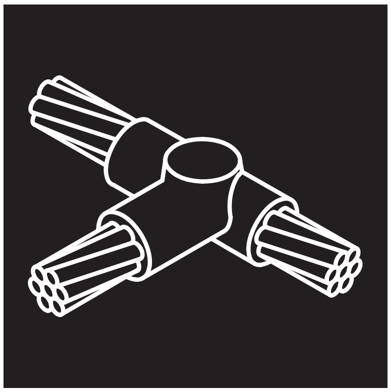
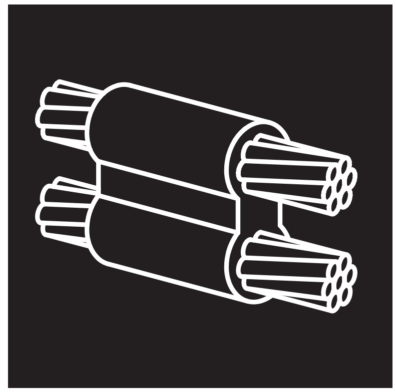
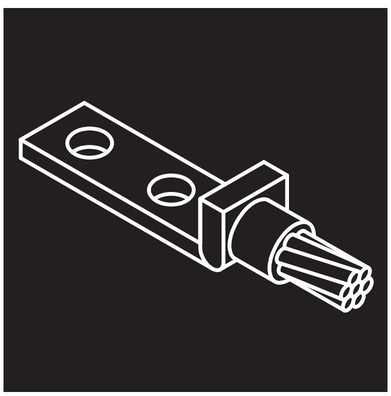
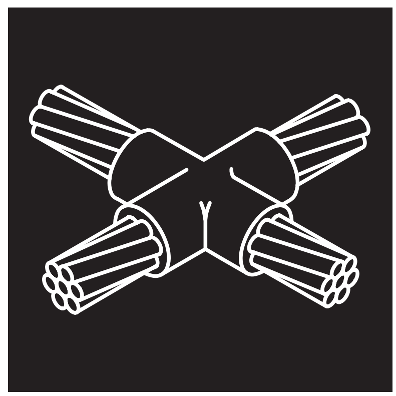
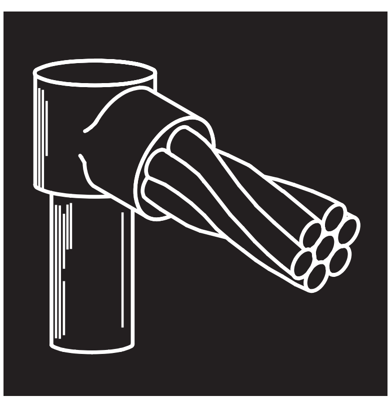
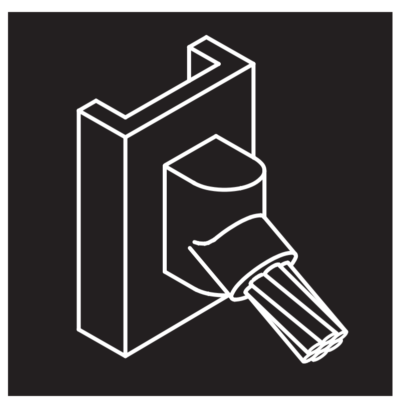
FACILITY ELECTRICAL PROTECTION

CADWELD®

A6A
6/00 Issue

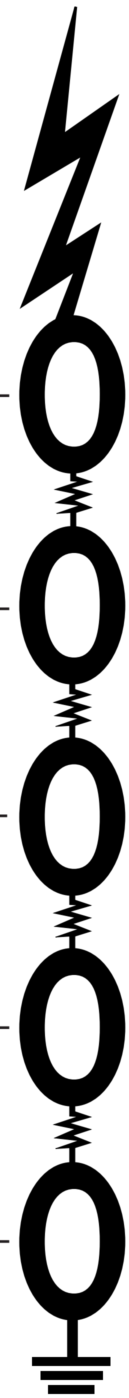







GROUNDING SEMINAR REVIEW

This booklet provides a brief review of the seminar covering fundamental design criteria for high current grounding.

This seminar is available on VHS video tape.
Other tape formats are available.

A high current grounding system is like a chain. Each link must be made strong enough to assure reliable performance. Each component must be designed to a very low value of resistance in order to dissipate massive faults again and again for periods of time as long as 40 years without harm to personnel or damage to equipment.



conductor

Conductor material and cross section must be sufficient to conduct anticipated faults without fusing.

connector

Connections must be of proper material and mass, and be able to resist corrosion to maintain original low resistance up to 40 years.

ground rod

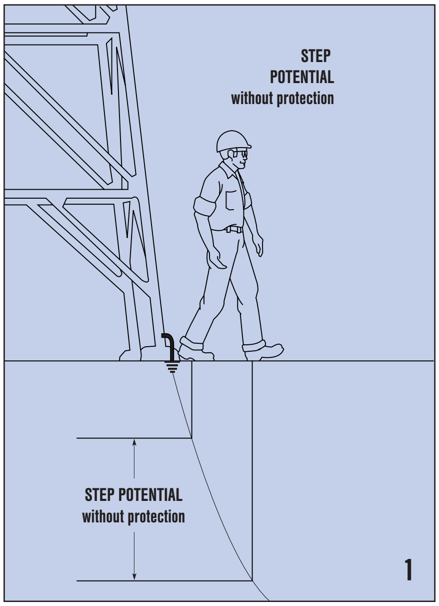
Ground rods must be of proper material and cross section to provide a low resistance path to the fault current.

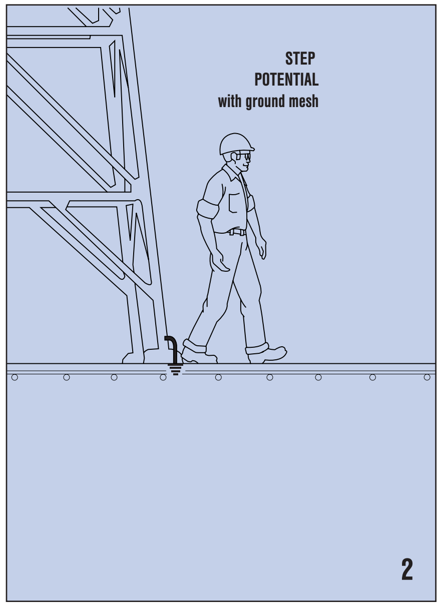
rod-to-soil

Rod resistance is affected by length, relative placement, and most importantly, coupling integrity where rods are joined for deep driving.

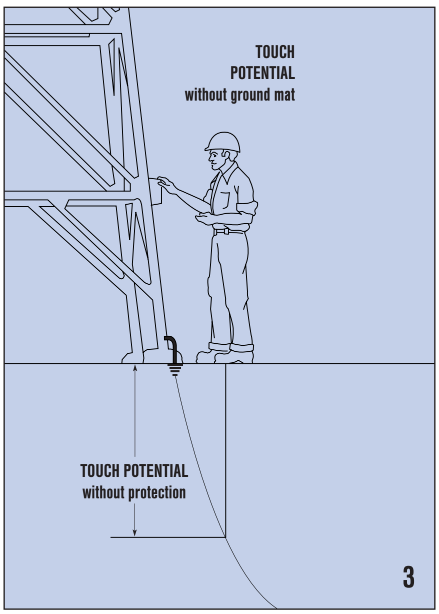
soil

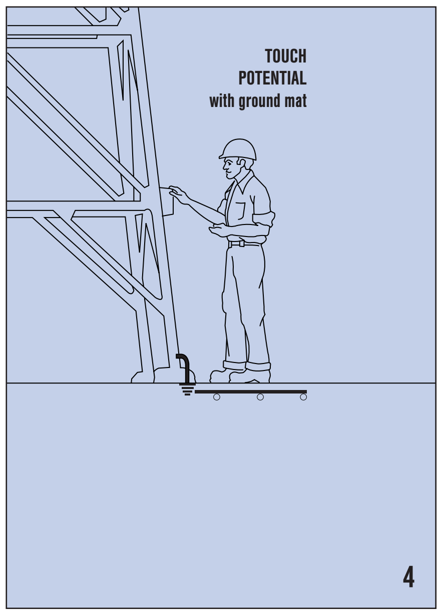
Soil resistivity must be carefully considered, including moisture content and temperature.



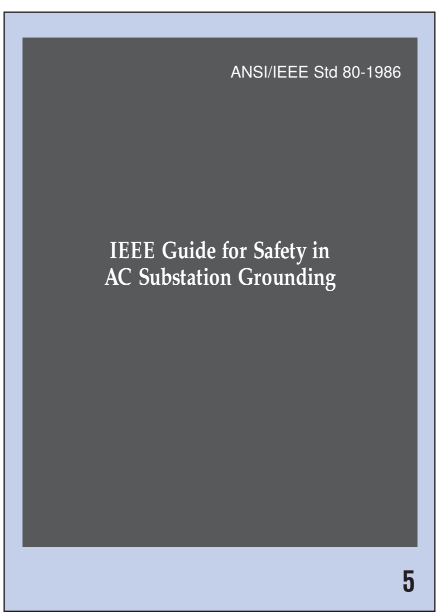


Step Potential, shown in figure 1, is the voltage difference between a person's feet, caused by the dissipation gradient of a fault entering the earth. Thirty inches away from the entry point, voltage will have reduced by 50%. For example, a 1000 amp fault in a 5 ohm grounding system will enter the earth at 5000 volts. Thirty inches away, less than the distance of a normal step, a fatal potential of 2500 volts will exist. In figure 2, a ground mesh is installed close to surface level and connected to the main ground grid. This essentially equalizes voltage along the surface and protects personnel against excessive potential difference.

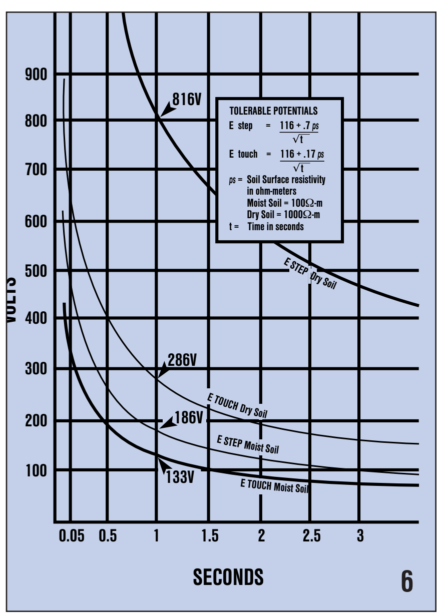




Touch Potential, figures 3 and 4, is the same fundamental situation as Step Potential, except that the current path passes through the arm and heart region, a more dangerous situation. In this case, the potential can be essentially eliminated by a ground mat connected to switches and other equipment which personnel must touch.


ANSI/IEEE Std 80-1986

IEEE Guide for Safety in
AC Substation Grounding



IEEE Standard 80 Guide for Safety in Substation Grounding contains valuable design criteria for high current grounding systems, including basic data on voltage and time durations considered tolerable for Step and Touch Potentials presented in figure 6.

FOR COPPER CONDUCTORS, THE EXACT FORMULA FROM IEEE STD 80 CAN BE SIMPLIFIED TO:

$$I = \frac{A}{K\sqrt{S}}$$

Where:
I = RMS current in amperes
A = Conductor size in circular mils
S = Current duration in seconds
K = Constant for maximum allowable temperature

The Chart below lists the maximum allowable fault current in kiloamperes allowed by IEEE Std 80 for various conductor sizes.

MAXIMUM ALLOWABLE CURRENT (kA) FOR CONDUCTORS USING CADWELD CONNECTIONS

TIME(sec)	CONDUCTOR SIZE/kcmil			
S	#2	2/0	4/0	500
1/4	18.9	38.0	60.4	142.7
1/2	13.4	26.9	42.7	100.9
1	9.5	19.0	30.2	71.3
2	6.7	13.4	21.3	50.4
3	5.5	11.0	17.4	41.2
4	4.7	9.5	15.1	35.7
5	4.2	8.5	13.5	31.9

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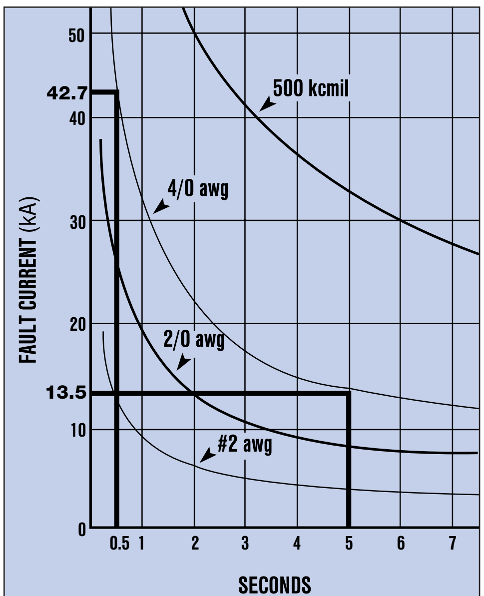


8

The first link in our grounding system chain is the conductor. It must be large enough in cross section to handle anticipated faults without fusing (melting). In figure 7, the IEEE Std 80 fusing formula is shown as the source for the simplified version derived specifically for copper conductor, based on a 40°C ambient temperature. This formula considers conductor cross section, time and fusing current.

These relationships are graphically portrayed in figure 8 for #2AWG to 500 kcmil copper conductor. The darker example lines show that 4/0 conductor can withstand 42,700 amps for 1/2 second before fusing, but only 13,500 amps for 5 seconds. This time dependence emphasizes the importance of using proper fault time in design calculations to prevent fusing. Although protective relays may operate in a few cycles, the possibility of malfunction must be considered. IEEE Std 80 suggests using 3 seconds for small substations, which is equal to the short-time rating of switchgear.

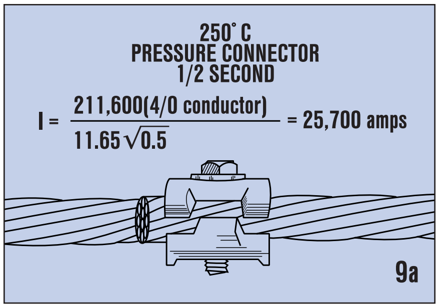
The second link in a grounding system is the connections. Three basic connection types exist, and are rated for use by their allowable maximum temperature limits by IEEE Std 80. These limits are:

Exothermic welds[1]	1083°C
Brazed	450°C
Pressure type[2]	250-350°C

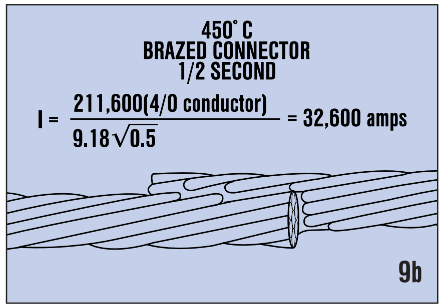
The formula of figure 7 assigns values of “K” to these temperature limits as follows:

Connection Type	**“K”**
Exothermic welds[1]	7.01
Brazed	9.18
Pressure Type[2]	10.10-11.65

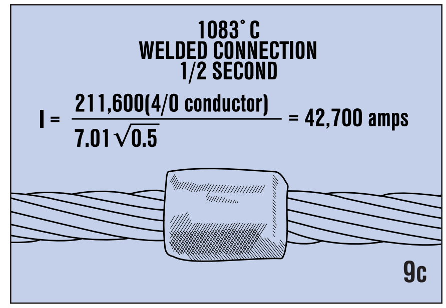
1 This temperature and value of “K” is the same as the melting point of copper.
2 Pressure types include bolted, compression and wedge types. If these types of connectors meet all the requirements of IEEE Std 837, they may be allowed to be used at a higher temperature.



9a

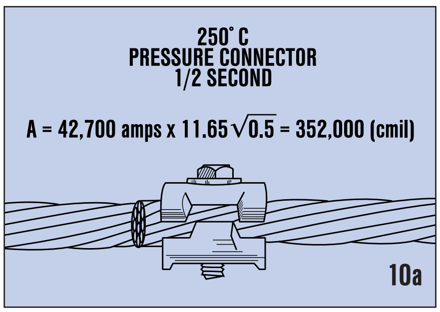


9b

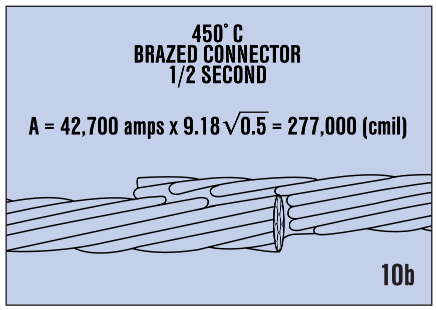


9c

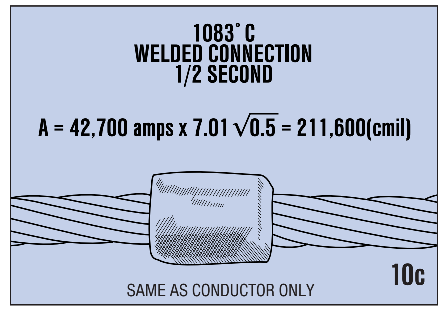
For a 4/0 conductor (211,600 circular mils) at a 1/2 second fault, the fusing currents are shown in figures 9a, 9b and 9c for Pressure, Brazed, and Welded connections, based on their temperature limits.



10a

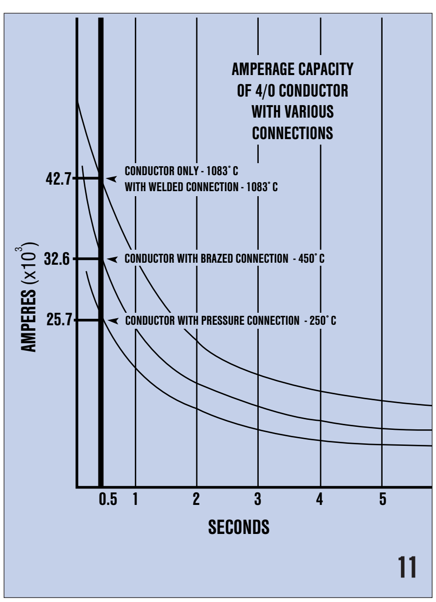


10b

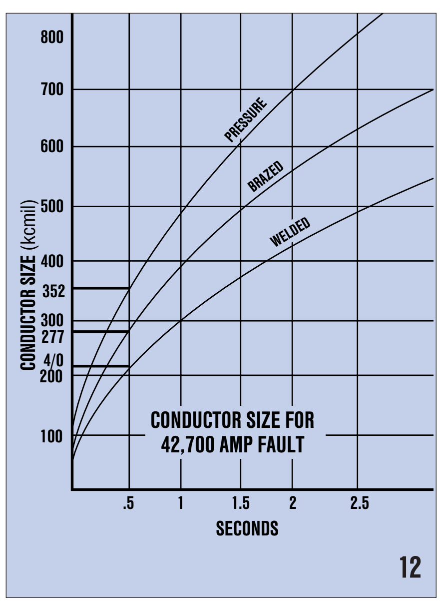


10c

To withstand a 42,700 amp fault current, which is the rating of a 4/0 conductor, Pressure and Brazed connections require a conductor with a larger cross section because of the lower temperature limits of these types of connectors. However, conductor size need not be increased with use of Welded connections because conductor and connector temperature limit is equal. Calculated conductor sizes are shown in figures 10a thru 10c.

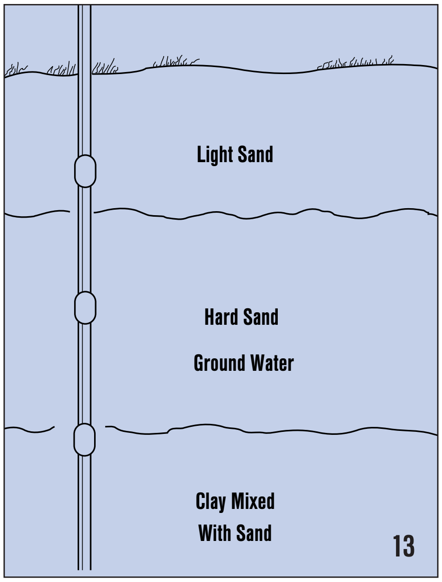


11



12

The importance of the fusing limits applied to different types of connections is shown above. Figure 11, at far left, graphically extends the time periods for data presented in figures 9a thru 9c. Figure 12 extends time periods for data presented in figures 10a thru 10c.



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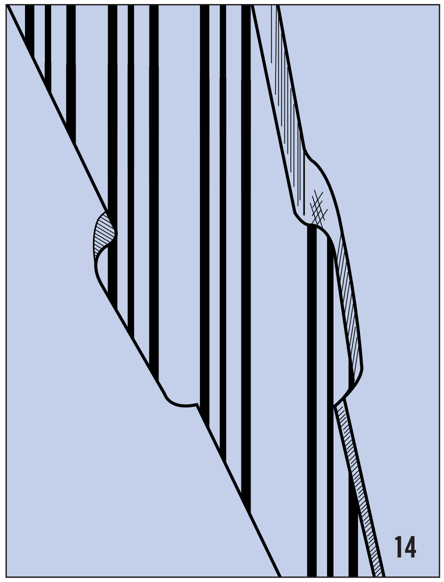


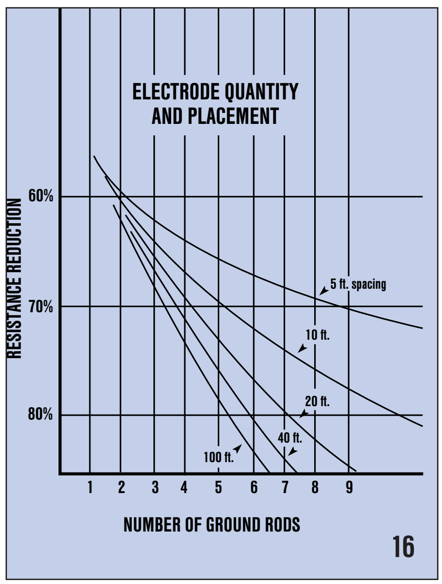
14

The third link in the grounding chain is the grounding rod. The greatest effect of ground rods on overall system resistance is focused at the splice of deep driven rods. If these splices corrode or mechanically fail, then the value of the rod below the splice is lost, causing a serious increase in system resistance. The most effective splice is welded and is considered equal to a continuous rod as shown in figure 14.

SOIL VARIATION AROUND THE COUNTRY

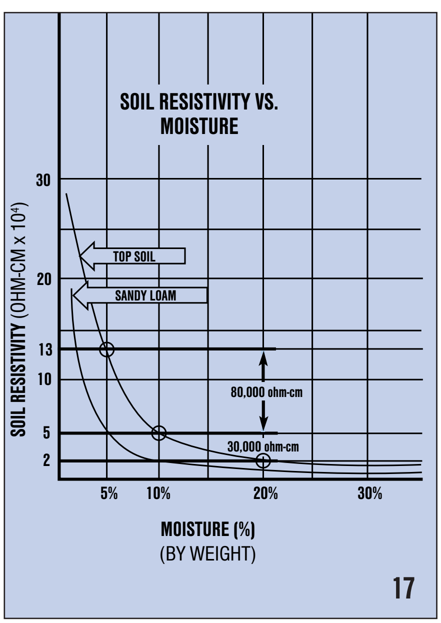
LOCATION	RESISTANCE (ohms)	
BOSTON, MASSACHUSETTS	0.5 + @8'	0.5 @ 30'
CLEVELAND, OHIO	18 @ 8'	8 @ 16'
JACKSON, MISSISSIPPI	250 @ 8'	6 @ 30'
COLUMBIA, SOUTH CAROLINA	1150 @ 8'	11 @ 96'
PANAMA CITY, FLORIDA	1800 @ 8'	19 @ 64'
MOBILE, ALABAMA	3000 @ 8'	6 @ 32'

15

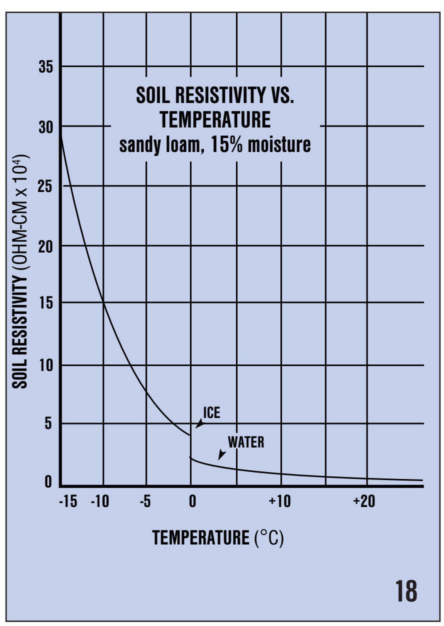


16

The fourth link in the grounding chain is ground electrode to soil resistance. Amount of rod surface and rod placement are the controlling factors. Doubling **diameter** reduces resistance by only 10% and is not cost effective. Doubling rod **length**, however, theoretically reduces resistance by 40%. But actual reduction indicated in figure 15 depends on soil resistivities of typically encountered multi-layered soils. Most common solution is proper placement of multiple rods, driven to required depths, as shown in figure 16.



17



18

Soil resistivity is the fifth and final link in our chain. Because soil moisture and temperature are major controllers of resistivity, rods should be driven below frost level, and to a subsurface layer with a relatively constant moisture content above 10% and of a low resistance. Resistivity values as a function of moisture and temperature are shown in figures 17 and 18.

With close attention to all design criteria, you can have a safe, low resistance grounding system which will protect personnel and equipment for the life of your structure.

AVAILABLE CATALOGS AND BROCHURES

Facility Electrical Protection Solutions
Includes information on The 6 Point Plan - including lightning protection, grounding & bonding, and surge & transient protection. X7A

CADWELD Catalog of High Current Grounding Connections
Covers techniques and equipment required for making ground connections for cable, bus bar, rail, rebar, lugs, ground rods, steel and cast iron surfaces, ground plates, receptacles and studs. A1A

Fence Grounding
Explains use of inexpensive welding cable to bond gate frames to fence posts. Also covers grounding connections to round and square posts. A-4Q

Prefabricated Grounding Mesh
Specifications and application data are presented for personnel safety mats such as those used in substations to protect against Touch and Step Potential. Also covered are high performance RF shields to protect against interference, and to minimize ground plane fluctuations at radio transmitters, satellite tracking stations, and other antenna installations. G-1A

Lightning Protection
Contains cross reference of manufacturers' cable catalog numbers, and describes lightning protection connections for virtually all applications including lugs, grounding receptacles, and rail. A-1E

Cathodic Protection
Covers cable-to-cable, cable-to-pipe, and cable-to-ground rod connections. Also included are lug connections, as well as preformed flange jumper bonds. CA-1A

Bus Bar
Connections for copper and aluminum bus bar. A-1H

Computer Grounding
Explains the need for Signal Reference Grids (SRGs) and equipment connections to protect data. A-4P

Substation Grounding
Details the various grounding applications in an electrical substation or switchyard. A-4G

Telephone System Grounding
Details the various grounding applications in a CO, repeaters, towers, etc. A-4T

Installer's & Inspector's Guide
This handy pocket guide assists both the installer and inspector. A-7D

Ground Bars
Ground bars are made to your specifications. A-4S

Contractor Tips
Answers to typical questions asked about CADWELD Connections. A-9E

CADWELD® is the trade name describing exothermically welded electrical connections developed by ERICO, Inc. in the 1930's. Subsequently, CADWELD has become the reliability standard for copper-to-copper, as well as copper-to-steel high current grounding connections. CADWELD connections can't loosen. They are not subject to galvanic corrosion. They ensure higher fault current capacity than the conductors themselves.

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