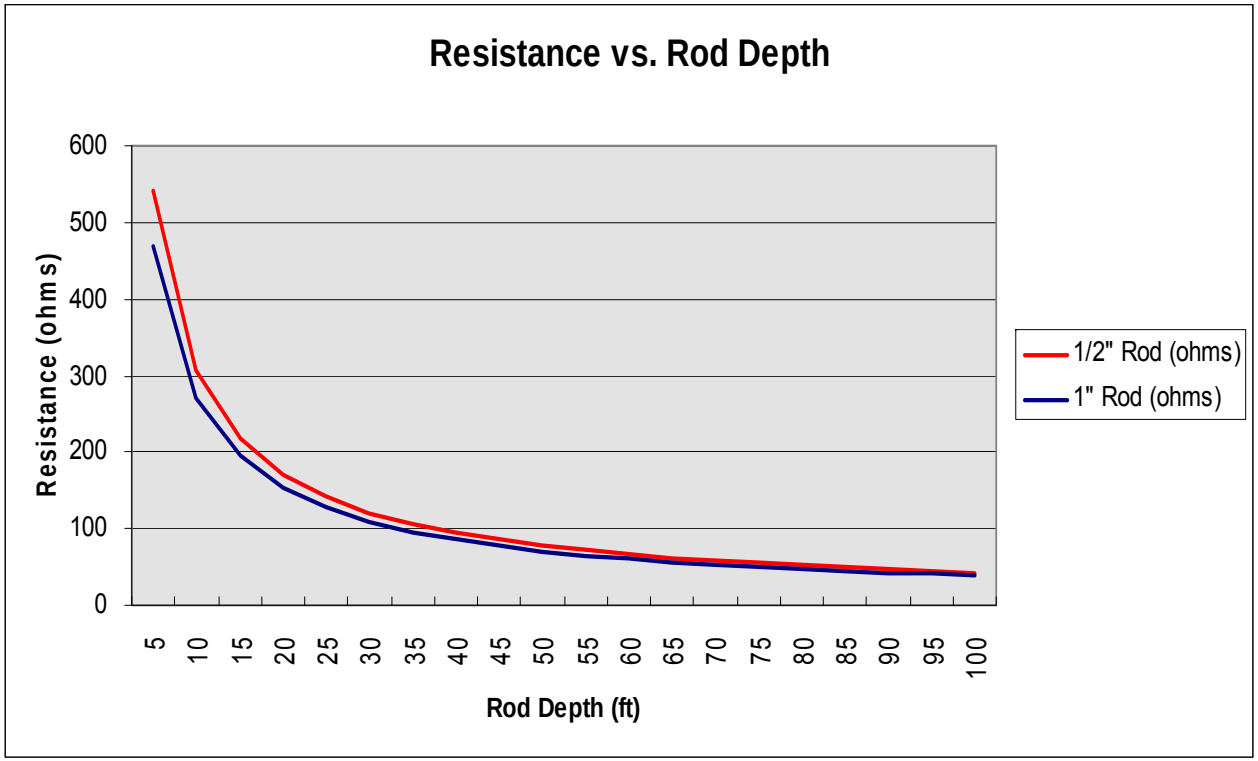
- What Affects the Grounding Resistance?
  - Diameter of the Ground Electrode
  - Length / Depth of the Ground Electrode
  - Number of Ground Electrodes
  - Grounding System Design

Lowering Ground Resistance



Rod Diameter Has Minor Effect on Resistance

Lowering Ground Resistance



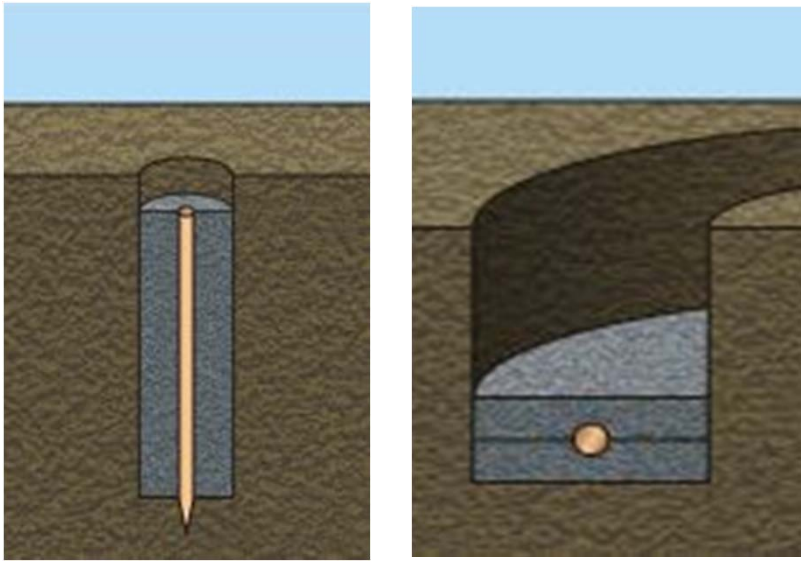
Doubling Rod Depth Reduces Resistance 40% In Uniform Soil

Lowering Ground Resistance

- Ground Enhancement Methods
  - Chemicals (Salts) and Chemical Ground Rods
    - May Need to Be Periodically Recharged
    - May Have Environmental Concerns Depending on Materials
  - Bentonite
    - Primarily Comprised of the Mineral Montmorillionite
    - Requires Moisture to Maintain Low Resistance

Lowering Ground Resistance

- Earthing (Ground) Enhancement Materials
  - Available in Several Forms Including Powders, Granules, Pellets, Gels and Cementitious Mixtures

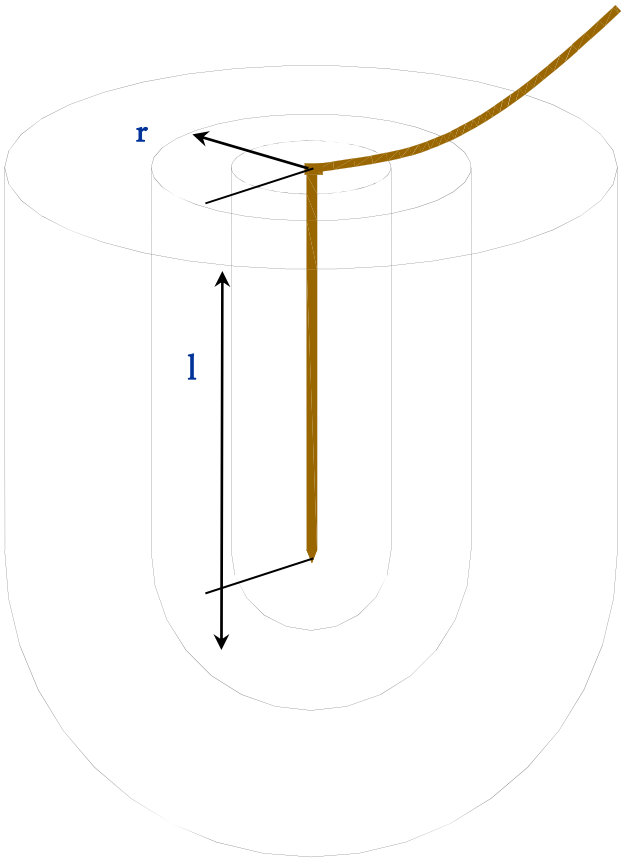


Ground Rod and Conductor with Earthing (Ground) Enhancement Material

Lowering Ground Resistance

- Copper Sulfate / Copper-based Solutions (Gels)
  - Chemical Treatment
  - Electrolytic or Ionic Conduction
- Carbon Based Materials
- Cementitious Materials
  - Permanent
  - Does Not Leach or Wash Away
  - Shown to be Effective in Long Term Independent Studies (NEGRP)

Ground Enhancement Material



Radius (r) in Meters	Percent of Resistance
0.03	25%
0.06	38%
0.09	46%
0.15	52%
0.3	68%
1.5	86%
3	94%

Resistance Around Rod

International Electrotechnical Commission

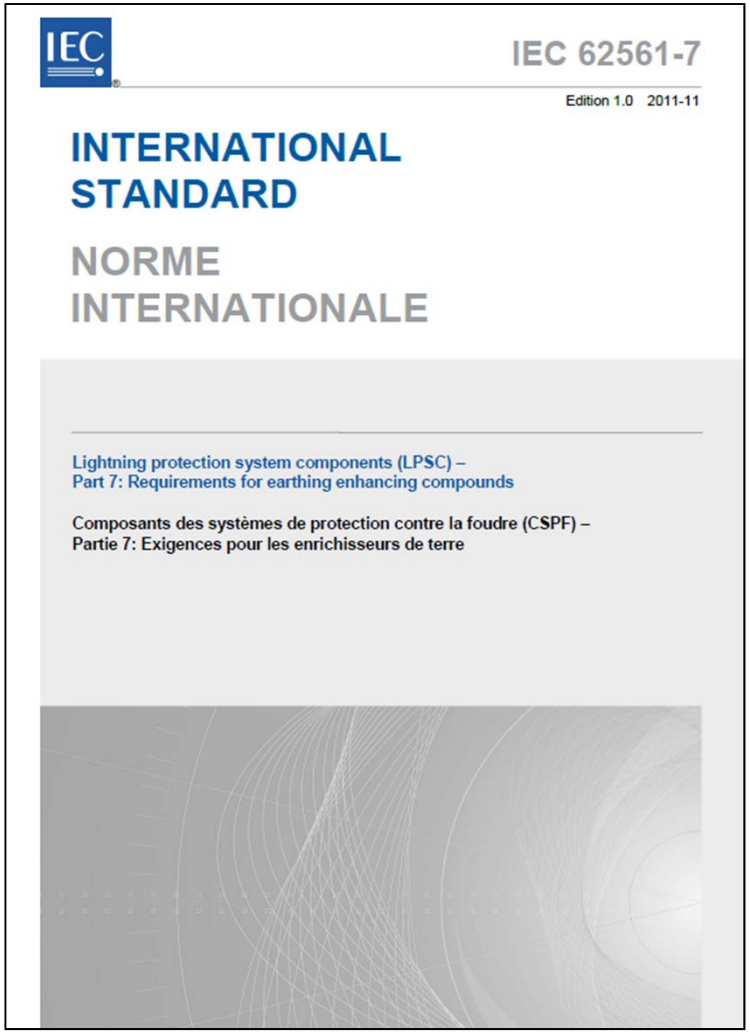
- Established in 1906
- Non-profit, Non-Governmental
- Headquartered in Geneva, Switzerland
- Part of World Standards Corporation
- 6,178 Published Standards

Standards Development

Technical Experts
↓
National Committees
↓
Technical Committees / Subcommittees
↓
IEC Standards

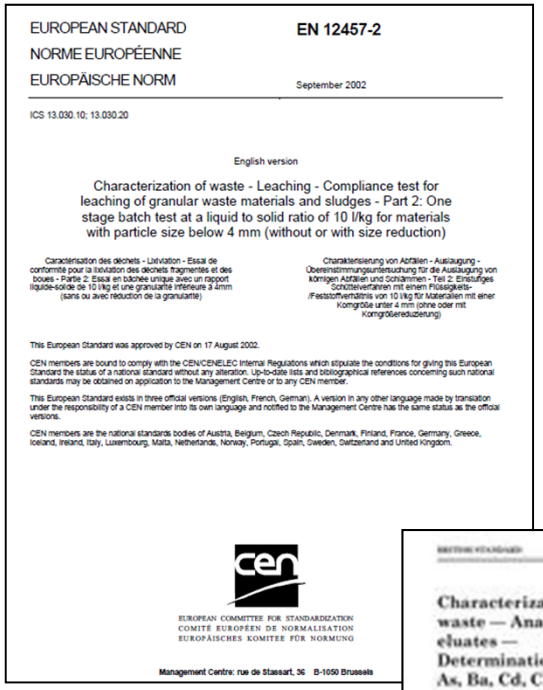
IEC 62561-7

- Lightning Protection System Components (LPSC), Part 7: Requirements for Earthing Enhancing Compounds
- Published November, 2011
  - Leaching
  - Sulfur
  - Resistivity
  - Corrosion
  - Marking / Indications
  - Test Report



IEC 62561-7 Leaching Tests

- Earth Enhancement Materials must be Chemically and Physically Stable
  - EN 12457-2
    - “Characterization of Waste - Leaching - Compliance Test for Leaching of Granular Waste Materials and Sludges - Part 2”
  - EN 12506
    - “Characterization of Waste - Analysis of Eluates - Determination of pH, As, Ba, Cd, Cl-, Co, Cr, Cr VI, Cu, Mo, Ni, NO2-, Pb, total S, SO_4^{2-}, V and Zn”.



EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 12457-2

September 2002

ICS 13.030.10; 13.030.20

English version

Characterization of waste - Leaching - Compliance test for leaching of granular waste materials and sludges - Part 2: One stage batch test at a liquid to solid ratio of 10 l/kg for materials with particle size below 4 mm (without or with size reduction)

Caractérisation des déchets - Lixiviation - Essai de conformité pour la lixiviation des déchets fragmentés et des boues - Partie 2: Essai en bâchée unique avec un rapport liquide-solide de 10 l/kg et une granularité inférieure à 4mm (sans ou avec réduction de la granularité)

Charakterisierung von Abfällen - Auslaugung - Übereinstimmungsuntersuchung für die Auslaugung von körnigen Abfällen und Schlämmen - Teil 2: Einstufiges Schüttelverfahren mit einem Flüssigkeits-/Feststoffverhältnis von 10 l/kg für Materialien mit einer Korngröße unter 4 mm (ohne oder mit Korngrößereduzierung)

This European Standard was approved by CEN on 17 August 2002.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN
EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

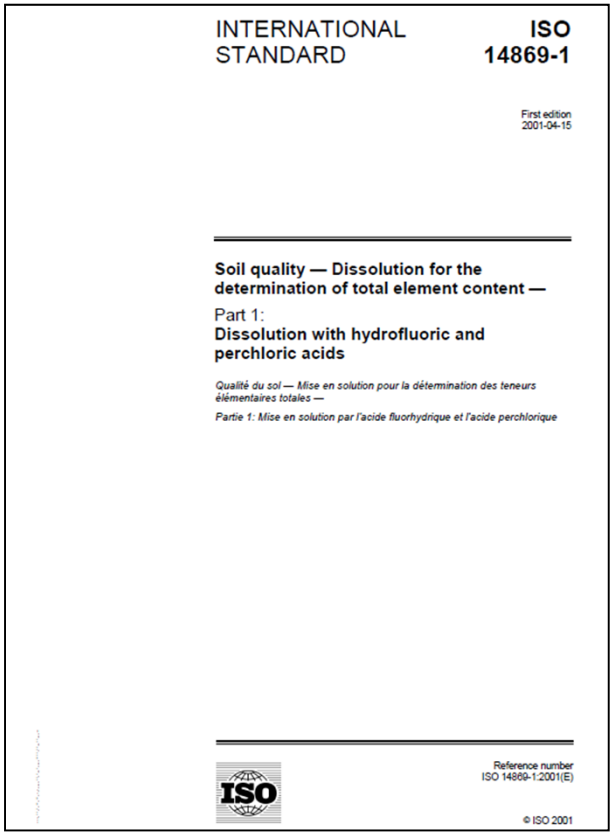
Management Centre: rue de Stassart, 36 B-1050 Brussels

Characterization of waste — Analysis of eluates — Determination of pH, As, Ba, Cd, Cl⁻, Co, Cr, Cr VI, Cu, Mo, Ni, NO_2^-, Pb, total S, SO_4^{2-}, V and Zn

BSI

IEC 62561-7 Sulfur Tests

- Sulfur Content
- Petroleum Coke often Used
- Corrosive to Ground Electrodes
- ISO 14869-1
  - "Soil quality - Dissolution for the Determination of Total Element Content -- Part 1: Dissolution with Hydrofluoric and Perchloric Acids"



INTERNATIONAL STANDARD

ISO 14869-1

First edition
2001-04-15

Soil quality — Dissolution for the determination of total element content —

Part 1:
Dissolution with hydrofluoric and perchloric acids

Qualité du sol — Mise en solution pour la détermination des teneurs élémentaires totales —

Partie 1: Mise en solution par l'acide fluorhydrique et l'acide perchlorique

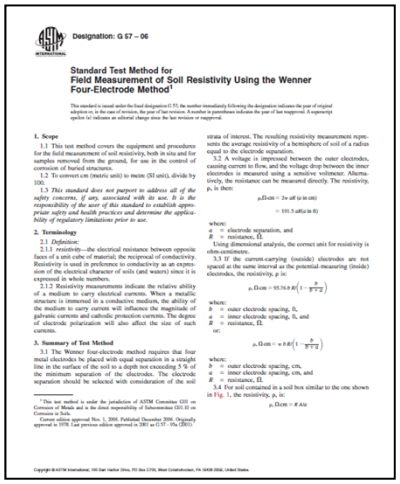
ISO

Reference number
ISO 14869-1:2001(E)

© ISO 2001

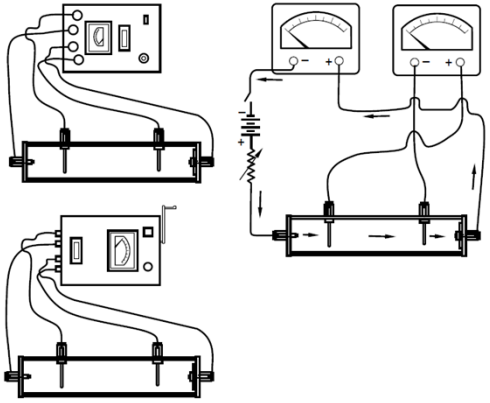
IEC 62561-7 Resistivity

- No Requirement for Minimum Resistivity
- Must be Marked on Packaging
  - Product Data Sheets
  - Catalog
  - Instruction Sheets
- Tested in Accordance to ASTM G-57
  - “Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method”.



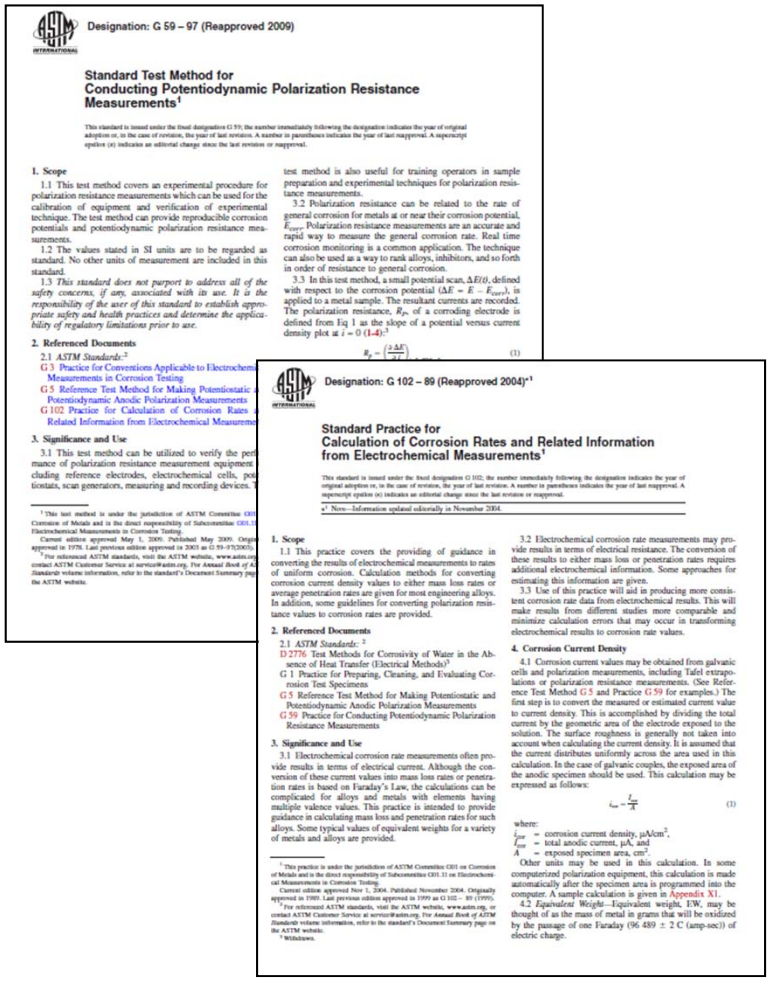
Designation: G 57 – 06

Standard Test Method for
Field Measurement of Soil Resistivity Using the Wenner
Four-Electrode Method[1]



IEC 62561-7 Corrosion

- Linear Polarization Resistance Method
- ASTM G59-97
  - "Standard Test Method for Conducting Potentiodynamic Polarization Resistance Measurements"
- ASTM G102-89
  - "Standard Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements"



Designation: G 59 – 97 (Reapproved 2009)

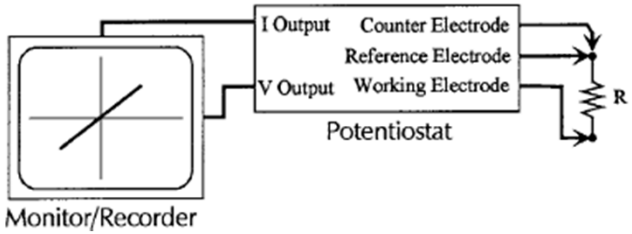
Standard Test Method for Conducting Potentiodynamic Polarization Resistance Measurements[1]

Designation: G 102 – 89 (Reapproved 2004)[ε1]

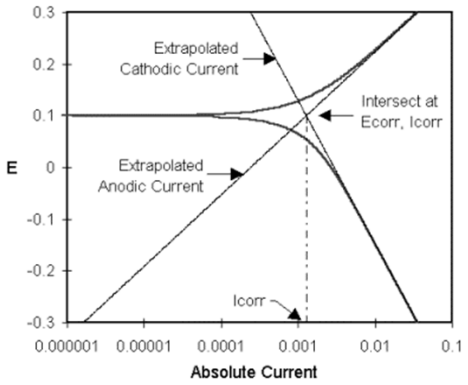
Standard Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements[1]

IEC 62561-7 Corrosion

- Polarization Resistance
  - Related to the Rate of General Corrosion for Metals at or Near their Corrosion Potential
  - Potentiostat Measures Current as a Function of Voltage
  - Results in Polarization Curve



Potentiostat



Polarization Curve

IEC 62561-7 Corrosion

- Polarization Resistance is Related to the Corrosion Current (Anodic or Cathodic) by the Stern-Geary Coefficient *B*

$$i_{corr} = \frac{B}{R_p}$$

B = Proportionality Constant (mV)

R_p = Linear Polarization Resistance ($\varsigma.m^2$)

i_{corr} = Corrosion Current (μA/cm2)

IEC 62561-7 Corrosion

- Stern-Geary Coefficient *B*
  - Determined Empirically by Weight Loss Experiments

    or
  - Calculated from Slopes of Anodic and Cathodic Tafel Curves

$$B = \frac{b_a b_c}{2.3(b_a + b_c)}$$

B = Stern-Geary Coefficient (mV)

b_a = Slope of Anodic Curve

b_c = Slope of Cathodic Curve

IEC 62561-7 Corrosion

- Conversion of Corrosion Current i_{corr} from μA/cm² to μm/yr

$$\frac{mA}{cm^2} = 3.28\frac{M}{nd}$$

1 μA/cm2 = 11.6 μm/yr for Copper

1 μA/cm2 = 15.0 μm/yr for zinc

M = atomic mass

n = number of electrons freed by corrosion reaction

d = density

IEC 62561-7 Corrosion

Copper

Corrosion Rate *C*

μm/yr

$$C = \frac{11.6B}{10R_p}$$

Zinc

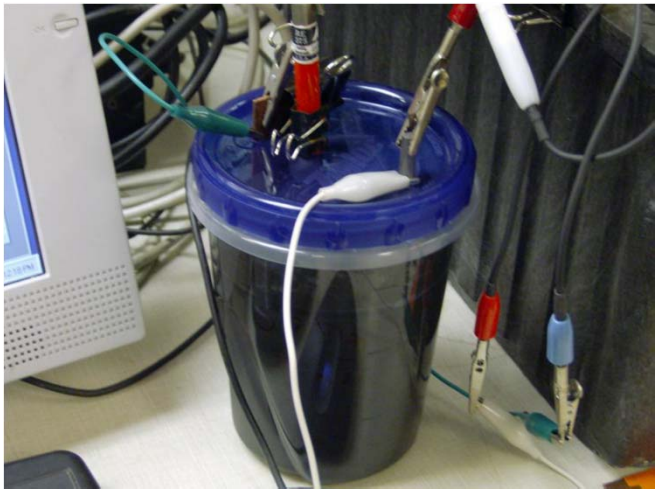
Corrosion Rate *C*

μm/yr

$$C = \frac{15.0B}{10R_p}$$

IEC 62561-7 Stern-Geary Constants

- Copper
  - Non-Aggressive Environments
    B = 25 mV
  - Aggressive Environments
    B = 50 mV
- Zinc
  - Non-Aggressive Environments
    B = 20 mV
  - Aggressive Environments
    B = 50 mV



Calculation of Polarization Resistance

- Copper
  - 10 mils (254 μm) Copper
  - Lifetime = 35 years
  - Corrosion Rate for Copper-bonded Ground Rods Must be Less than 7.3 μm/yr
  - Polarization Resistance
    - 4 Ω·m2 for Non-aggressive Environments
    - 8 Ω·m2 for Aggressive Environments

$$C = \frac{11.6B}{10R_p}$$

Copper

Calculation of Polarization Resistance

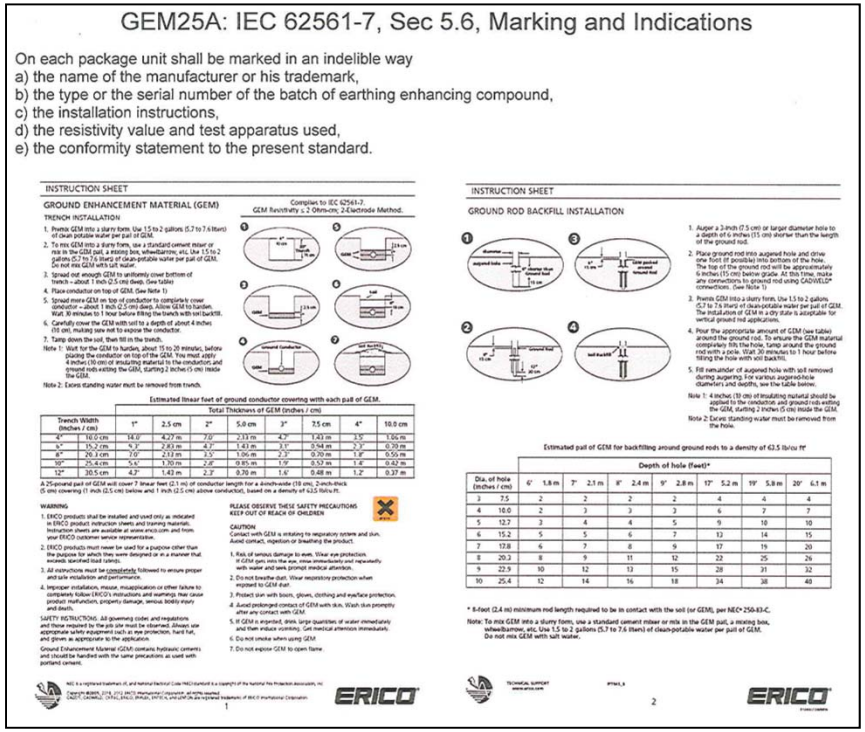
- Zinc
  - 3.9 mils (99 μm) of Zinc
  - Lifetime = 10 years
  - Corrosion Rate Must not Exceed 9.9 μm/yr
  - Polarization Resistance Greater Than
    - 3 Ω·m2 for Non-aggressive Environments
    - 7.6 Ω·m2 for Aggressive Environments

$$C = \frac{15.0B}{10R_p}$$

Zinc

IEC 62561-7 Marking and Indications

- The Following Must be Included:
  - Manufacturer's name, trademark or identifying symbol
  - Serial or Lot number
  - Must Include Installation Instructions
  - Resistivity and Test Apparatus Used
  - Conformity statement to IEC 62561-7



GEM25A: IEC 62561-7, Sec 5.6, Marking and Indications

On each package unit shall be marked in an indelible way
a) the name of the manufacturer or his trademark,
b) the type or the serial number of the batch of earthing enhancing compound,
c) the installation instructions,
d) the resistivity value and test apparatus used,
e) the conformity statement to the present standard.

INSTRUCTION SHEET

GROUND ENHANCEMENT MATERIAL (GEM)

TRENCH INSTALLATION

INSTRUCTION SHEET

GROUND ROD BACKFILL INSTALLATION

IEC 62561-7 Structure of Test Report

- **Report identification**
- **Specimen description**
- **Description of Test Procedure, Testing Equipment, and Measuring Instruments**
- **Results, Parameters, Passing Criteria**
- **Pass/Fail Statement**

Declaration of Conformity	
Supplier:	ERICO International Corporation 34600 Solon Road Solon, OH 44139 USA
Product Part Numbers:	GEM25A - 25-lb. (11.36 kg) bag with handle GEM25ABKT - 25-lb. (11.36 kg) plastic bucket
Standards Applied:	IEC 62561-7 (2011) - Lightning Protection System Components (LPSC) – Part 7: Requirements for Earthing Enhancing Compounds
Criteria:	Passed Leaching per EN 12457-2 method Passed Sulphur per ISO 14869-1 method Resistivity is less than 2 ohm-cm for a two-electrode method Corrosion passed per ASTM G59-97 and G102-89 method
We declare that, on the date the device accompanied by this declaration is placed on the market, the product conforms to all the technical and regulatory requirements of the above listed standard.	
Name, title, and signature:	Thomas Bockstoce Project Engineer, Product Development (Signature) (Date) 11/1/12
Document Reference (File/Revision):	ECDOC120901 Rev. B

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