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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 Thomas Bockstoce (Signature) 11/1/12 (Date)
Document Reference (File/Revision):	ECDOC120801 Rev. B

PRECISION ANALYTICAL, INC.

July 16, 2012

Tom Bockstose

Erico

34600 Solon Rd.

Solon, OH 44139

Subject: IEC 62561-7 data review

Mr. Bockstose,

Erico presented samples to Precision Analytical in May for analysis. The samples were three batches of Erico Product GEM25A. The original work-orders were 1205795 and 1205796. Additional analysis was performed on the samples on work-order 1207020.

Erico requested that PAI review the data generated against criteria spelled out in IEC 62561-7

5.2 Leaching Test

The leaching test was performed as required in the specification. The passing criteria cited in section 5.2.3 of IEC 62561-7 state criteria are given by national or international regulations. Attached is an Ohio EPA limit for a DI leach regarding the beneficial reuse of waste. This does not list all the metals run on per the IEC 62561-7. All samples submitted passed this criteria.

5.3 Sulfur Determination

The analysis was performed by ISO 14869-1 as required in the specification. Section 5.3.2 defines material passes test if all results are below 2%. All results for the samples were well below 2% therefore the material passes.

Cary Mathias

President

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Test ID# 1562 – GEM25A: IEC 62561-7, Sec 5.4, Determination of Resistivity

Greg Martinjak – (440) 248 – 0100 ext. 2051
Engineering Labs, Electrical
ERICO International Corporation, Solon, OH, USA
October 10, 2012

Project				
Ground Enhancement Material (GEM), part number GEM25A, an earth enhancement material was tested to determine the effective resistivity in standard lab conditions.				
System	**Batch #'s**			
GEM25A(Improved, IEC Compliant)		G1296B2 G1296B62 G1296B122	G1307-1 G1307-2 G1307-3	G1313-1 G1313-2 G1313-3
Test ID	**Revision**	**Test Title**		
1562	A	GEM25A:IEC62561-7, Sec 5.4, Determination of Resistivity		
Test Purpose				
Test IEC compliant GEM25A to IEC62561-7, Sec 5.4, Determination of Resistivity				
General Conditions to be Tested				
Resistivity of GEM25A				
Project Number	**Eng Number**	**Date Completed**		
ERT10-003	ESN16473	2012 – 07 – 17		

Conclusions/Observations

The following table shows that IEC Compliant GEM25A samples are less than 2 ohm-cm.

Batch #	Resistivity Average (Ω·cm)
G1036B *(Average):*	0.541
G1296 *(Average):*	0.488
G1307 *(Average):*	0.546
G1313 *(Average):*	0.275
Improved GEM (IEC Compliant):	0.436

Testing by	**Authorized by**
Greg Martinjak	Thomas Bockstoce

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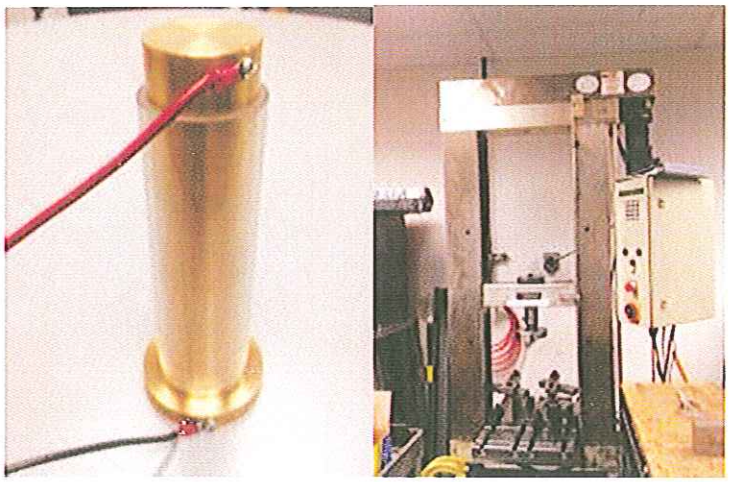
I. INTRODUCTION

Testing referenced by ID# 1562 was performed from June 26th through July 17th to provide knowledge regarding resistivity of a customized product known as GEM25A (Ground Enhancement Material) to IEC62561-7 (2011) - Lightning Protection System Components (LPSC) – Part 7: Requirements for Earthing Enhancing Compounds, Sec 5.4, Determination of Resistivity. A two-pole method was used to measure the resistance of a known amount of GEM25A contained in a known volume. All samples were tested in the same exact way using the same test setup and methodology.

II. EQUIPMENT AND TEST SETUP

ERICO's Tensile Machine and Earth Ground Tester were used for testing. The use of a custom test fixture as seen in **Figure 1** allowed for accurate resistance measurements with the Earth Ground Tester. The custom fixture would be placed in the Tensile Machine seen in **Figure 2** during testing. Insulation was carefully used to electrically isolate the custom fixture from the Tensile Machine.



Figures 1 and 2: Customized test fixture for the GEM (left) used alongside the Tensile Machine (right)

Table 1: Measurement equipment used for testing

Equipment Make	Description	Serial #	Model #	Operational Range	Last Calibration Date
Test Resources	Mechanical Tension/Compression Seismic Machine	TEN015	11kN	100-10000 lbs; 20" stroke	4/24/2012
LEM	Earth Ground Digital Tester	02-09	A604510307	0.001Ω - 299.9kΩ	(N)
MonoBloo	Weighing Scale	B13019	PB8001-S	8100g ±1g - 5g ±0.1g	6/11/2012

Table 1 shows the equipment used to measure values recorded in this report. The weighing scale enabled weighing the GEM to be measured with an accuracy of ±0.1g.

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III. EXPERIMENT METHODOLOGY

Test Methodology

Each GEM sample was quantified to be 10g using the scale specified in **Table 1**. The sample was then placed inside of the custom brass fixture. Using insulation, the fixture was electrically isolated and then placed inside of the Tensile Machine. The Tensile Machine was used to place a force of 451 lb (2006 N) which applied a pressure of 192 psi (1,323.8 kPa) to the sample.

Once the GEM was compressed, the total height of material that the GEM contained was recorded and three resistance measurements were taken using the Earth Ground Tester. The resistance of the brass custom fixture was subtracted from resistance obtained from testing and checked at the beginning and end of every test period to ensure consistency. The GEM, now completed with testing, was then removed from the customized test fixture and the fixture was then cleaned and prepared for the next sample.

To calculate the resistivity of the GEM samples, the following formula was used:

$$R = \frac{\rho \ell}{A}$$

$$\therefore \rho = R \cdot \frac{A}{\ell}$$

Where ℓ is the recorded length (cm)
A is the area of the brass cylinder (cm^2)
R is the resistance (Ω)
ρ is the resistivity $(\Omega \cdot cm)$

Sample Calculation:

$$R_1 = 0.061\ \Omega,\ R_2 = 0.060\ \Omega,\ R_3 = 0.060\ \Omega,\ R_{AVG} = 0.0603\ \Omega$$

$$\ell = 0.25" = 0.635\ cm$$

$$\rho = R \cdot \frac{A}{\ell} = (0.0603\ \Omega - 0.049\Omega)\frac{15.14\ cm^2}{0.635\ cm} = 0.269\Omega \cdot \text{cm}$$

Three samples of GEM were tested from each sample. The average resistivity of the three samples was then considered the final resultant value.

Passing criteria

The specimens are deemed to have passed the test if the obtained resistivity value from the three samples are equal or less than the resistivity value claimed by the manufacturer.

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IV. RESULTS

GEM SAMPLES 1036

GEM 1036 was the first mixture of New GEM. The mixture was created using a non-production process to create a 'prototype' GEM sample. The results can be seen below in **Table 2**.

Table 2: Results from first GEM Batch 1036

Resistivity (Ω·cm)					Average
G1036B	0.61	0.41	0.60		0.541

GEM SAMPLES 1296

GEM 1296 was the second mixture of New GEM. The mixture was created using the same machines used for GEM25A production. Samples were taken throughout the mixing process at various points. The first samples taken were referenced as B2 (Bag #2), the middle samples to be acquired were referenced as B62 (Bag #62), and the final samples to be obtained were referenced as B122 (Bag #122). Three 10g amounts were tested from each location in the mixture, as referenced by *EXPERIMENT METHODOLGY*. The results can be seen below in **Table 3**.

Table 3: Results from second GEM Batch 1296

Resistivity (Ω·cm)					Average
G1296 B2	0.64	0.42	0.49		0.516
G1296 B62	0.61	0.36	0.50		0.489
G1296 B122	-	0.31	0.49		0.404
G1296 *(Average):*					0.470

GEM SAMPLES 1307

GEM 1307 was the third mixture of New GEM. Similarly to GEM 1296, samples were acquired from the beginning, middle, and end of mixing. Three 10g amounts were tested from each location in the mixture, as referenced by *EXPERIMENT METHODOLGY*. The results can be seen in **Table 4**.

Table 4: Results from third GEM Batch 1307

Resistivity (Ω·cm)					Average
G1307-1	0.55	0.50			0.524
G1307-2	0.52	0.62	0.58		0.571
G1307-3	0.55	0.54			0.542
G1307 *(Average):*					0.546

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GEM SAMPLE 1313

GEM 1313 was the fourth mixture of New GEM. Similarly to GEM 1296, samples were acquired from the beginning, middle, and end of mixing. Three 10g amounts were tested from each location in the mixture, as referenced by *EXPERIMENT METHODOLGY*. The results can be seen in **Table 5**.

Table 5: Results from fourth GEM Batch G1313

Resistivity (Ω·cm)					Average
G1313-1	0.27	0.24			0.257
G1313-2	0.25	0.30			0.273
G1313-3	0.33	0.26			0.296
G1313 *(Average):*					0.275

V. CONCLUSIONS

GEM25A resistivity is less than 2 Ω · cm.

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ANNEX A – TEST REQUEST INSTRUCTIONS

Resistivity of Granular and Powder Materials Test Procedure

Equipment

- Digital low resistance ohm meter
- Compression test stand capable of 500 lbs of force
- 4.39 cm diameter brass plugs with low resistance ohmmeter leads attached. (see ERT10003D1)
- Sample Chamber. A hollow acrylic cylinder, 5.21 cm in diameter with a 3 mm wall thickness. (see ERT10003D1)

Procedure

1. Weigh out 10.0 grams of sample material.

2. Assemble the brass platans/acrylic die fixture (both brass platans in acrylic sleeve.)

3. Apply pressure to an empty die, release, apply pressure to a sample filled die, release, and record all height measurements necessary for the calculation of the resistivity.

4. Begin the resistivity method.

5. The initial step of the method allows enough room for placement of the entire fixture between the platens of the test stand. Be sure to include a nonconductive sheet between the top brass plug and the top platen of the test stand. After a brief time the top test platen will lower and apply a given force of 451lbs., take a measurement and release. This measurement will be recorded as the "set zero" reading. The applied force equates to a pressure of 192 pounds per square inch on the sample material.

$(451\ lbs/[((4.39cm/2)^2\pi)\ /2.54^2]\ x\ cm^2/in^2cm^2 = 192\ lbs/in^2$

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6. Again, the method will release pressure and allow enough room for removal of the fixture. At this point the top brass platan is removed and the sample material is funneled into the ceramic sleeve and the brass platan replaced. Replace entire fixture into test stand and include the nonconductive sheet.

7. Following the method, the test stand will now apply a force of 451lbs., hold this force for a given period of time, take a measurement and release. The measurement represents the sample height under pressure. While the sample is under pressure, record the reading of resistance on the low resistance ohmmeter (follow the manufacturers manual for the correct meter reading procedures). This reading is the total resistance of the sample.

8. The sample height is calculated by subtracting the set zero height from the height of the sample under pressure.

9. Calculation of resistivity: Resistivity is defined mathematically as the product of sample area and resistance divided by sample height:

$$\rho = \Omega \times \text{area/height}$$

10. Calculate the resistivity by multiplying the measured resistance by the sample area. Divide this product by the measured sample height.

11. Example:

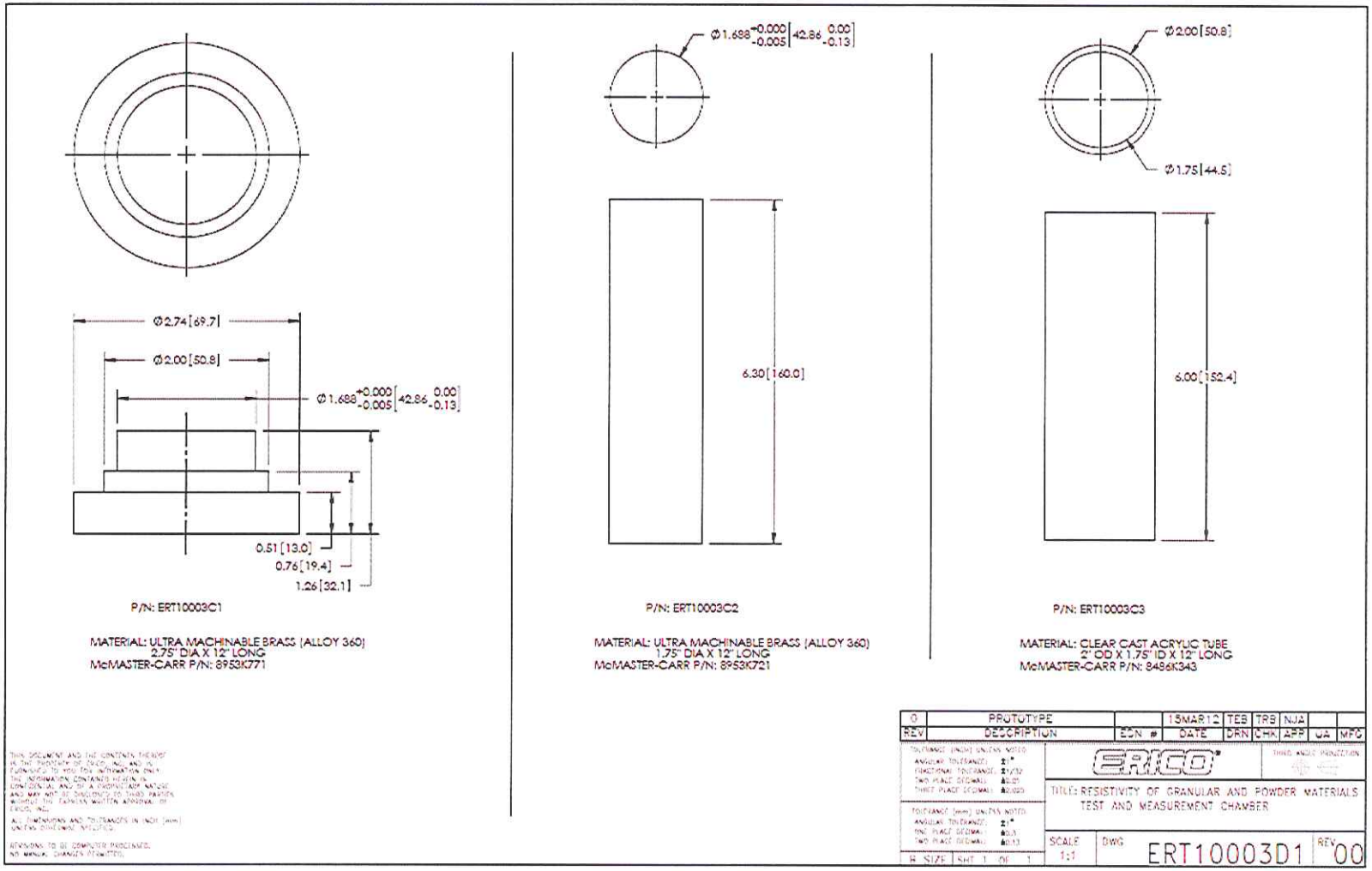
DIMENSIONAL ANALYSIS

$$\text{Resistivity } (\rho) = \text{ohm } (\Omega) \times \text{cm}^2/\text{cm} = \text{ohm} \times \text{cm} = \text{resistance} \times \text{length}$$

Using metric units, the final resistivity measurement should be reported in units of "ohm centimeters".

12. Resistivity must be calculated; it will never be equal to the resistance indicated on the ohmmeter, except by coincidence.

ANNEX B – DRAWING OF CUSTOM TEST FIXTURE



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GEM25A: IEC 62561-7, Sec 5.5, Corrosion Tests

Project		
Ground Enhancement Material (GEM), part number GEM25A, an earth enhancement material was tested to determine the corrosiveness used as earth enhancement compound.		
System	**Component(s)**	
GEM25A	Improved, IEC Compliant GEM25A	
Test ID	**Revision**	**Test Title**
051409	A	GEM25A:IEC62561-7, Sec 5.5, Corrosion Tests

Test Purpose

Test IEC compliant GEM25A to IEC62561-7, Sec 5.5, Corrosion Tests. The corrosion rate is determined by using Potentiodynamic Polarization Resistance methods as outlined in the ASTM Standards G59-97 "Standard Test Method for Conducting Potentiodynamic Polarization Resistance Measurements" and G102-89 "Standard Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements".

General Conditions to be Tested

Corrosiveness of GEM25A

Project Number	**EN Number**	**Date Completed**
ERT10-003	ESN16473	May 14, 2009

Conclusions/Observations

Test No.	B (mV)	Mean LPR, 0-40 days ($\Omega.m^2$)	Initial corrosion rate (µm/year)	Mean LPR, 40+ days ($\Omega.m^2$)	Long term corrosion rate (µm/year)
4C	25	16.95	0.48, 1.7	25.6	0.33, 1.1
4D	50	11.36	5.1	152.7	0.4

Test 4C = IEC Compliant GEM25A
Test 4D = IEC Compliant GEM25A in NaCl environment

All results for the samples were well greater than the **4 $\Omega.m^2$** therefore the material passes.

Testing by	**Authorized by**
Dr. Franco D'Alessandro PhysElec Solutions Pty Ltd	Thomas Bockstoce

IEC compliant GEM25A Tested to IEC 62561-7, Sec 5.5, Corrosion Tests
ERICO, 14 May 2009

Calculation Overview

Calculations are carried out using the Stern-Geary Equation,

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

where B = proportionality constant for a particular system (mV), R_p is the linear polarisation resistance ($W.m^2$) and the corrosion current i_{corr} is in units of $\mu A/cm^2$.

B can he determined empirically (calibrated from separate weight loss measurements) or, as shown by Stern and Geary, can be calculated from b_a and b_c, the slopes of the anodic and catholic Tafel curves, where

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

Conversion of $\mu A/cm^2$ to $\mu m/yr$

The conversion of $\mu A/cm^2$ to $\mu m/yr$ is simply: **1 $\mu A/cm^2$ = 11.6 $\mu m/yr$ for Copper**. This conversion is based on the molar density of copper and Faraday's constant.

Hence, the corrosion rate C ($\mu m/yr$) is given by:

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

It is important to note the factor of 10, which comes into the equation from the mix of SI and non-SI units (cm, m, etc).

What value of B should be used for copper?

Past studies have shown that:

- B = 7 mV for copper in bentonite buried deep in rock (oxygen free spent nuclear fuel storage) [1]; , i.e., ideal conditions;
- B = 25 mV in impermeable concrete, more typical for GEM-type applications;
- For steel in concrete under severe attack by the environment (e.g., 350 ppm NaCl testing as carried out), it is often claimed to be 50, but Monash have found B = 80 mV under aggressive conditions.

[1] Rosborg, B.; Pan, J.; Leygraf, C., 2008, *Corrosion Science*, *47*, 3267-3279.

So, we will use B = 25 mV for "non-aggressive environments" and B = 50 mV for "aggressive environments". The other alternative is to carry out another series of tests to determine the value of B experimentally.

Based on the above methodology, it then follows that if the corrosion rate must not exceed 7.3 $\mu m/yr$ (10 mils or 254 μm of copper that must last 35 years), the polarization resistance must be > 4 $\Omega.m^2$ for non-aggressive environments and > 8 $\Omega.m^2$ for aggressive environments.

Results Summary

Test No.	B (mV)	Mean LPR, 0-40 days ($\Omega.m^2$)	Initial corrosion rate (µm/year)	Mean LPR, 40+ days ($\Omega.m^2$)	Long term corrosion rate (µm/year)
4C	25	16.95	0.48, 1.7	25.6	0.33, 1.1
4D	50	11.36	5.1	152.7	0.4

Test 4C = IEC Compliant GEM25A
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All results for the samples were well greater than the **4 $\Omega.m^2$** therefore the material passes.

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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)

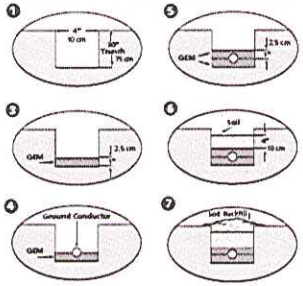
Complies to IEC 62561-7.
GEM Resistivity ≤ 2 Ohm-cm; 2-Electrode Method.

TRENCH INSTALLATION

1. Premix GEM into a slurry form. Use 1.5 to 2 gallons (5.7 to 7.6 liters) of clean potable water per pail of GEM.
2. To mix GEM into a slurry form, use a standard cement mixer or mix in the GEM pail, a mixing box, wheelbarrow, etc. Use 1.5 to 2 gallons (5.7 to 7.6 liters) of clean-potable water per pail of GEM. Do not mix GEM with salt water.
3. Spread out enough GEM to uniformly cover bottom of trench – about 1 inch (2.5 cm) deep. (See table)
4. Place conductor on top of GEM. (See Note 1)
5. Spread more GEM on top of conductor to completely cover conductor – about 1 inch (2.5 cm) deep. Allow GEM to harden. Wait 30 minutes to 1 hour before filling the trench with soil backfill.
6. Carefully cover the GEM with soil to a depth of about 4 inches (10 cm), making sure not to expose the conductor.
7. Tamp down the soil, then fill in the trench.

Note 1: Wait for the GEM to harden, about 15 to 20 minutes, before placing the conductor on top of the GEM. You must apply 4 inches (10 cm) of insulating material to the conductors and ground rods exiting the GEM, starting 2 inches (5 cm) inside the GEM.

Note 2: Excess standing water must be removed from trench.



Estimated linear feet of ground conductor covering with each pail of GEM.

Trench Width (Inches / cm)		Total Thickness of GEM (Inches / cm)							
		1"	2.5 cm	2"	5.0 cm	3"	7.5 cm	4"	10.0 cm
4"	10.0 cm	14.0'	4.27 m	7.0'	2.13 m	4.7'	1.43 m	3.5'	1.06 m
6"	15.2 cm	9.3'	2.83 m	4.7'	1.43 m	3.1'	0.94 m	2.3'	0.70 m
8"	20.3 cm	7.0'	2.13 m	3.5'	1.06 m	2.3'	0.70 m	1.8'	0.55 m
10"	25.4 cm	5.6'	1.70 m	2.8'	0.85 m	1.9'	0.57 m	1.4'	0.42 m
12"	30.5 cm	4.7'	1.43 m	2.3'	0.70 m	1.6'	0.48 m	1.2'	0.37 m

A 25-pound pail of GEM will cover 7 linear feet (2.1 m) of conductor length for a 4-inch-wide (10 cm), 2-inch-thick (5 cm) covering (1 inch (2.5 cm) below and 1 inch (2.5 cm) above conductor), based on a density of 63.5 lb/cu ft.

WARNING

1. ERICO products shall be installed and used only as indicated in ERICO product instruction sheets and training materials. Instruction sheets are available at www.erico.com and from your ERICO customer service representative.
2. ERICO products must never be used for a purpose other than the purpose for which they were designed or in a manner that exceeds specified load ratings.
3. All instructions must be completely followed to ensure proper and safe installation and performance.
4. Improper installation, misuse, misapplication or other failure to completely follow ERICO's instructions and warnings may cause product malfunction, property damage, serious bodily injury and death.

SAFETY INSTRUCTIONS: All governing codes and regulations and those required by the job site must be observed. Always use appropriate safety equipment such as eye protection, hard hat, and gloves as appropriate to the application.

Ground Enhancement Material (GEM) contains hydraulic cements and should be handled with the same precautions as used with portland cement.

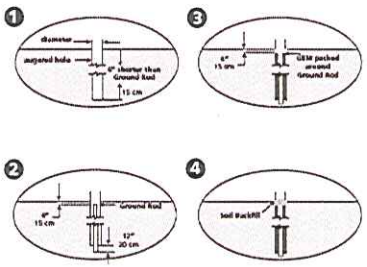
PLEASE OBSERVE THESE SAFETY PRECAUTIONS
KEEP OUT OF REACH OF CHILDREN

CAUTION
Contact with GEM is irritating to respiratory system and skin. Avoid contact, ingestion or breathing the product.

1. Risk of serious damage to eyes. Wear eye protection. If GEM gets into the eye, rinse immediately and repeatedly with water and seek prompt medical attention.
2. Do not breathe dust. Wear respiratory protection when exposed to GEM dust.
3. Protect skin with boots, gloves, clothing and eye/face protection.
4. Avoid prolonged contact of GEM with skin. Wash skin promptly after any contact with GEM.
5. If GEM is ingested, drink large quantities of water immediately and then induce vomiting. Get medical attention immediately.
6. Do not smoke when using GEM.
7. Do not expose GEM to open flame.

INSTRUCTION SHEET

GROUND ROD BACKFILL INSTALLATION



1. Auger a 3-inch (7.5 cm) or larger diameter hole to a depth of 6 inches (15 cm) shorter than the length of the ground rod.
2. Place ground rod into augered hole and drive one foot (if possible) into bottom of the hole. The top of the ground rod will be approximately 6 inches (15 cm) below grade. At this time, make any connections to ground rod using CADWELD® connections. (See Note 1)
3. Premix GEM into a slurry form. Use 1.5 to 2 gallons (5.7 to 7.6 liters) of clean-potable water per pail of GEM. The installation of GEM in a dry state is acceptable for vertical ground rod applications.
4. Pour the appropriate amount of GEM (see table) around the ground rod. To ensure the GEM material completely fills the hole, tamp around the ground rod with a pole. Wait 30 minutes to 1 hour before filling the hole with soil backfill.
5. Fill remainder of augered hole with soil removed during augering. For various augered-hole diameters and depths, see the table below.

Note 1: 4 inches (10 cm) of insulating material should be applied to the conductors and ground rods exiting the GEM, starting 2 inches (5 cm) inside the GEM.

Note 2: Excess standing water must be removed from the hole.

Estimated pail of GEM for backfilling around ground rods to a density of 63.5 lb/cu ft*

Dia. of hole (Inches / cm)		Depth of hole (feet)*						
		6' 1.8 m	7' 2.1 m	8' 2.4 m	9' 2.8 m	17' 5.2 m	19' 5.8 m	20' 6.1 m
3	7.5	2	2	2	2	4	4	4
4	10.0	2	3	3	3	6	7	7
5	12.7	3	4	4	5	9	10	10
6	15.2	5	5	6	7	13	14	15
7	17.8	6	7	8	9	17	19	20
8	20.3	8	9	11	12	22	25	26
9	22.9	10	12	13	15	28	31	32
10	25.4	12	14	16	18	34	38	40

* 8-foot (2.4 m) minimum rod length required to be in contact with the soil (or GEM), per NEC® 250-83-C.

Note: To mix GEM into a slurry form, use a standard cement mixer or mix in the GEM pail, a mixing box, wheelbarrow, etc. Use 1.5 to 2 gallons (5.7 to 7.6 liters) of clean-potable water per pail of GEM. Do not mix GEM with salt water.