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NEGRP TEST SUMMARY

Joseph A. Lanzoni, November 2005

The National Electrical Grounding Research Project (NEGRP) was a project managed and sponsored by the National Fire Protection Association (NFPA) Research Foundation. The objective of the project was to test several different types of grounding electrodes in different types of soils, and then to compare their grounding resistances to earth.

The first site was installed in 1992 in Las Vegas, Nevada. During subsequent years, additional sites were installed in Dallas, Texas; Northbrook, Illinois; Poughkeepsie, New York; and Staunton, Virginia. At the first site, 18 different types of grounding electrodes were installed. At the four subsequent sites, 15 different types of grounding electrodes were installed. The variety of electrodes included conventional ground rods, copper plates, bare wire, rebar, etc. See the attached appendix, NEGRP Electrode Legend.

After installation, the resistance to earth of each electrode was measured every month. The measurements were taken by technicians from local electric utilities, working under the direction of the NFPA Research Foundation. The test data was then compiled and distributed by the NFPA Research Foundation. The measurements continued for several years until the project was discontinued after a sufficiently large volume of data was collected. The last full set of data from all five sites was gathered in December 2000. See the attached appendix, NEGRP Test Data from December 2000.

At all five sites, Electrode R is a ten foot long LEC Chem-Rod backfilled with Grounding Augmentation Fill (GAF). At the sites other than the one in Nevada, Electrode Y is a ten foot long horizontal Chem-Rod backfilled with GAF. GAF is a conductive material made for backfilling around any type of grounding electrode.

As you can see from the test data, the lowest resistance readings are consistently generated by Electrodes R and Y. For example, at the Nevada site, the lowest reading is 18 ohms by Electrode R. In another example, at the Virginia site the lowest reading is 10 ohms by Electrode R3, while the second lowest reading is 11 ohms by Electrode Y2.

It is important to note that these test measurements were taken by utility company technicians, working under the direction of the NFPA Research Foundation. At no time did LEC measure or compile the data. This project is a true, independent demonstration of the effectiveness of the LEC Chem-Rod.

Attachments
Appendix 1 - NEGRP Electrode Legend
Appendix 2 - NEGRP Test Data from December 2000

Appendix 1
NEGRP ELECTRODE LEGEND

Site Location:
Las Vegas, Nevada

A	#2 horizontal copper wire, 50' long, 36" deep, centered in 6"x12" sand
B	#4 steel horizontal rebar, 20' long, 12" deep, centered in 12"x12" concrete
C	#4 horizontal copper wire, 25' long, 12" deep, centered in 6"x6" GEM[1]
D	#4 horizontal copper wire, 25' long, 12" deep, centered in 6"x6" concrete
E	5/8"x8' copper clad vertical ground rod in 9" diameter hole with GEM[1]
F	5/8"x8' copper clad horizontal ground rod, 22" deep, centered in 4"x6" GEM[1]
G	5/8"x8' copper clad horizontal ground rod 24" deep
H	5/8"x8' copper clad vertical ground rod
I	3/4"x10' galvanized vertical ground rod
J	3/4"x10' galvanized horizontal ground rod 24" deep
K	12"x12" copper grounding plate 24" deep
L	XIT[2] vertical chemical rod, 8' long, buried 9' deep in 9" diameter hole
M	#4 rebar cage with 6 bars, in 24" diameter hole 30" deep, with concrete
N	#4 copper wire 20' long, coiled in 30" diameter hole 24" deep, with concrete
O	#4 copper wire 20' long, coiled in 30" diameter hole 24" deep, with GEM[1]
P	Wood utility pole wrapped with #6 copper wire with 7.5" diameter butt plate
Q	1/2"x8' horizontal copper clad ground rod, 36" deep, in 6"x12" sand
R	Chem-Rod[4] vertical chemical rod, 10' long, in 9" diameter hole with GAF[3]

Suffix “1”	Exothermically welded connection
Suffix “2”	Bolted connection

Site Locations
Staunton, Virginia
Poughkeepsie, New York
Dallas, Texas
Northbrook, Illinois

B	#4 steel horizontal rebar, 20' long, 12" deep, centered in 12"x12" concrete
E	5/8"x8' copper clad vertical ground rod in 9" diameter hole with GEM[1]
F	5/8"x8' copper clad horizontal ground rod, 28" deep, centered in 4"x6" GEM[1]
G	5/8"x8' copper clad horizontal ground rod 30" deep
H	5/8"x8' copper clad vertical ground rod
K	12"x12" copper grounding plate 24" deep
L	XIT[2] vertical rod 10' long, buried 11' deep in 9" diameter hole with bentonite
R	Chem-Rod[4] vertical rod 10' long buried 11' deep in 10" diameter hole with GAF[3]
S	8' horizontal XIT[2] electrode 36" deep centered in 9" diameter bentonite backfill
T	3/4"x8' vertical galvanized steel pipe
V	4/0 horizontal stranded copper wire, 20' long, 36" deep
W	Cage of eight 5/8"x6' copper clad vertical ground rods, in 30" diameter hole with concrete
X	5/8"x8' stainless steel clad vertical ground rod
Y	10' horizontal Chem-Rod[4] electrode 42" deep centered in 9" GAF[3] backfill
Z	#6 copper 4"x4" mesh, 36" deep, overall dimensions of 2'x8'

Suffix “a”	Exothermically welded connection
Suffix “b”	Mechanical connection
Suffix “c”	Compression connection

Notes
1. GEM is Ground Enhancement Material, a conductive backfill material manufactured by Erico.
2. The XIT rod is a type of chemical ground rod, 2" in diameter, manufactured by Lyncole Industries.
3. GAF is Grounding Augmentation Fill, a conductive backfill material manufactured by Lightning Eliminators & Consultants.
4. The Chem-Rod is a type of chemical ground rod, 2.625" in diameter, manufactured by Lightning Eliminators & Consultants.

Appendix 2
NEGRP TEST DATA FROM DECEMBER 2000

Las Vegas, Nevada

NEGRP

Location: Las Vegas, NV
Year: 2000
Test Site: BALBOA

	Read Date 1/30	Read Date 2/27	Read Date	Read Date 4/6	Read Date 5/30	Read Date 7/1	Read Date 7/31	Read Date 8/27	Read Date 9/30	Read Date 10/21	Read Date 11/18	Read Date 12/28
Soil Ohm-cm @10 Ft.	9077	15550		4385	3236	8904.7	8062.2	8981	8904.7	8138.5	10801	9958
Soil Ohm-cm @20 Ft.	15282	16086		14439	12677	12103	13673	13864	11720	13788	14363	12218
ELECTRODE ID	Ohms	Ohms	Ohms	Ohms	Ohms	Ohms	Ohms	Ohms	Ohms	Ohms	Ohms	Ohms
A1	117	106		93	72	70	66	59	60	78	91	53
A2	117	106		93	72	70	66	59	60	78	91	53
B1	65	44		37	35	41	44	38	35	45	53	61
B2	65	44		37	35	41	44	38	35	45	53	61
C1	8800	5200		288	2100	784	568	361	686	755	2560	17500
C2	47	48		53	68	1056	1260	861	975	1005	1150	1070
D1	74	51		43	41	52	55	48	40	50	64	85
D2	74	50		43	41	52	55	48	40	50	64	85
E1	33	24		23	20	20	20	19	20	22	24	20
E2	33	24		23	20	20	20	19	20	22	24	20
F1	55	39		34	29	32	32	28	32	40	43	46
F2	55	39		34	29	32	32	28	32	40	43	46
G1	555	492		378	288	335	359	305	335	415	502	596
G2	555	493		378	288	335	359	305	335	415	502	596
G3	555	492		379	288	335	359	305	335	415	502	600
H1	102	91		89	81	81	74	71	63	59	85	87
H2	96	91		89	81	81	74	71	63	59	85	87
H3	101	91		89	81	81	74	71	63	57	85	87
I1	45	39		38	35	34	31	31	32	32	36	38
I2	45	39		38	35	34	31	31	32	32	36	38
J1	159	152		130	103	102	98	88	80	101	131	174
J2	158	152		130	103	102	98	88	80	101	131	174
K1	1798	554		474								
K2	752	743		578	501	566	582	512	565	651	895	1050
L1	35	29		29	27	22	23	22	20	23	24	26
L2	35	29		29	27	22	23	22	20	23	24	26
M1	157	123		103	90	105	107	94	112	115	141	169
M2	157	123		103	90	105	107	94	112	115	141	169
M3	158	123		103	90	105	107	94	112	115	141	169
N1	110	85		74	65	74	74	66	62	77	95	113
N2	110	86		74	65	74	74	66	62	77	95	113
N3	110	85		74	65	74	74	66	62	77	95	113
O1	79	58		52	47	50	51	45	45	60	67	73
O2	79	59		52	47	50	51	45	45	60	67	73
P1	99	88		83	73	71	67	65	67	74	81	85
P2	99	88		83	73	71	67	65	67	74	81	85
Q1	456	452		407	309	356	369	321	335	365	425	20000
Q2	461	452		407	309	356	369	321	335	365	425	20000
R1	28	22		22	21	20	18	18	18	18	19	19
R2	28	22		22	21	20	18	18	18	18	19	19
S1												
S2												

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Dallas, Texas

NATIONAL ELECTRICAL GROUNDING RESEARCH PROJECT
Test Measurement Template

Soils Resistivity
Electrode Resistance
Soil Temperature, Soil Moisture

SITE	AVO-Dallas
BY	Jimmy Rogers
DATE	12/28/2000
GT INST	Meger DT 2/2
Freq -	150
Filter -	off
Multimeter -	AVO800
Ammeter	Current Probe
Thermometer	Omega
Moist Inst	Delmhorst

RED = Ground Rod		YELLOW = Gal Pipe	
DC Volts	15.23	DC Volts	15.19
Hrs.	1316.9	Hrs	778.5
Test to DC1D		Test to DC2D	
Current	ma	Current	ma
DC1A	5.5	DC2A	5.71
DC1B	5.43	DC2B	5.64
DC1C	5.49	DC2C	5.73
DC1D	19.36	DC2D	20.2

Dissimilar Metals DM	
Current	ma
DM1	1.25
DM2	0.73
DM3	0.73

RESISTIVITY CALCULATIONS

P = 2PI R X
R = Resistance
X = Distance Between Electrodes

Convert Ohm-Ft. to Ohms-Cm
Ohm-Ft = 30.48 Ohm-Cm
2pi 30.48 = 191.5

10 FT. SOILS RESISTIVITY			
Meter reading in Ohms ----------	1.609	Soils Resistivity ------	3081 OHM-CM

20 FT. SOILS RESISTIVITY			
Meter reading in Ohms ----------	0.804	Soils Resistivity ------	3079 OHM-CM

SOILS TEMPERATURE AND MOISTURE	SENSOR ID NO.		
	1	2	3
DEPTH	126"	78"	30"
TEMPERATURE	T1	T2	T3
	69.9	60.5	48.1
MOISTURE	M1	M2	M3
	95.2	-5.6	95.4

RESISTANCE IN OHMS			
	TERMINAL		
ELECT	A	B	C
B1	31	31	31
B2	37	37	37
B3	35	35	35
E1	4	4	4
E2	4	4	4
E3	4	4	4
F1	8	8	8
F2	6	6	6
F3	5	5	5
G1	14	14	14
G2	14	14	14
G3	17	17	17
H1	7	7	7
H2	6	6	6
H3	6	6	6
K1	17	17	17
K2	23	23	23
K3	23	23	23
L1	6	6	6
L2	4	4	4
L3	5	5	5
R1	2	2	2
R2	2	2	2
R3	3	3	3
S1	5	5	5
S2	5	5	5
S3	5	5	5
T1	5	5	5
T2	6	6	6
T3	6	6	6
V1	13	13	13
V2	12	12	12
V3	10	10	10
W1	5	5	5
W2	5	5	5
W3	5	5	5
X1	6	6	6
X2	7	7	7
X3	8	8	8
Y1	4	4	4
Y2	3	3	3
Y3	4	4	4
Z1	5	5	5
Z2	5	5	5
Z3	5	5	5

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Northbrook, Illinois

NATIONAL ELECTRICAL GROUNDING RESEARCH PROJECT
Test Measurement Template

Soils Resistivity
Electrode Resistance
Soil Temperature, Soil Moisture

SITE	NBK
BY	Dubiel
DATE	12/20/2000
GT INST	Meggar DET2/2
Freq -	150
Filter -	Off
Multimeter -	Fluke 87
Ammeter	AEMC K110
Thermometer	Omega HH-25KE
Moist Inst	Delmhorst KSD1

RED = Ground Rod		YELLOW = Gal Pipe	
DC Volts		DC Volts	
Hrs.	8533	Hrs	8561
Test to DC1D		Test to DC2D	
Current	ma	Current	ma
DC1A	5.1	DC2A	5.2
DC1B	5.1	DC2B	5.2
DC1C	5.4	DC2C	5.2
DC1D	15.8	DC2D	15.8

Dissimilar Metals DM	
Current	ma
DM1	0.1
DM2	0.6
DM3	0.6

RESISTIVITY CALCULATIONS

P = 2PI R X
R = Resistance
X = Distance Between Electrodes

Convert Ohm-Ft. to Ohms-Cm
Ohm-Ft = 30.48 Ohm-Cm
2pi 30.48 = 191.5

10 FT. SOILS RESISTIVITY			
Meter reading in Ohms ----------	1.532	Soils Resistivity ------	2,934 OHM-CM

20 FT. SOILS RESISTIVITY			
Meter reading in Ohms ----------	0.55	Soils Resistivity ------	2,107 OHM-CM

SOILS TEMPERATURE AND MOISTURE	SENSOR ID NO.		
	1	2	3
DEPTH	126"	78"	30"
TEMPERATURE	T1	T2	T3
	53.5	41.4	49.5
MOISTURE	M1	M2	M3
	96.5	96.8	96.7

RESISTANCE IN OHMS			
	TERMINAL		
ELECT	A	B	C
B1	7	7	7
B2	6	6	6
B3	6	6	6
E1	6	6	6
E2	6	6	6
E3	7	7	7
F1	6	5	5
F2	6	6	6
F3	6	6	6
G1	7	7	7
G2	9	9	9
G3	8	9	8
H1	9	9	9
H2	9	9	9
H3	8	8	8
K1	28	28	28
K2	28	28	28
K3	32	33	32
L1	4	4	4
L2	3	3	3
L3	5	5	5
R1	3	3	3
R2	3	3	4
R3	3	3	3
S1	3	3	3
S2	3	3	3
S3	4	4	4
T1	11	11	11
T2	11	11	11
T3	12	12	12
V1	5	5	5
V2	5	5	5
V3	4	4	4
W1	4	4	4
W2	4	4	4
W3	4	4	4
X1	9	9	9
X2	10	10	10
X3	10	10	10
Y1	4	4	4
Y2	5	5	5
Y3	5	5	5
Z1	4	5	5
Z2	5	5	5
Z3	5	5	5

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Poughkeepsie, New York

NATIONAL ELECTRICAL GROUNDING RESEARCH PROJECT
Test Measurement Template

Soils Resistivity
Electrode Resistance
Soil Temperature, Soil Moisture

SITE	Poughkeepsie
BY	Huynh N. Nguyen
DATE	12/13/2000
GT INST	AEMC 4500
Freq -	Std
Filter -	No
Multimeter -	Fluke 733
Ammeter	AEMC K110
Thermometer	Omega
Moist Inst	Delmhorst

RED = Ground Rod		YELLOW = Gal Pipe	
DC Volts	15.31	DC Volts	15.36
Hrs.	8427	Hrs	8425
Test to DC1D		Test to DC2D	
Current	ma	Current	ma
DC1A	3.61	DC2A	-0.03
DC1B	-0.21	DC2B	-0.18
DC1C	0.14	DC2C	-0.25
DC1D	-4.06	DC2D	-0.34

Dissimilar Metals DM	
Current	ma
DM1	0.26
DM2	0.12
DM3	0.07

RESISTIVITY CALCULATIONS

P = 2PI R X
R = Resistance
X = Distance Between Electrodes

Convert Ohm-Ft. to Ohms-Cm
Ohm-Ft = 30.48 Ohm-Cm
2pi 30.48 = 191.5

* Comparing with data in previous months, something seems wrong here. I believe the small resisters between AC/DC converter to DC1B, DC1C, DC2A, DC2B, DC2C are the problems.

10 FT. SOILS RESISTIVITY			
Meter reading in Ohms ----------	11.09	Soils Resistivity ------	21237 OHM-CM

20 FT. SOILS RESISTIVITY			
Meter reading in Ohms ----------	5.44	Soils Resistivity ------	20835 OHM-CM

SOILS TEMPERATURE AND MOISTURE	SENSOR ID NO.			
	1	2	3	
DEPTH	126"	78"	30"	
TEMPERATURE	T1	T2	T3	T3A
	49.2	46.5	39.5	37.5
MOISTURE	M1	M2	M3	M3A
	96.4	95.2	-6.8	93.9

RESISTANCE IN OHMS			
	TERMINAL		
ELECT	A	B	C
B1	81	81	80
B2	72	72	72
B3	83	83	83
E1	49	49	49
E2	53	53	53
E3	60	60	60
F1	92	92	92
F2	79	79	79
F3	71	70	70
G1	261	259	259
G2	222	222	222
G3	223	223	223
H1	151	151	151
H2	145	145	145
H3	151	151	151
K1	705	705	704
K2	407	403	404
K3	455	455	457
L1	28	28	28
L2	24	24	24
L3	30	30	30
R1	28	28	28
R2	29	29	29
R3	26	25	26
S1	82	82	83
S2	71	70	70
S3	59	59	59
T1	91	91	92
T2	101	101	101
T3	92	92	93
V1	167	167	167
V2	146	146	146
V3	145	145	145
W1	40	40	40
W2	45	45	45
W3	45	45	45
X1	109	109	108
X2	111	111	111
X3	119	119	119
Y1	43	43	43
Y2	46	46	46
Y3	58	58	58
Z1	95	95	95
Z2	90	90	90
Z3	85	85	85

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Staunton, Virginia

NATIONAL ELECTRICAL GROUNDING RESEARCH PROJECT
Test Measurement Template

Soils Resistivity
Electrode Resistance
Soil Temperature, Soil Moisture

SITE	Staunton
BY	TLE/RLE
DATE	12/27/2000
GT INST	AEMC 4500
Freq -	Std
Filter -	No
Multimeter -	Tek
Ammeter	AEMC K110
Thermometer	Omega
Moist Inst	Delmhorst

RED = Ground Rod		YELLOW = Gal Pipe	
DC Volts	15.67	DC Volts	15.71
Hrs.	n.a.	Hrs	722.6
Test to DC1D		Test to DC2D	
Current	ma	Current	ma
DC1A	86.1	DC2A	78.9
DC1B	85.4	DC2B	75.6
DC1C	84.4	DC2C	77.4
DC1D	173.6	DC2D	156.8

Dissimilar Metals DM	
Current	ma
DM1	2.4
DM2	1.5
DM3	2.6

RESISTIVITY CALCULATIONS

P = 2PI R X
R = Resistance
X = Distance Between Electrodes

Convert Ohm-Ft. to Ohms-Cm
Ohm-Ft = 30.48 Ohm-Cm
2pi 30.48 = 191.5

10 FT. SOILS RESISTIVITY			
Meter reading in Ohms ----------	5.17	Soils Resistivity -----	9901 OHM-CM

20 FT. SOILS RESISTIVITY			
Meter reading in Ohms ----------	2.52	Soils Resistivity -----	9652 OHM-CM

SOILS TEMPERATURE AND MOISTURE	SENSOR ID NO.		
	1	2	3
DEPTH	126"	78"	30"
TEMPERATURE	T1	T2	T3
	54.5	52.5	48.2
MOISTURE	M1	M2	M3
	95.3	94.8	93.6

RESISTANCE IN OHMS			
	TERMINAL		
ELECT	A	B	C
B1	46	46	46
B2	52	52	52
B3	58	48	48
E1	14	14	14
E2	17	17	17
E3	19	19	19
F1	26	26	26
F2	24	24	24
F3	29	28	28
G1	73	73	73
G2	93	93	93
G3	67	67	67
H1	28	27	28
H2	34	34	35
H3	23	23	23
K1	178	173	174
K2	162	160	159
K3	98	98	98
L1	19	19	19
L2	22	22	22
L3	18	18	18
R1	14	14	14
R2	14	14	14
R3	10	10	10
S1	20	20	20
S2	20	19	19
S3	20	20	20
T1	46	46	46
T2	38	38	39
T3	36	36	36
V1	35	35	35
V2	36	36	36
V3	50	50	50
W1	21	21	21
W2	19	19	19
W3	19	18	19
X1	35	35	35
X2	33	33	33
X3	26	26	26
Y1	12	12	12
Y2	11	11	11
Y3	17	17	17
Z1	25	25	25
Z2	30	30	30
Z3	39	39	39