Design Considerations That Help Avoid Electrical Disasters

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2017 BICSI Winter Conference & Exhibition

January 22-26 • Tampa, FL

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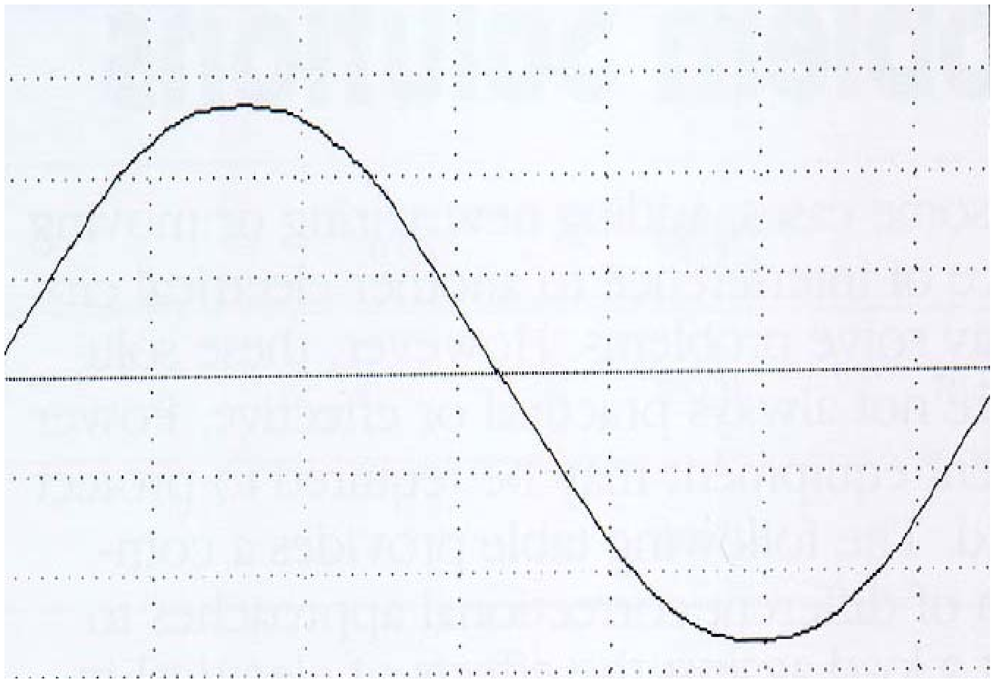
Basics of Power Quality

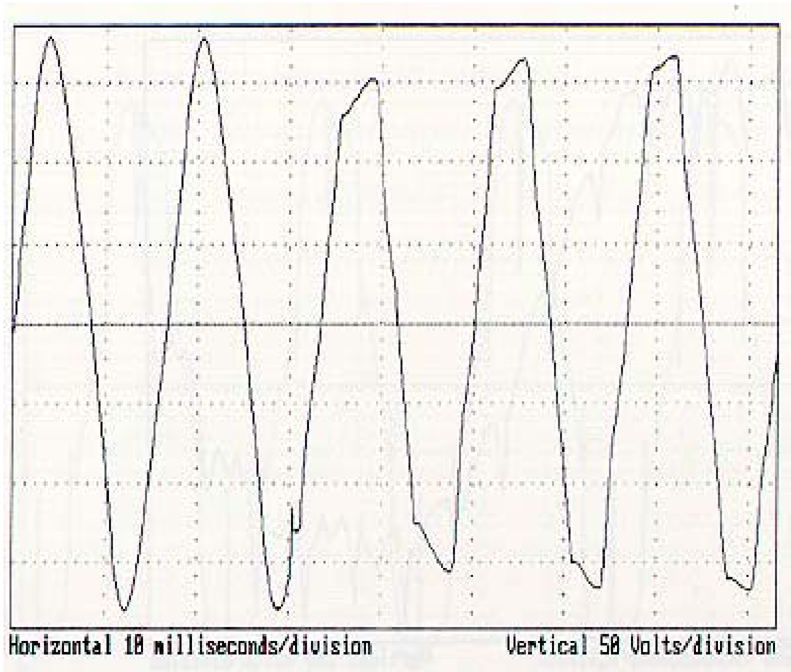
- Poor power quality...

is evidenced by characteristics of the incoming power to a device that deviate from the customary "pure" 60 Hz sine wave, and that can affect reliable and safe operation of the sensitive equipment

What the Equipment Wants



What the Equipment Sometimes Gets



Overview of This Presentation

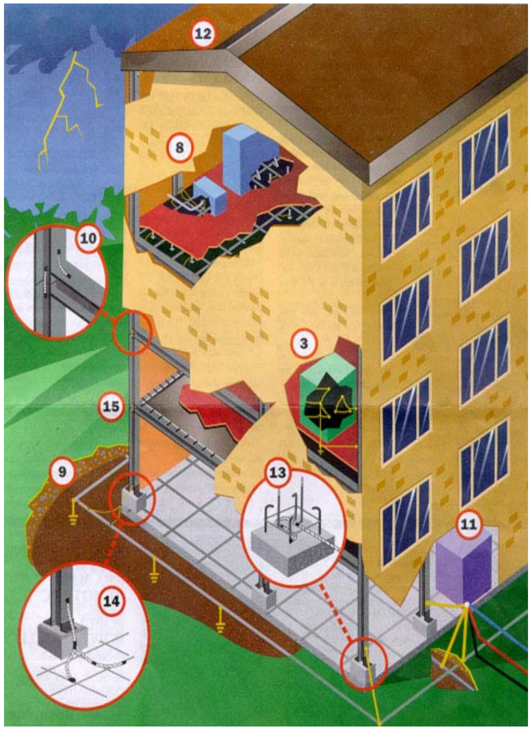
Elements of building infrastructure that can alleviate or cure power quality problems before they affect operations:

Grounding

Bonding

Circuiting

Lightning

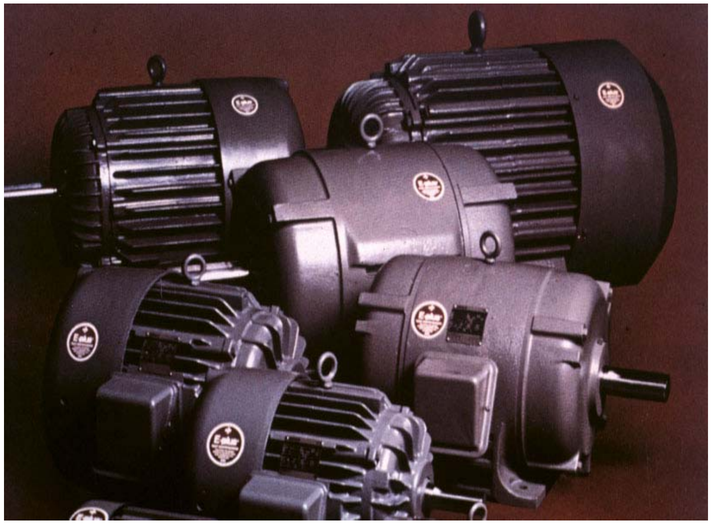


Equipment More Sensitive

- **Micro circuits are getting faster (radio frequency range)**
- **Microprocessors more ubiquitous**
- **Circuits are getting smaller**
- **Operating voltages are lower**

Old vs. New

What used to be acceptable service characteristics are no longer sufficient



The Real Cost

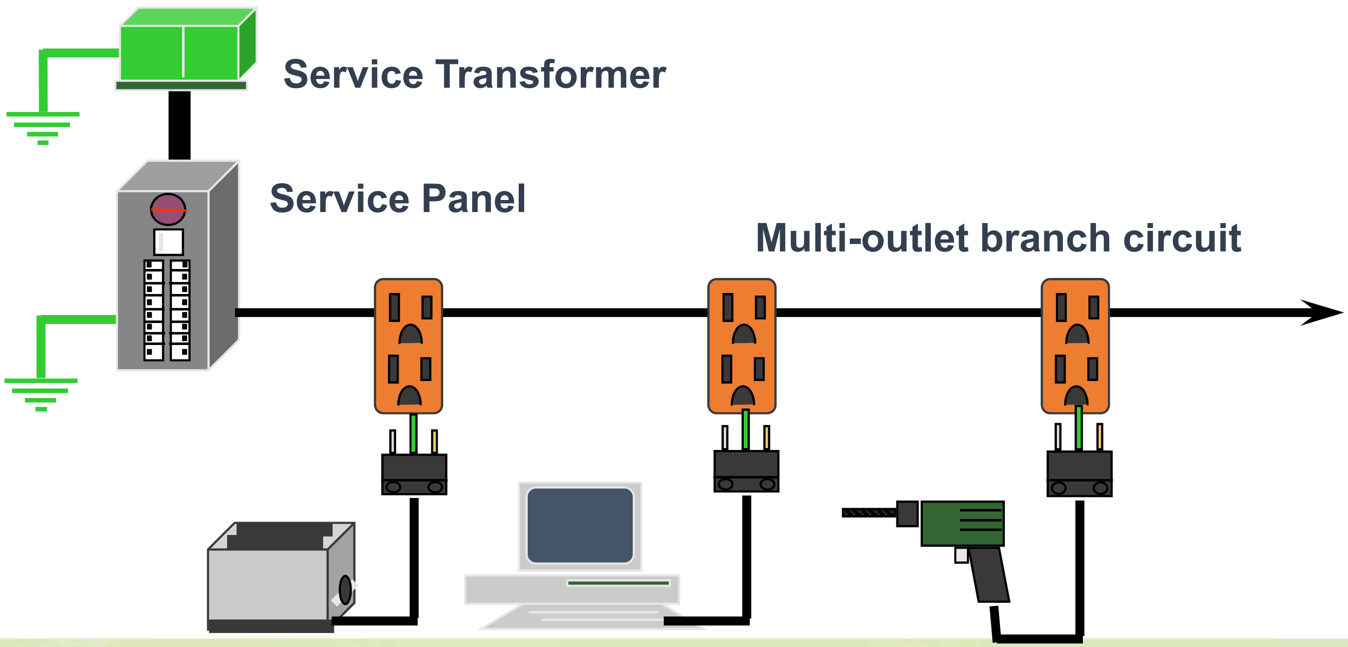
The real cost of poor power quality is in lost productivity (downtime).

- **Estimated at $15-30 billion per year plus in US**
- **Average cost of a data center outage $740,357 in 2016**
- **Exceeds $1 million/yr. at some buildings**

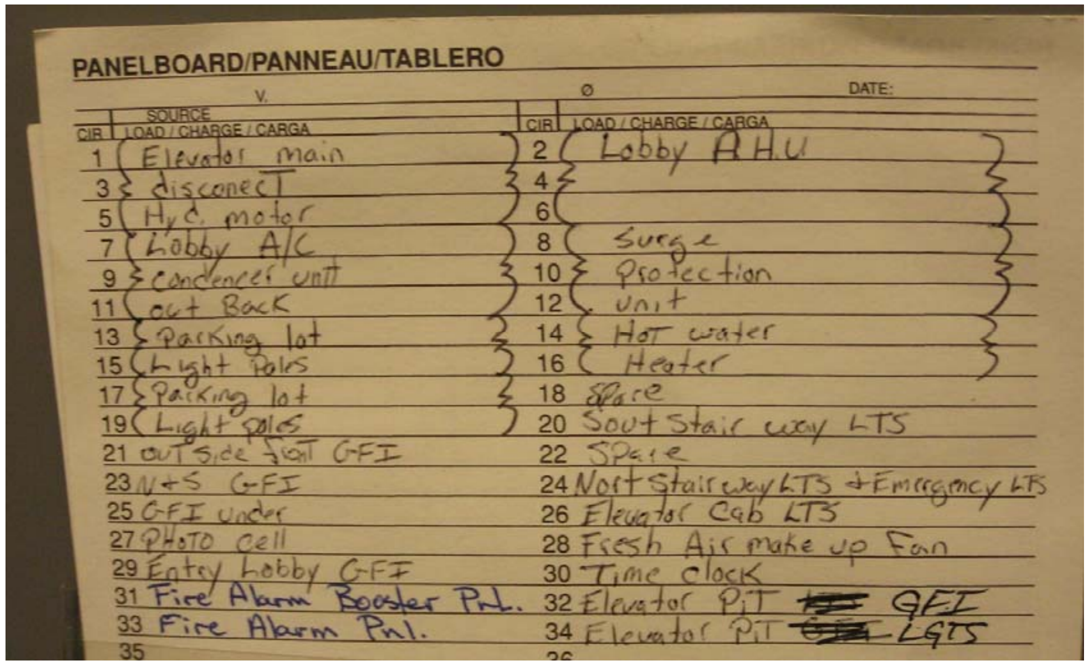
- E Source and Penton

Is the Computer a Problem?

or is it the way it's wired?



Fire Alarm and Parking Lot Lights



PANELBOARD/PANNEAU/TABLERO

V. Ø DATE:

CIR	SOURCE LOAD / CHARGE / CARGA	CIR	LOAD / CHARGE / CARGA
1	Elevator main	2	Lobby AHU
3	disconecT	4	
5	Hyd. motor	6	
7	Lobby A/C	8	Surge
9	condencer unit	10	Protection
11	out Back	12	unit
13	Parking lot	14	HoT water
15	Light Poles	16	Heater
17	Parking lot	18	Spare
19	Light poles	20	Sout Stair way LTS
21	ouT side front GFI	22	Spare
23	N+S GFI	24	Nort Stair way LTS + Emergency LTS
25	GFI under	26	Elevator Cab LTS
27	PHOTO cell	28	Fresh Air make up Fan
29	Entry Lobby GFI	30	Time clock
31	Fire Alarm Booster Pnl.	32	Elevator PiT GFI
33	Fire Alarm Pnl.	34	Elevator PiT LGTS
35		36	

Mainly Internal

Most power quality problems are related to grounding and neutral size issues

Over 80% are internally caused

source: EPRI

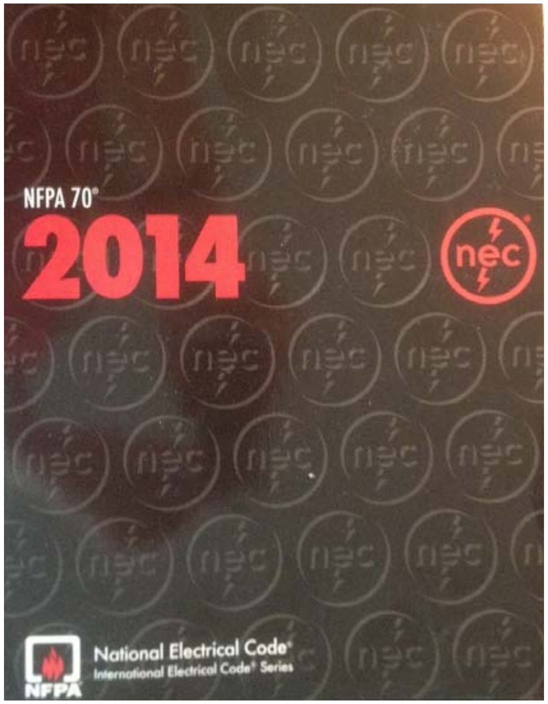
Bare Minimum Needed for Safety

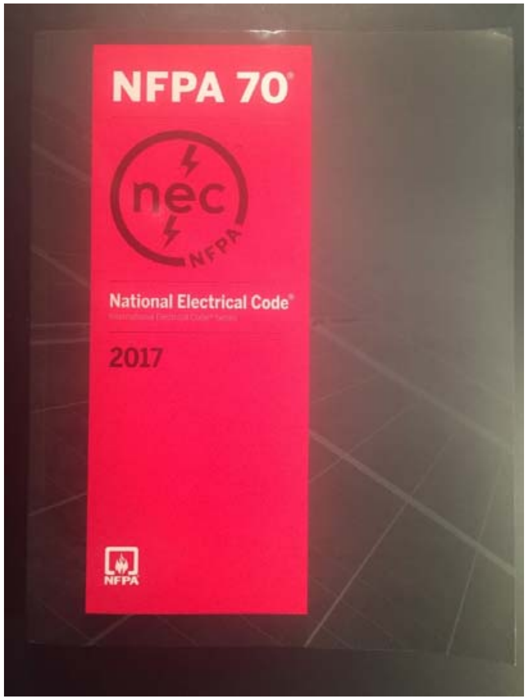
Good starting point, BUT..

Not a PQ Code

Not a lightning Code

Not a good grounding Code





Erratic Operation or Downtime

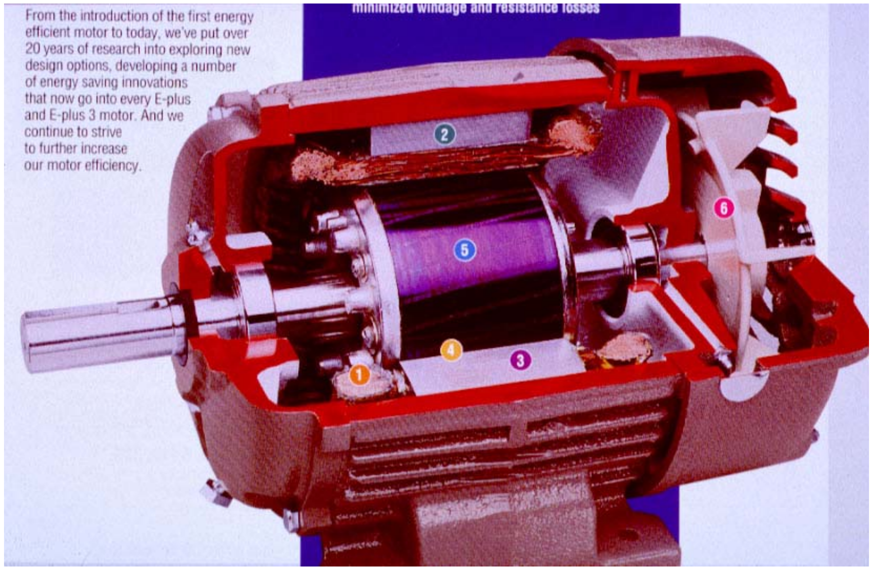
Erratic operation of sensitive electronic equipment (data errors, lockup, false images in medical diagnostics)

Cable Failures

Overheating of phase conductors or neutrals, nuisance tripping

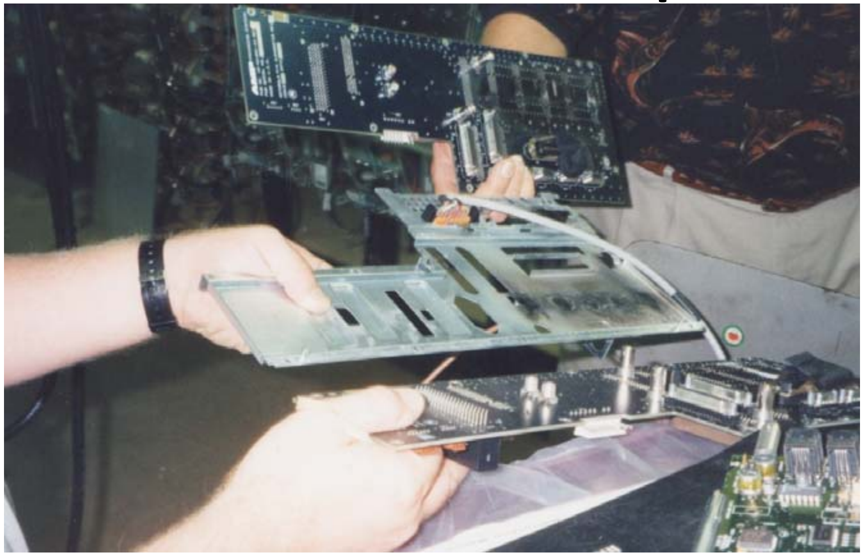
Motor Failures

Premature burnout of motor windings



Effects of Poor Power Quality

Failure of electronic components



Two Types of “Grounding”

- **System Grounding**

- **Equipment grounding (bonding)**

“Grounding”

Oddly enough, “ground” is not defined in the NEC.

Grounded (Grounding). Connected (connecting) to ground or to a conductive body that extends the ground connection.

System or Exterior Grounding

- **Needed for:**
- **Establishing a voltage reference**
- **Discharge high transient voltages (esp. lightning)**
- **Static Discharge**
- **Personnel Safety**

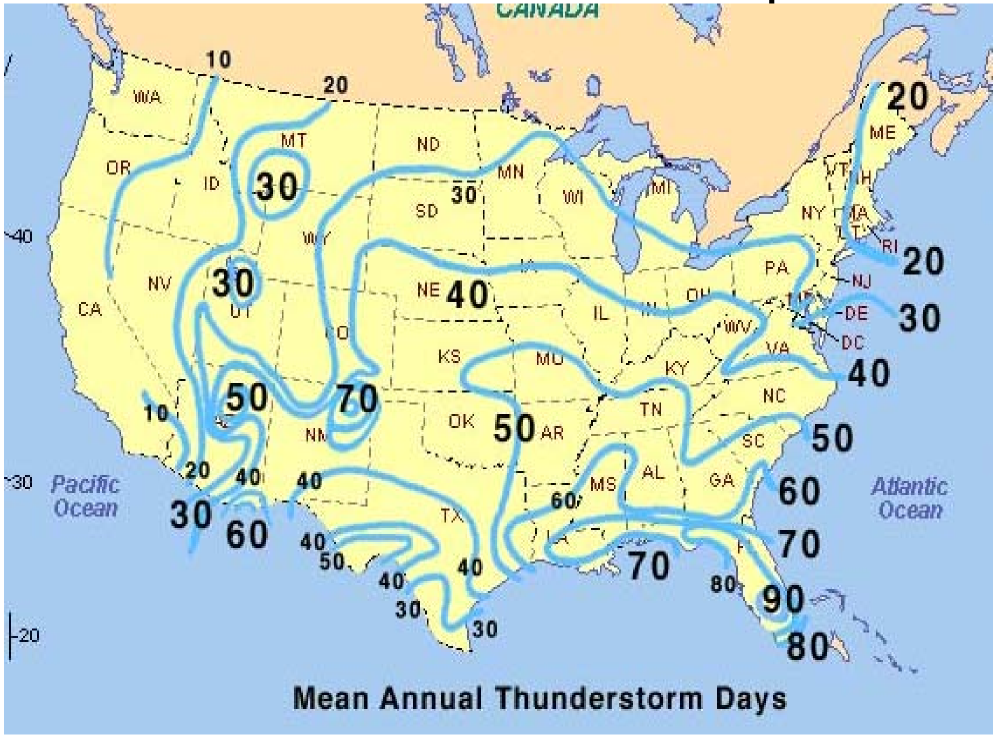
“Bonding”

- The intentional connection of normally non-current carrying parts of equipment together

- The two terms are frequently used interchangeably

Exterior Grounding

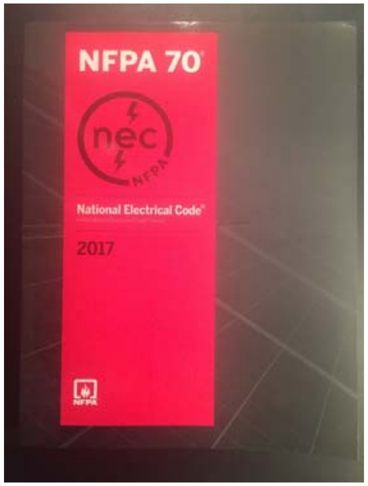
Isokeraunic Map



NEC is NOT Sufficient

- **250.53 (A)(1)** If <u>practicable</u>, rod,

pipe, and plate electrodes shall be embedded below permanent moisture level.



NEC “Alludes” to 25 Ohms

Water Pipe and 2 ground rods, even if result exceeds 25 ohms.

- **250.53 (A)(2)** A single rod, pipe,

or plate electrode shall be supplemented…

NEC "Alludes" to 25 Ohms

BUT

exception:

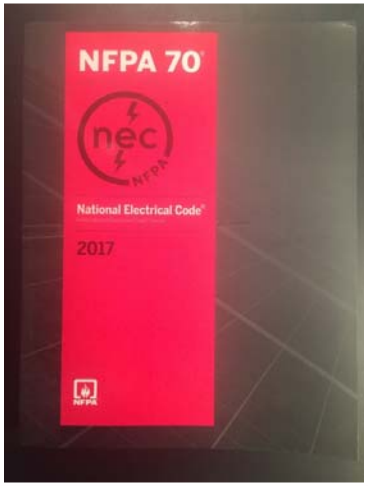
Exception: If a single rod, pipe, or plate grounding electrode has a resistance to earth of 25 ohms or less, the supplemental electrode shall not be required.

There are no testing parameters

Thus, if two rods are installed, you're done!

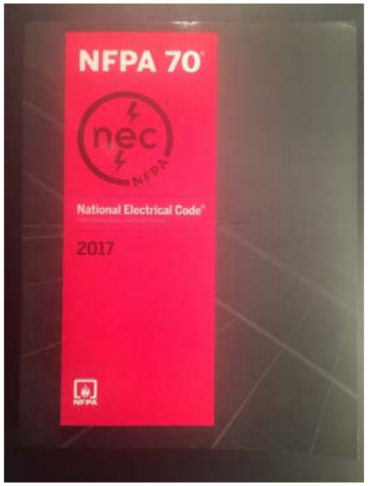
NEC Allows 6 Ft. Spacing

- **250.53 (A)(3) Supplemental Electrode.** If multiple rod, pipe, or plate electrodes are installed to meet the requirements of this section, they shall not be less than 1.8 m (6 ft.) apart.



NEC Allows 30 Inch Depth

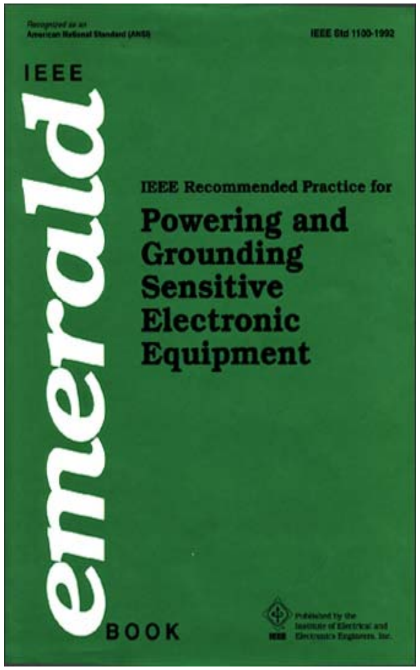
- **250.53 (F) Ground Ring.** The ground ring shall be buried at a depth below the earth's surface of not less than 750 mm (30 in.).



IEEE Emerald Book

- **ANSI/IEEE 1100**

Recommended practices are needed for power quality.



System Grounding

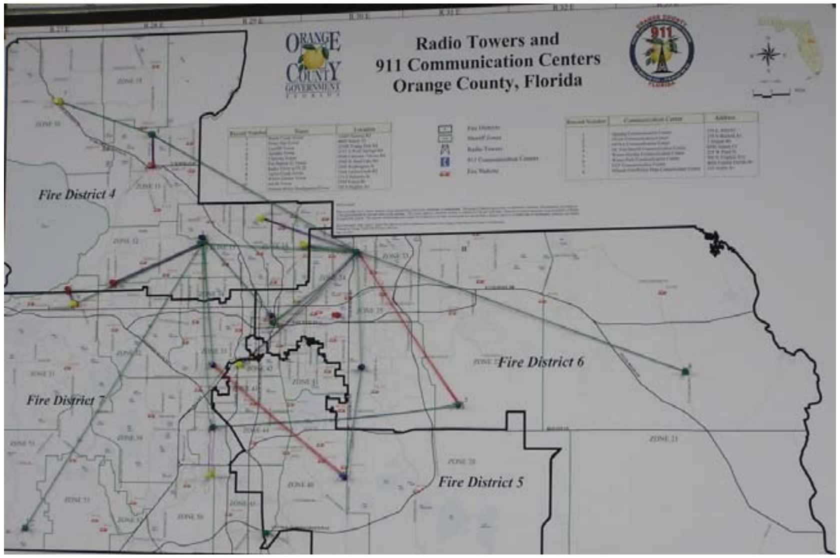
Desired Grounding Resistance:

- **5 ohms or less desired for power quality**
- **Many mfgrs. specify under 2 ohms**
- **IEEE recommends 1-5 ohms (Green Book)**

Case History

Orange County, FL 911

13 transmitter sites



Orange County, FL 911

Headquarters
Apopka, FL

Source: Power & System Innovations, Inc., Orlando

Headquarters Tower- Apopka, FL

280 foot tower

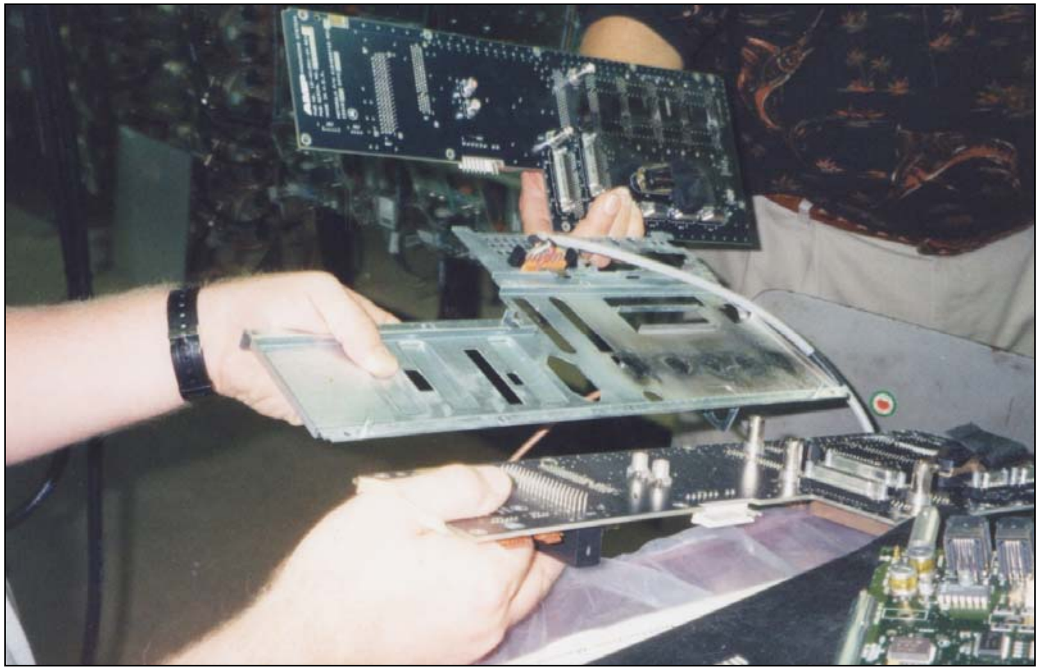
3 sets of 5 guys

Equipment Damages

$100 K/yr. damage at Apopka alone

Not including downtime

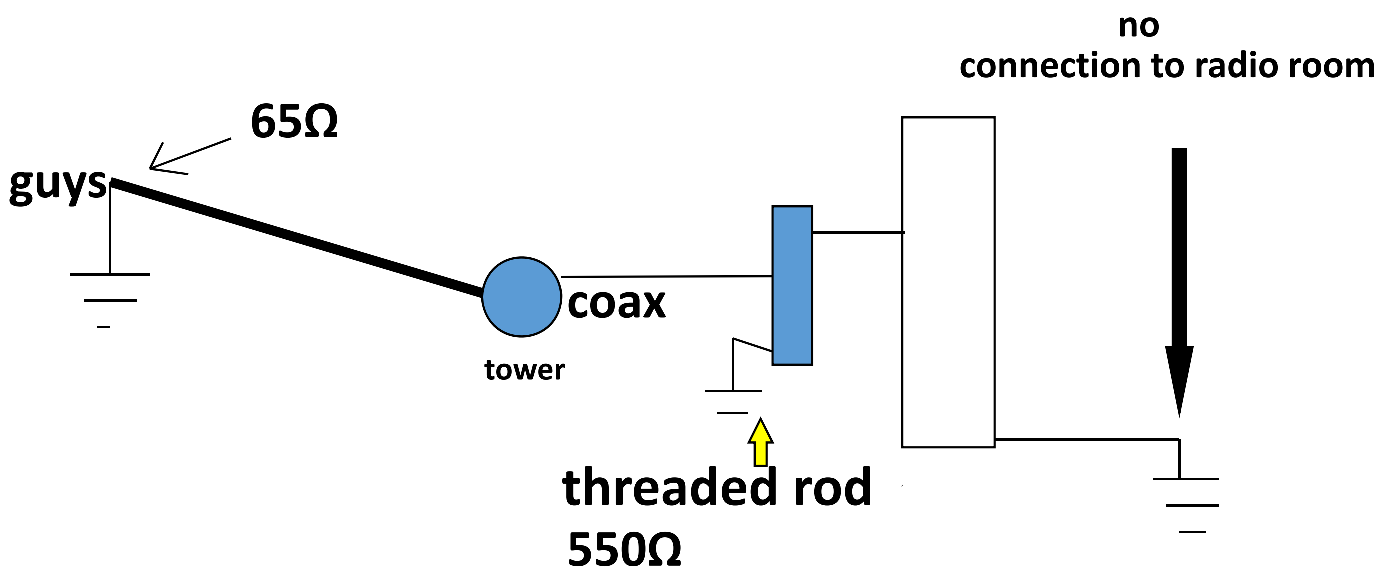
Internal Arcing



Staff Knew They Needed Help

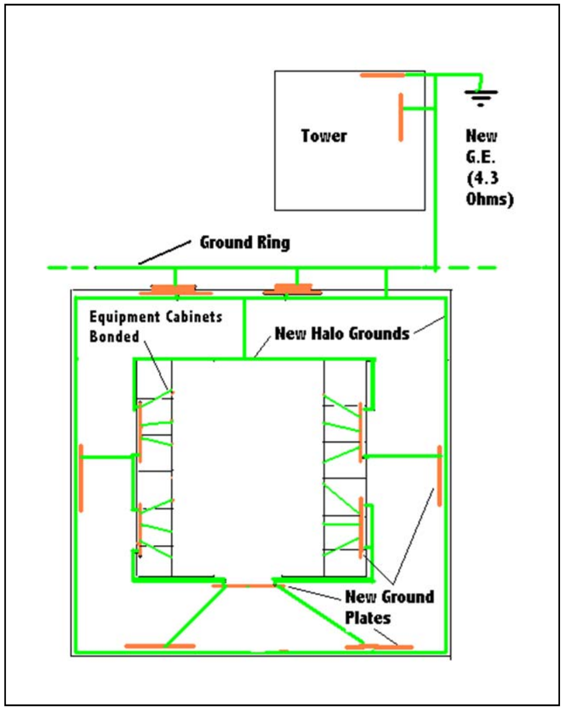
Staff was not expert in power quality, called in knowledgeable professional

3 Independent grounds

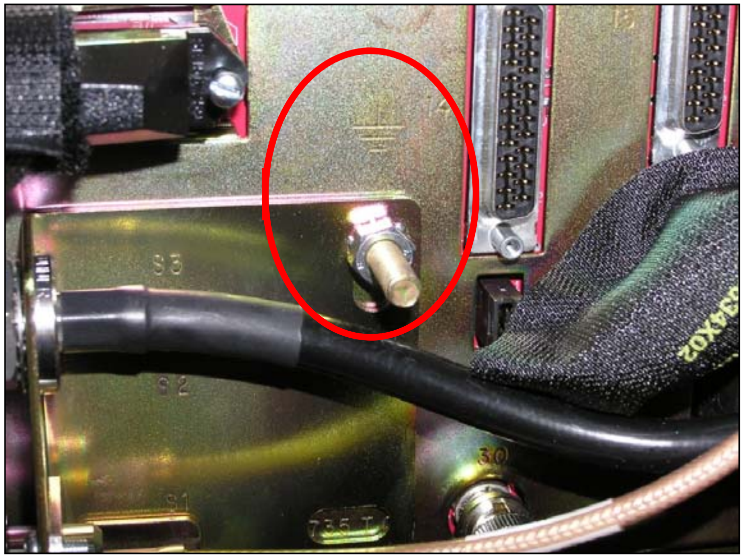


Refitted site

Everything bonded together



Ungrounded Equipment Cabinets

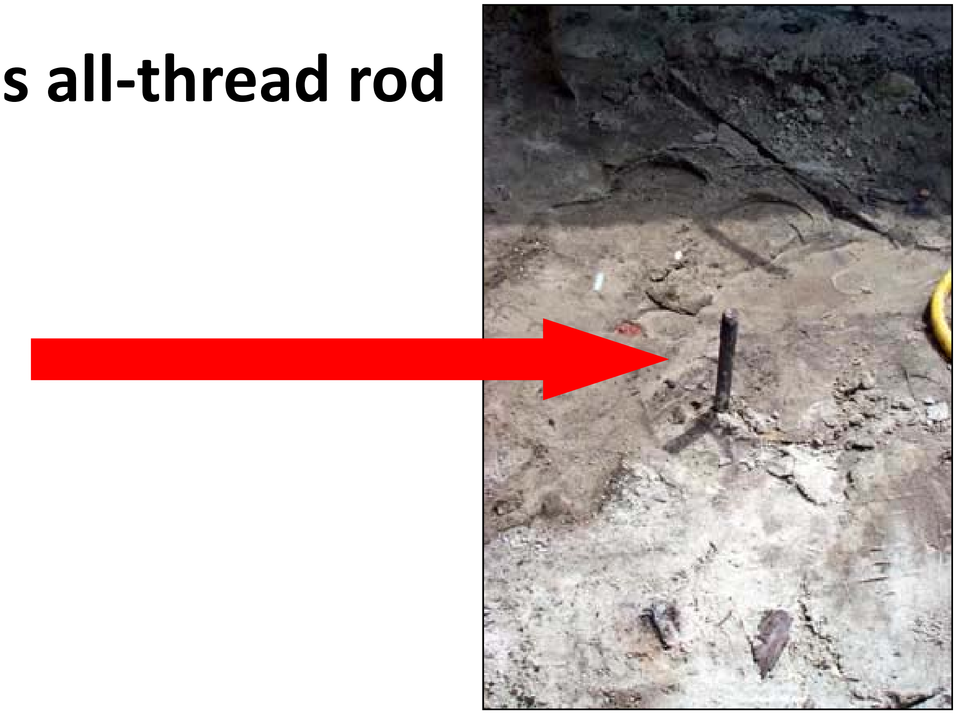


Outside Bulkhead

Only ONE Cu strip connected to electrode

Facility Ground at Apopka

Main electrode was all-thread rod



Original Ground Resistance

Measured 550 ohms

Apopka Tower Grounding

Retrofits:

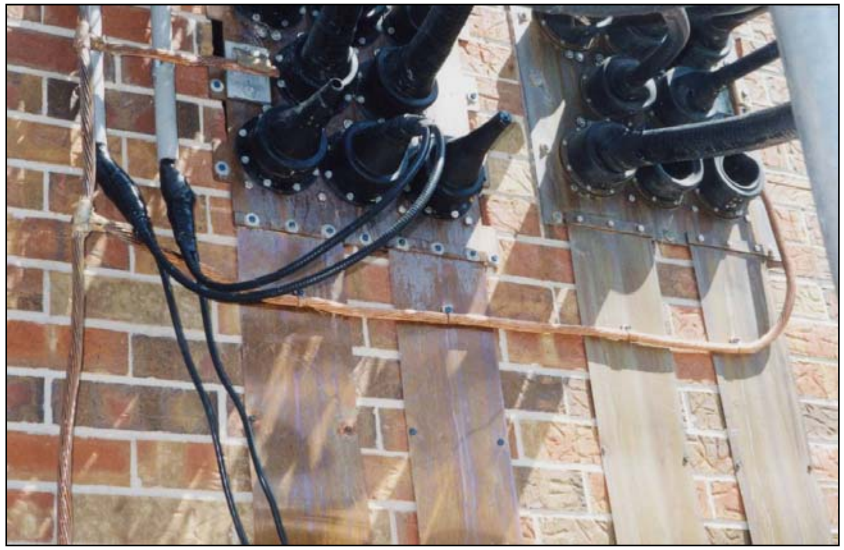
Deep (60 ft.) electrode supplements tower

New Coax Grounding On Tower

for coax grounds then 4/0 to electrode

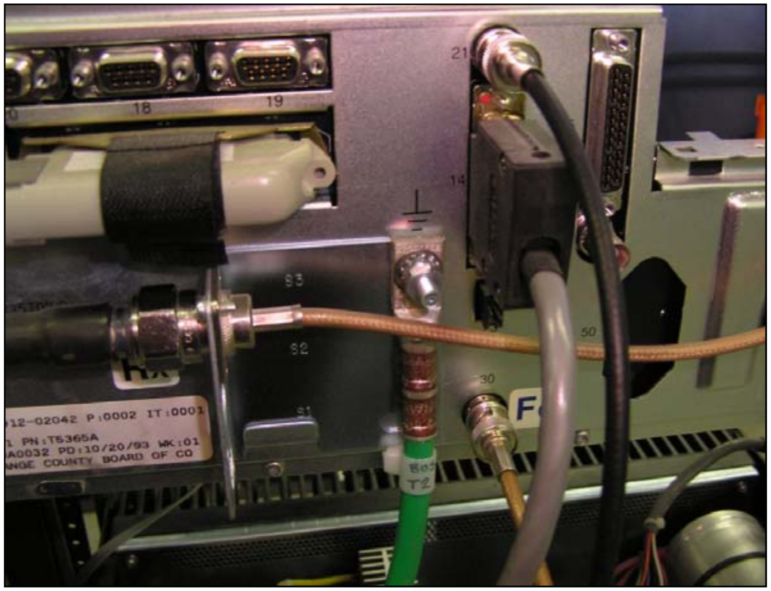
Outside Bulkhead

strip bonded together and to ring with 4/0



Bond Equipment Properly

Note double nuts and lockwasher



Halo Rings

All equipment bonds brought to buses

Buses tied to halo rings

Proper Coax Shield Grounding

- Andrews Cuffs

Reedy Creek

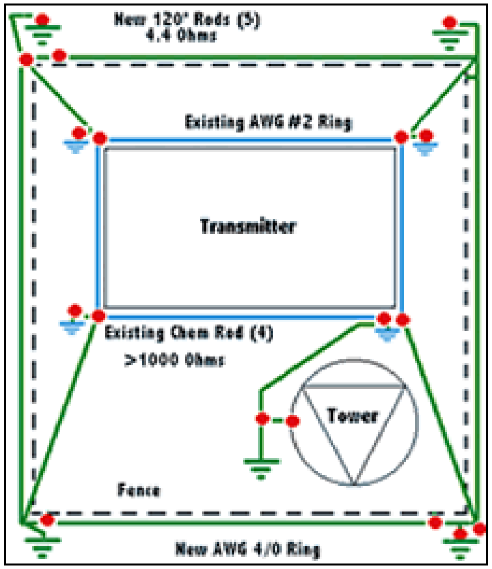
Remote repeater near Disney World

Reedy Creek

More real estate to work with

Reedy Creek

Grounding layout: double rings plus deep electrodes



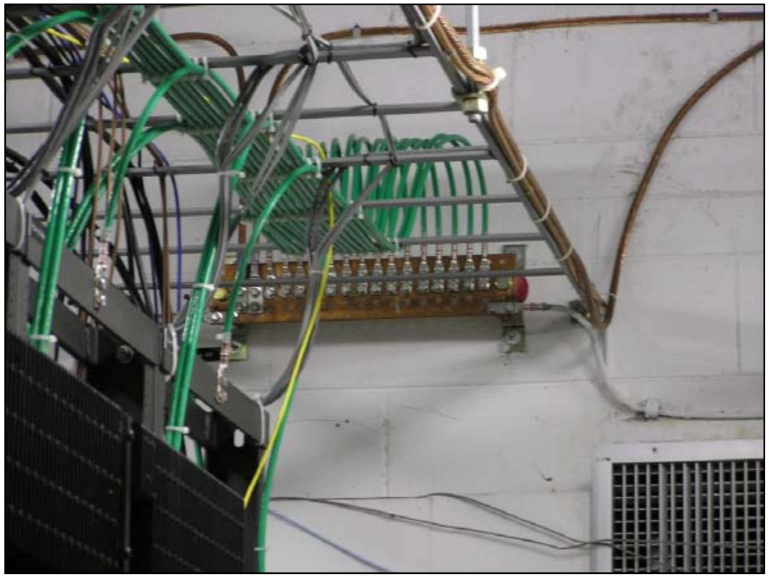
New Resistance 3.5Ω

< 5 ohms

independently

Sweeping Turns

Note wide, large diameter turns

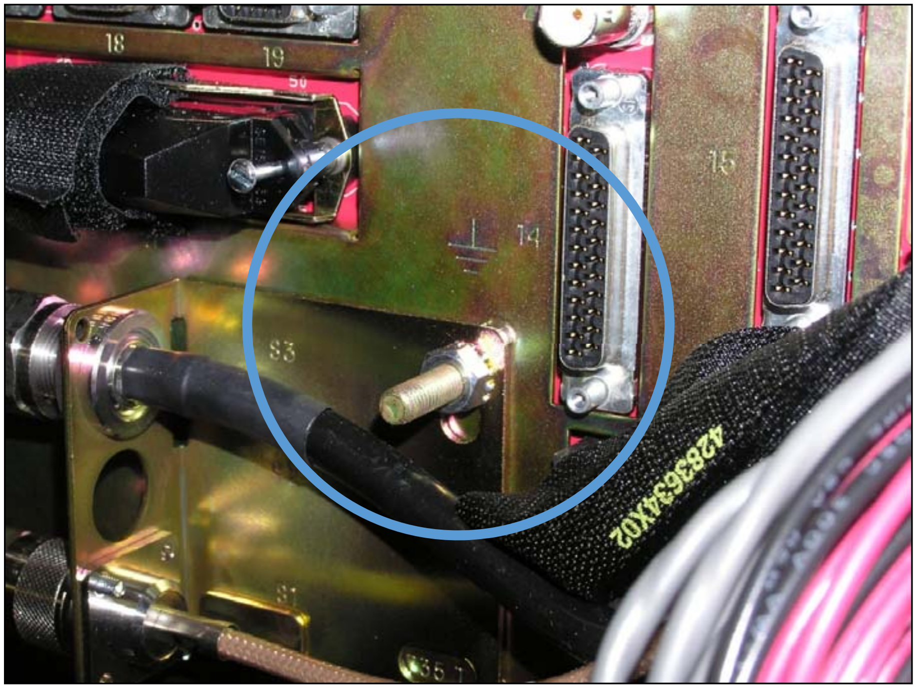


Replaced Connections

How many wires can you fit in a split-bolt?

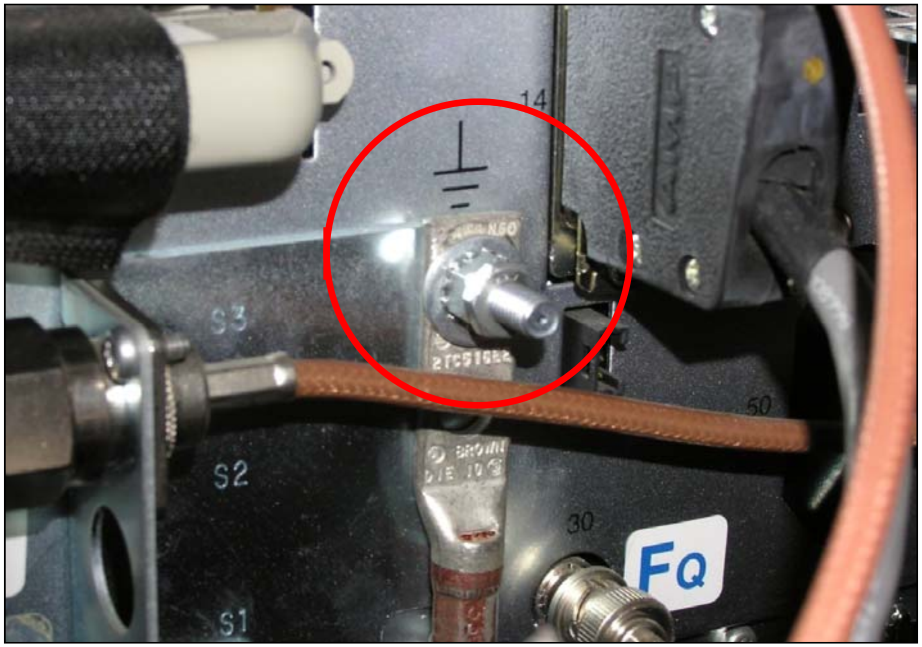
Ungrounded Equipment at Apopka

And this



Lightning Means Vibration

Lock washer, double nuts



SPD’s on Three Levels

SPD’s on main service entrance

Since Retrofit

- **Thousands of events recorded**
- **One strike witnessed**

- **NO Downtime! No equipment damage.**

Major Lessons

3 different contractors

- **electrical**
- **radio room**
- **tower**

No one party had responsibility

Power Quality is Cost-effective

OC 911:

<$500,000 cured $1 million damages

6-mos. to 1 year paybacks common

System Grounding Example

Can save big $$

Mt. Washington, NH

Mt. Washington, NH

Two 600 feet deep copper rods placed in 8 inch diameter well casings

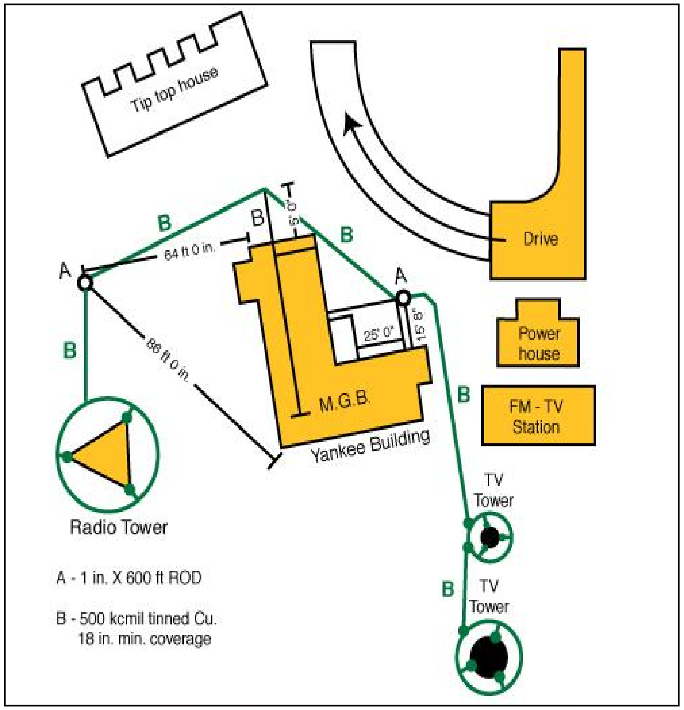
Backfill with bentonite grout

Interconnect with 500 kcmil copper cable

Achieved 6 ohm resistance

Site Layout

- **500 kcmil ring grounds (B)**
- **2-600 ft. deep vertical electrodes (A)**



Deep Electrodes

Through a mountain

Cost-effective

Before:

3-4 major events in 2 years (lightning)

$120,000 average equipment damage per year plus lost ad revenue (station downtime)

After:

No damages or disruptions in 4 years since improved grounding

Source: R. Cushman, Chief Engineer, WMTW-TV

Angel Fire Ski Resort

Angel Fire Ski Resort

- 2001 Spring Break, lightning caused shutdown
- People stranded on lift
- Loss over $2 M revenue

Base Station

Base control house

Similar at top

Computer controlled

Angel Fire

Grounding for communications cable

Terminus of messenger wire (only grounding between towers)

System Was Not Integrated

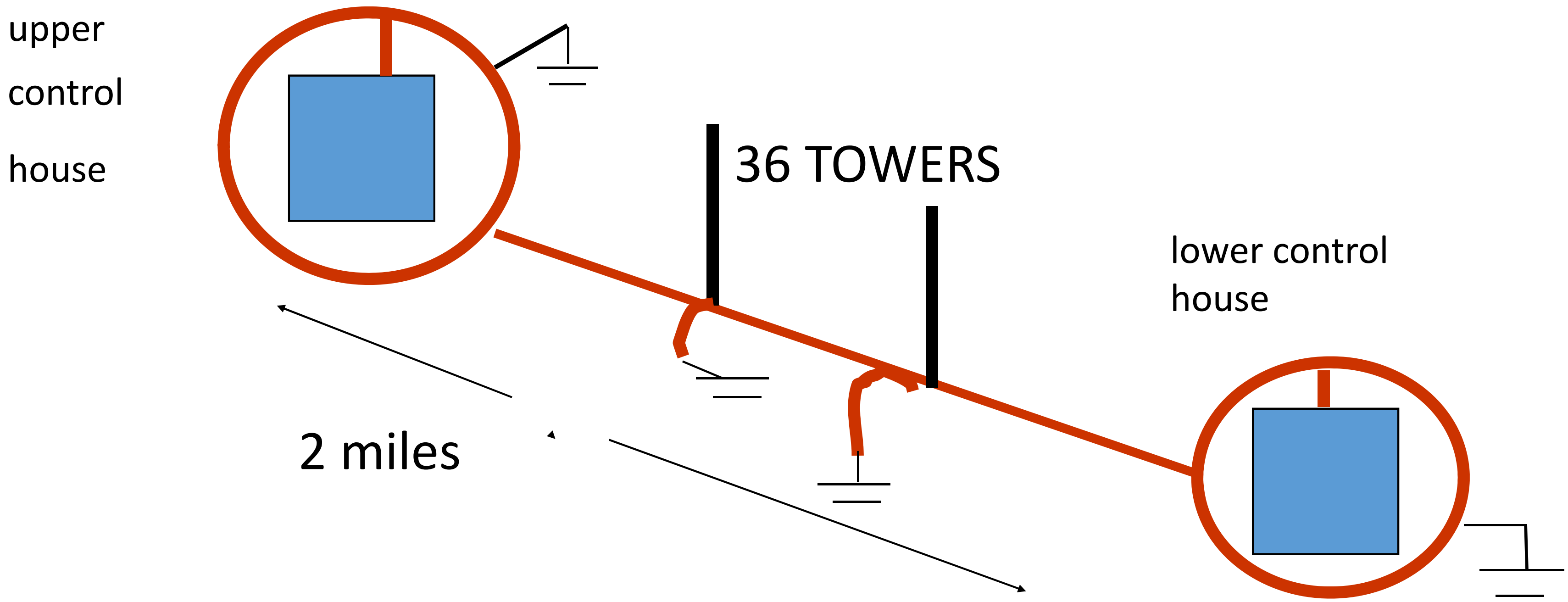
- Ground *system*
- Rod at each tower
- 2 miles of 2/0, each tower connected
- Rings at top and bottom stations
- No outages since!

Exothermic Welding

Lower Base Station

Soaking bentonite with water

Angel Fire Result



Multi Building Campus

Verestar

Largest satellite facility in North America

Verestar Control Room

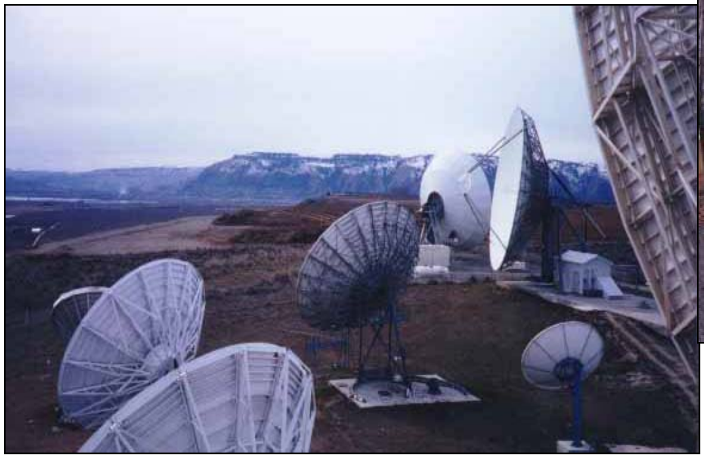
6 buildings

Over 100 acres

Dishes Are Remote

42 satellite dishes

3.5 m to 30 m



Basic Grounding Layout

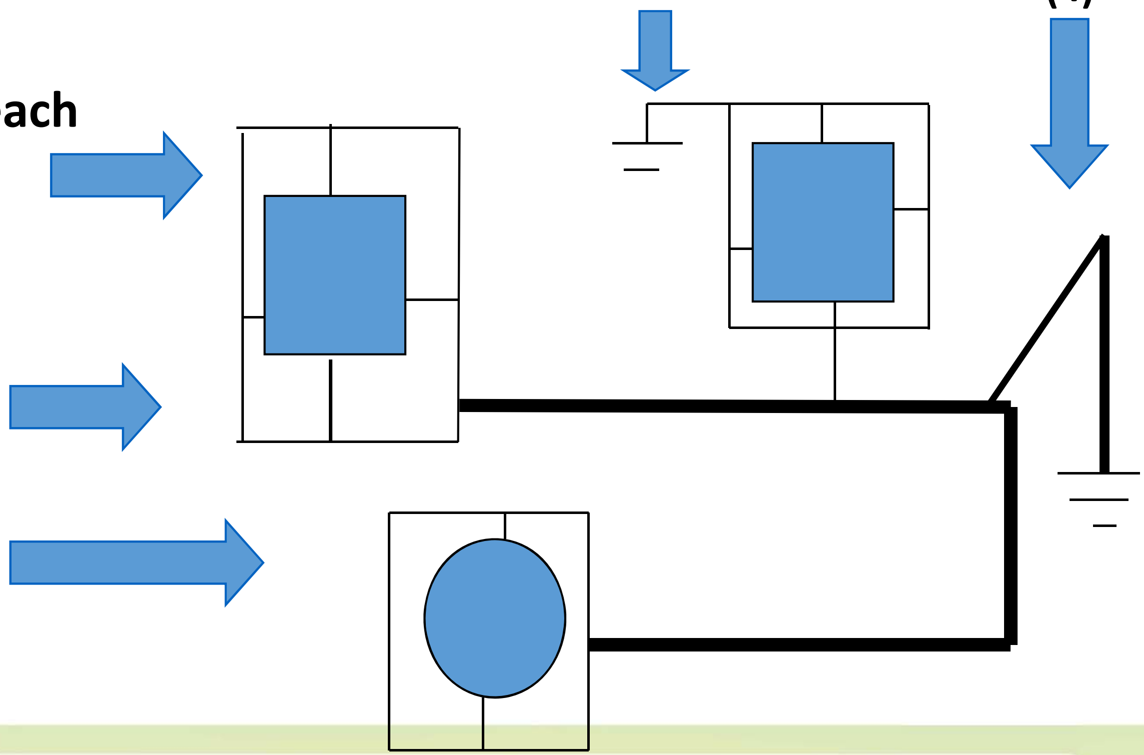
4/0 ring ground around each building (6)

750 kcmil spine

4/0 around each dish

(typ of 42)

<u>2 Ohm standard</u>



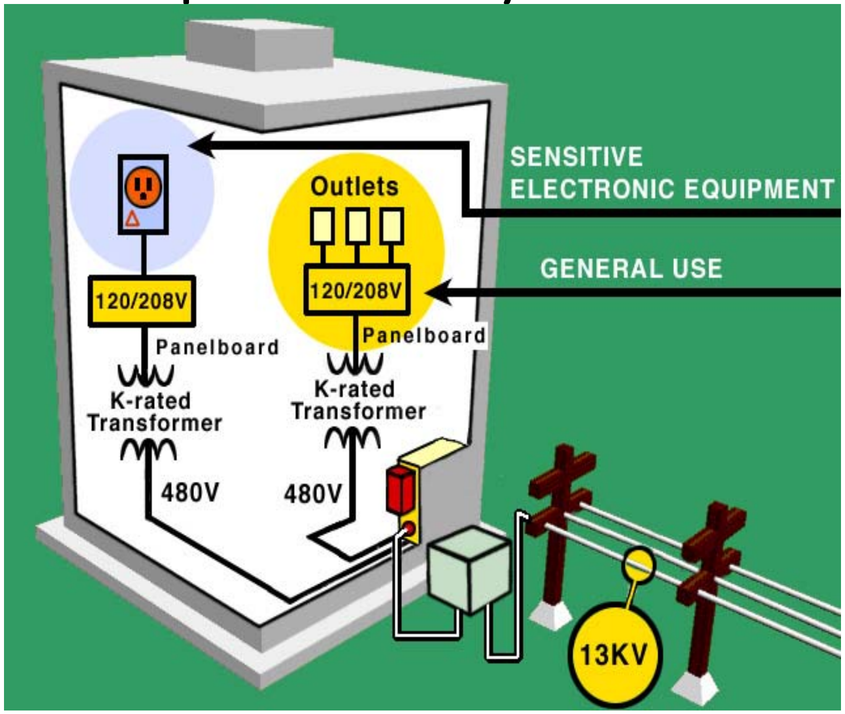
M.I.T. Case Study

Current Interior Design Standards:

Separate computer feeders, panels, and branch circuits

4 outlets per 20 amp. Branch circuit

Separate Systems



M.I.T. Design Standards

Current Design Standards:

- **10 ohms or less grounding resistance**
- **Double (and sometimes triple) neutrals**
- **K-rated transformers**
- **Always a separate grounding conductor**
- **Always copper**

System Grounding

- **Ground Ring System:**
- **500 MCM surrounding building**
- **1000 MCM “spine” between buildings**
- **36”-42” depth (below frost line)**
- **Tripled ground rods at each corner**
- **Tripled ground rods if span exceeds 200 ft.**

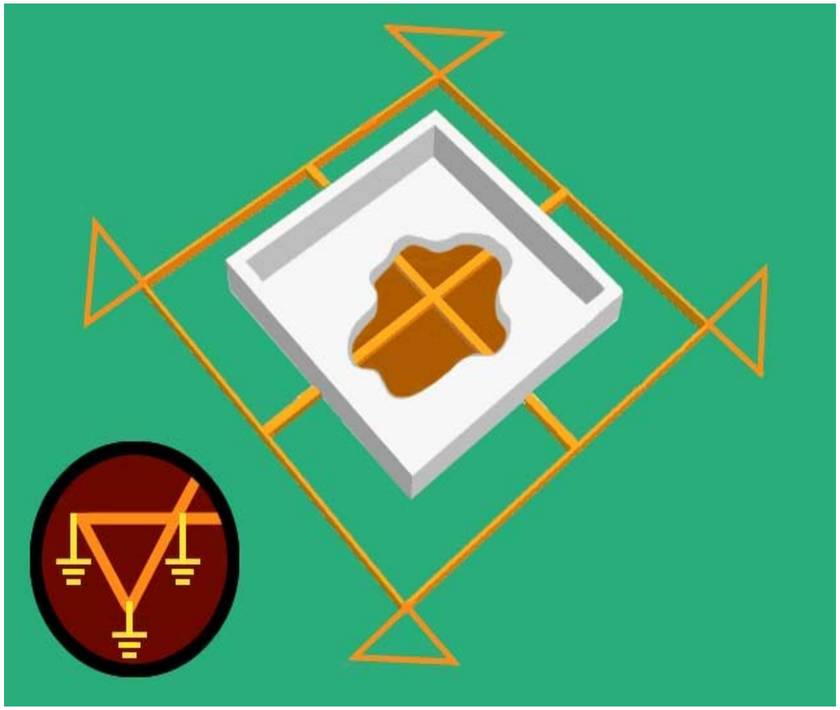
System Grounding

For slab – on- grade construction:

Ring ground

Triple rods at corners

Criss-cross under slab



Bonding

Connection of equipment cabinets that are not normally energized

KPTM-TV

4800 kW station

Studios in Omaha, NE

KPTM-TV

- **Lightning strikes damaged $1,000's of equipment, took station off the air.**

KPTM-TV

Tower was not bonded to studio

3-ohm resistance

2 electrodes at 125 foot deep

KPTM-TV

Satellite dishes were not bonded to studio

Note crowded site

Installed Master Ground Bus

Re-bonded all interior and exterior equipment:

- Equipment racks
- Satellite dishes
- Towers

to new MGB

- No damage
- No downtime

KPTH & KMEG-TV

KPTH & KMEG-TV

- Transmitter equipment bonded

KPTH & KMEG-TV

- Exterior equipment bonded

KPTH & KMEG-TV

- Ice bridge bonded
- Tower bonded

What Can Happen to a Ufer Ground?

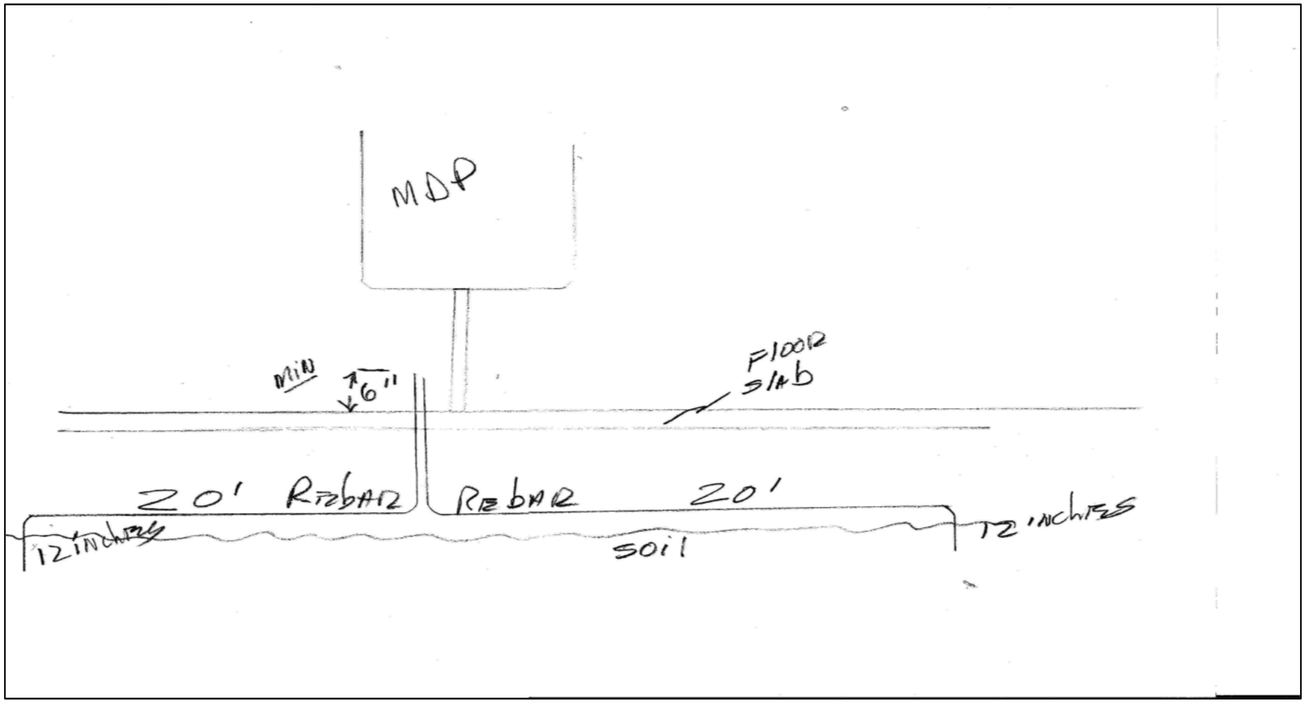
Lightning vs. Concrete Footer

Path in but not a good one out!

The reason for the damage

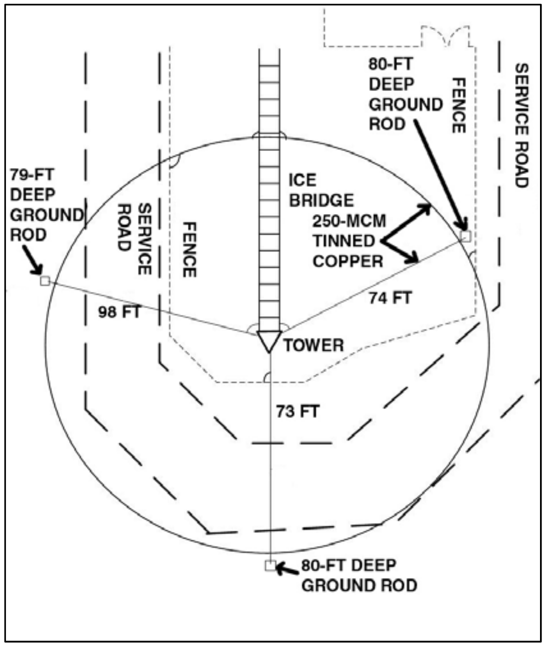
Burn scar on shattered concrete is evidence that lightning found a vertical reinforcing rod (center), which likely acted as an efficient Ufer ground, offering lower resistance than that of the installed grounding/lightning protection system.

Ufer Ground – Done Right



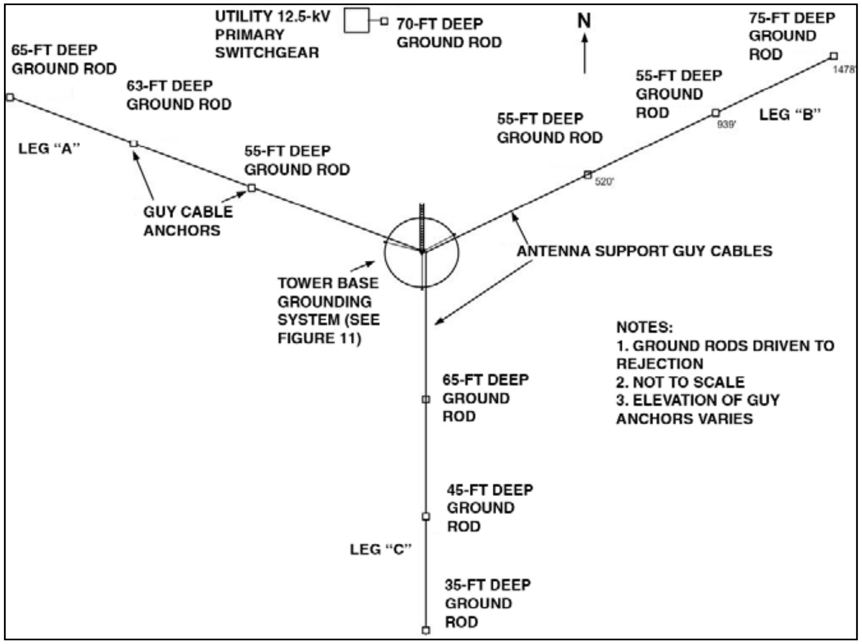
KPTH & KMEG-TV

- 250 kcmil ring around tower
- 80 ft. deep earth electrodes
- Bonded to ice bridge
- Bonded to transmitter



KPTH & KMEG-TV

- Site plan



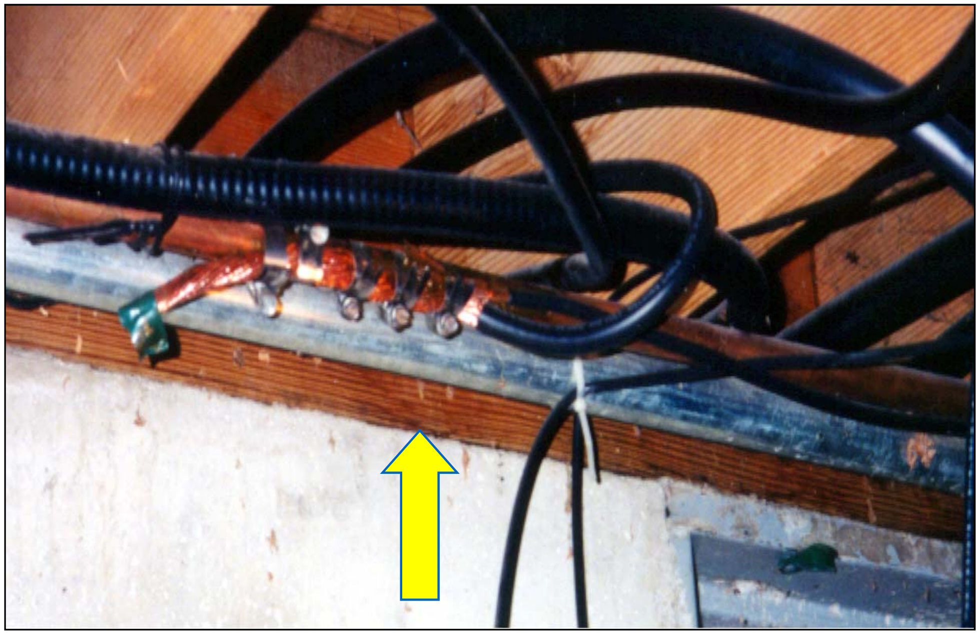
High Water Table Does Not Mean Low R

KROA-FM, Donephin, NE

- **5 ft. water table, near Platte River**
- **Water was "too" clean**

- **Tower hit by lightning**
- **Went off air, equipment damaged / destroyed**

Hose Clamps on Plumbing Tube



Tower Ground Connection

KROA Result of Corrections

- Lightning vulnerability greatly reduced
- Hum on signal disappeared
- Able to rent out to a second station

“Clean” Grounds

The Earth Cannot Be Used as a Conductor

Earth is never a satisfactory conductor

NEC, Art. 100:

Effective Ground-Fault Current Path. An intentionally constructed, low-impedance electrically conductive path designed and intended to carry current under ground-fault conditions from the point of a ground fault on a wiring system to the electrical supply source and that facilitates the operation of the overcurrent protective device or ground-fault detectors.

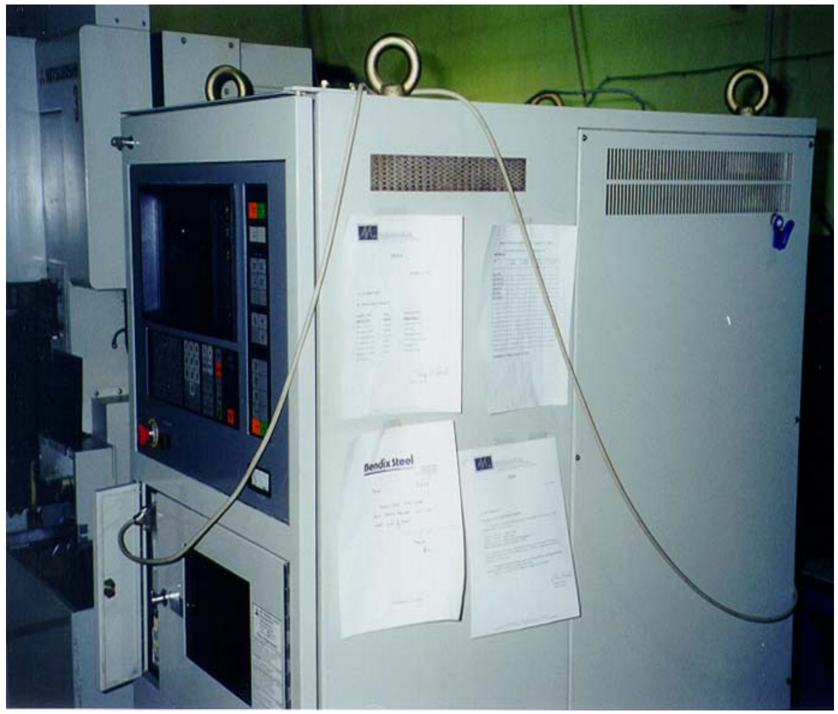
Case Study: “Clean Grounds”

McAfee Tool and Die

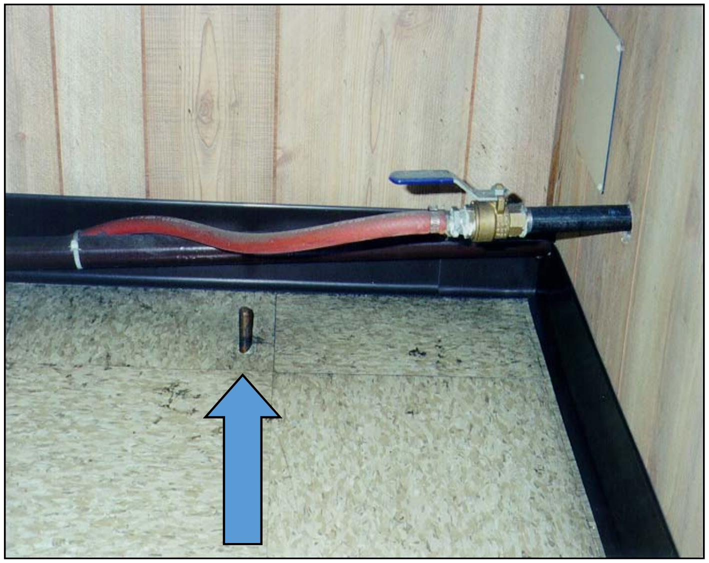
This is a High-Tech Environment

Every CNC Machine is Computer-driven

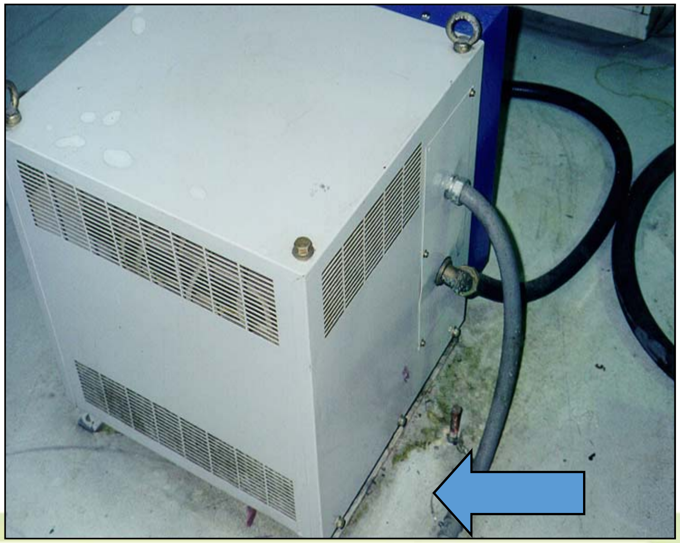
Comm Cable is Unintentional Antenna



“Clean Grounds”

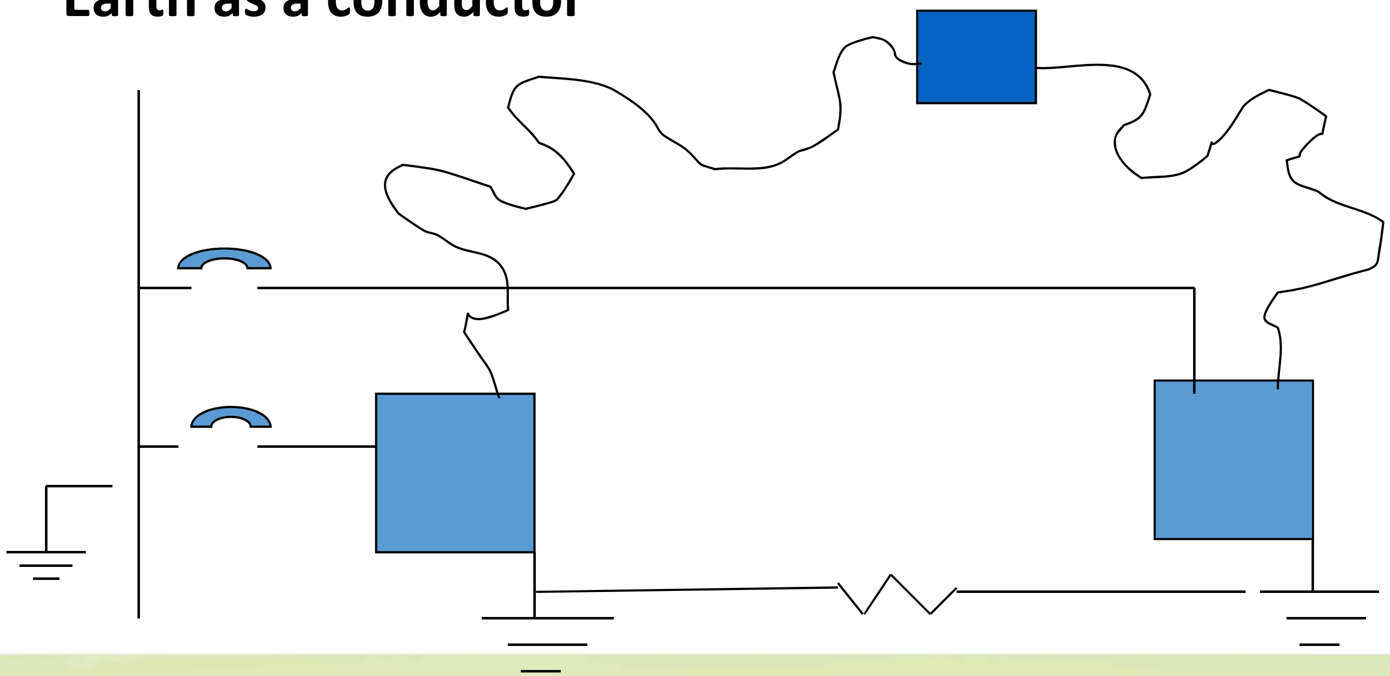


“Supplemental” electrodes abandoned



McAfee Layout

Earth as a conductor

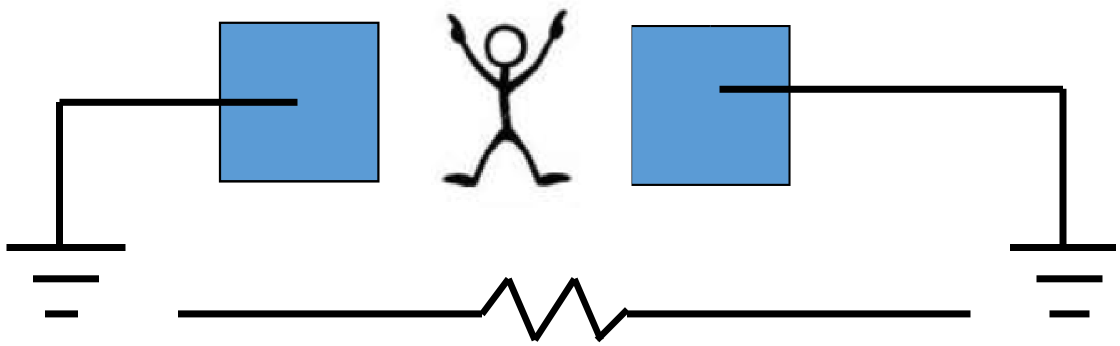


Earth is not a current path

No separate grounds allowed

only one grounding system

- **250.54 …**the earth shall not be used as an effective ground-fault current path…



What is an IG?

So if "supplemental" grounds are a no-no, what is an isolated ("insulated") ground?

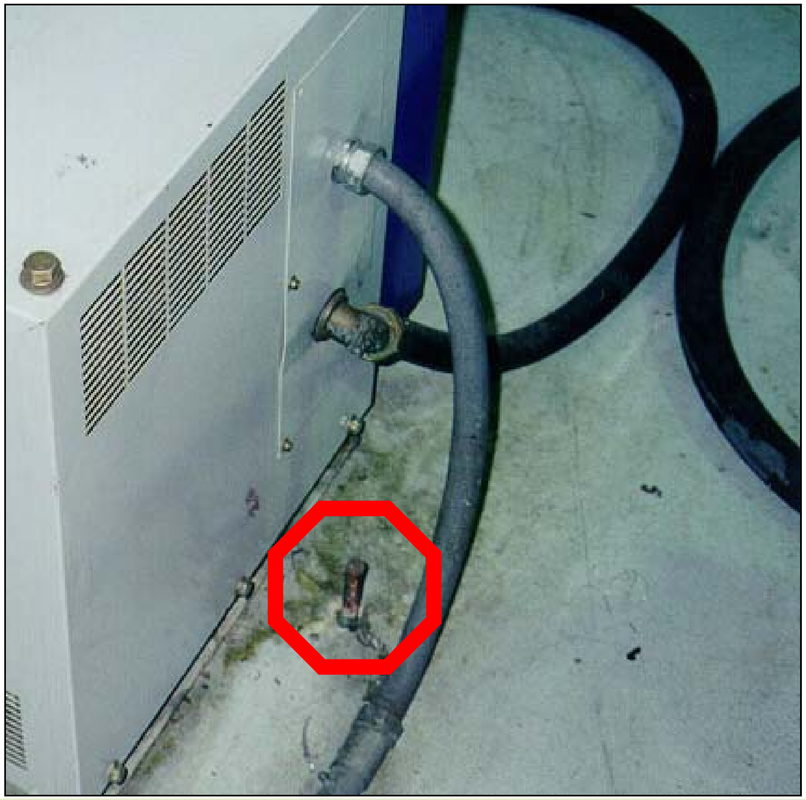
Insulated Grounding

Insulated Grounding (IG)

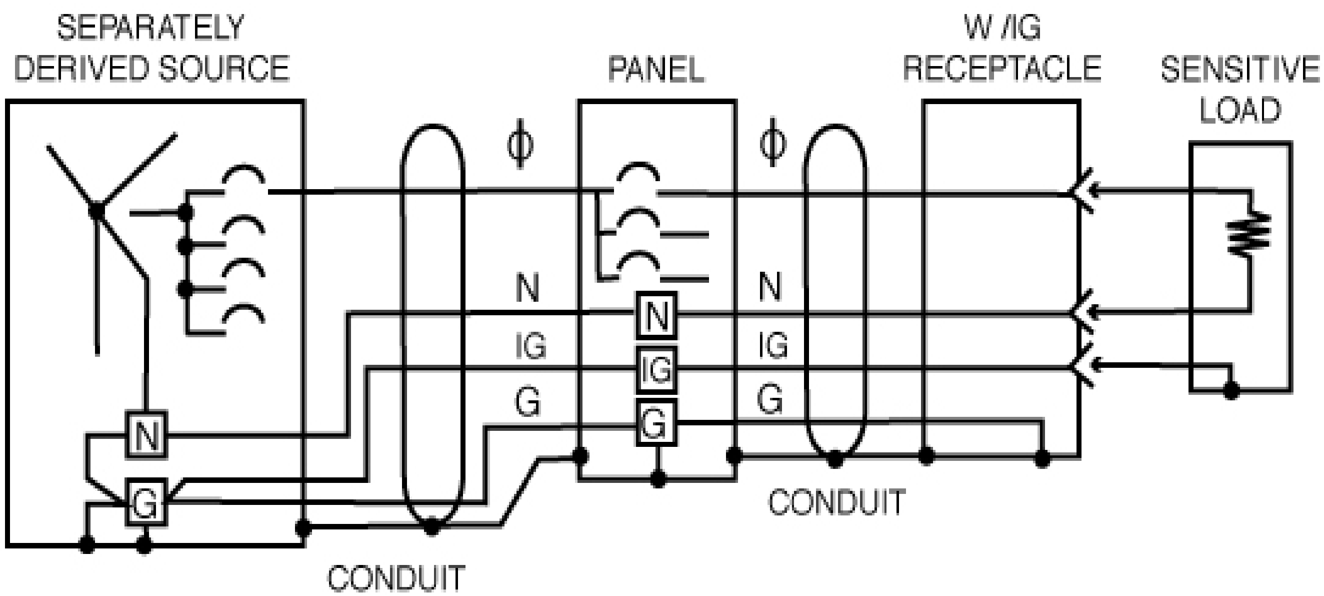
Good idea to install in new circuits

Gives flexibility to use or not

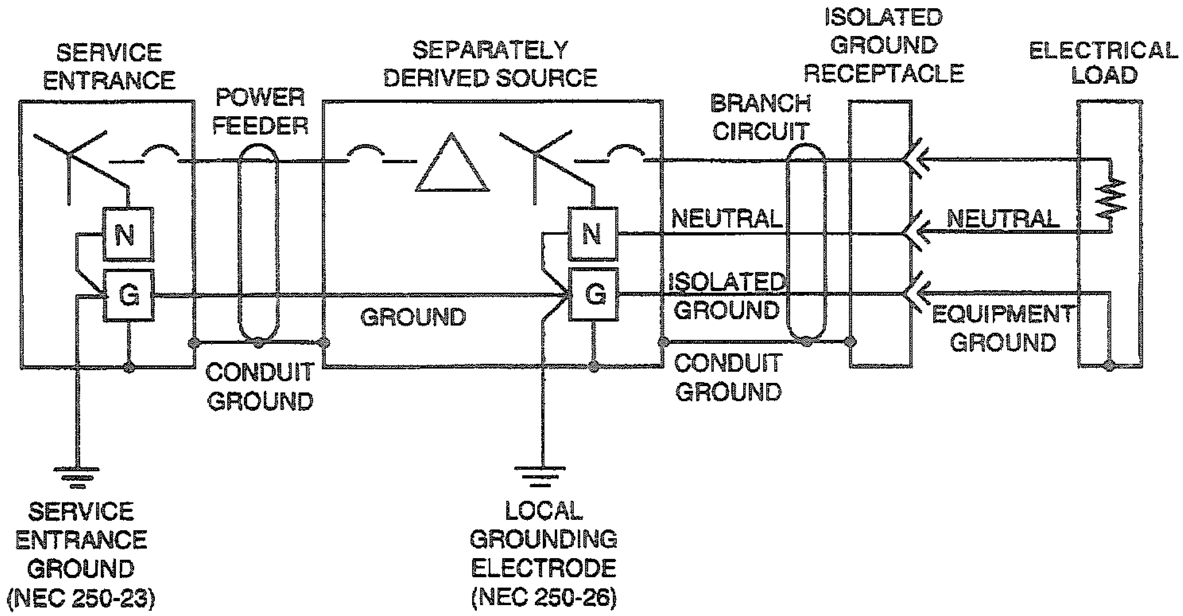
This is NOT IG



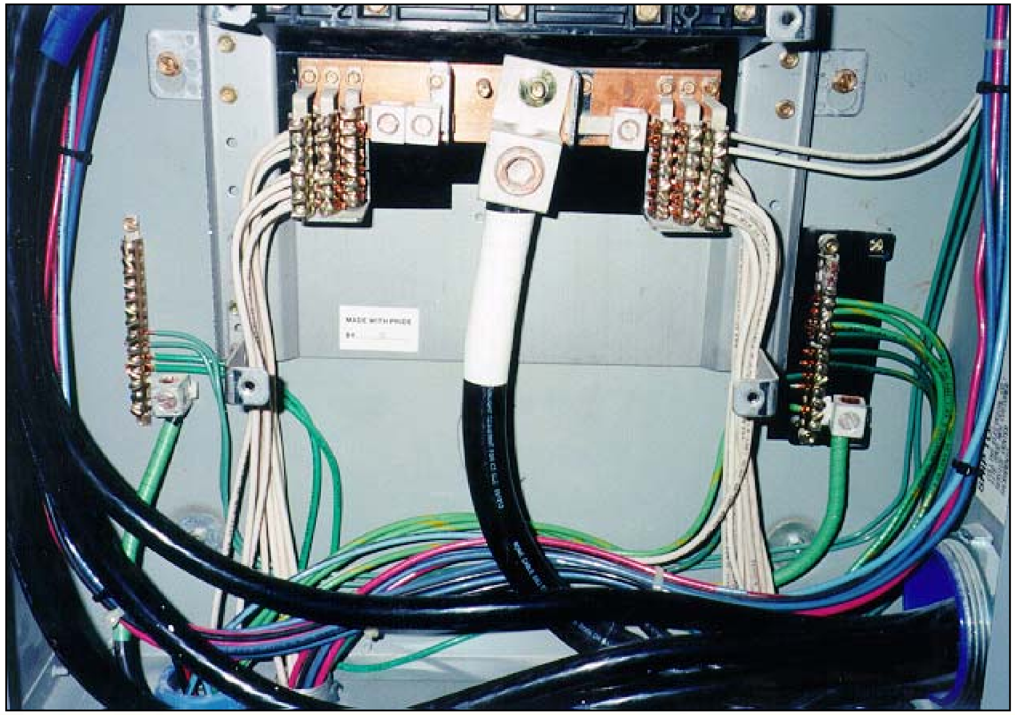
Isolated (Insulated) Grounding



IG Circuit with Transformer

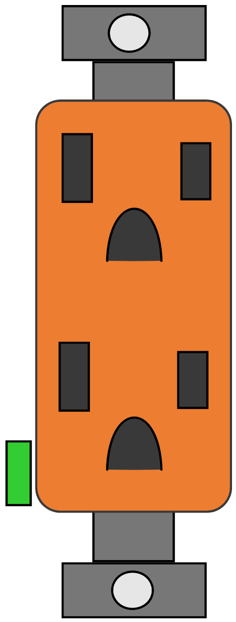


Not Connected to Cabinet

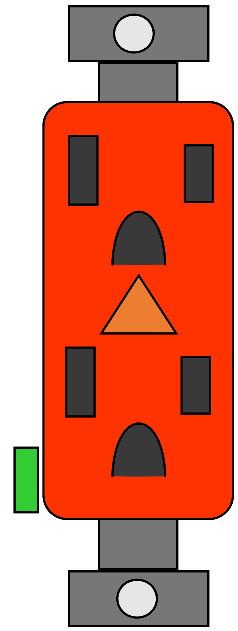


Receptacles

IG or SG?



IG



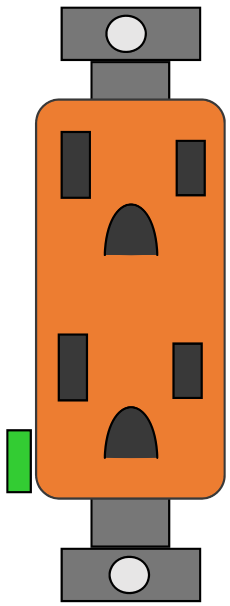
Either receptacle may be any color under the most recent NEC editions.

Receptacles

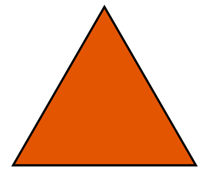
Do you see the difference?

Receptacles

IG or SG?

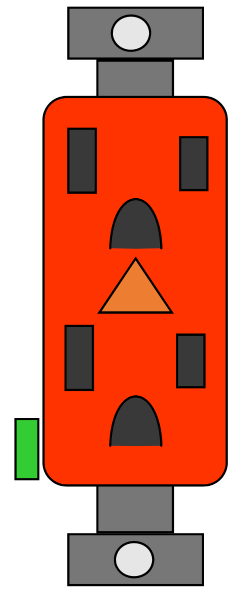


An orange color delta

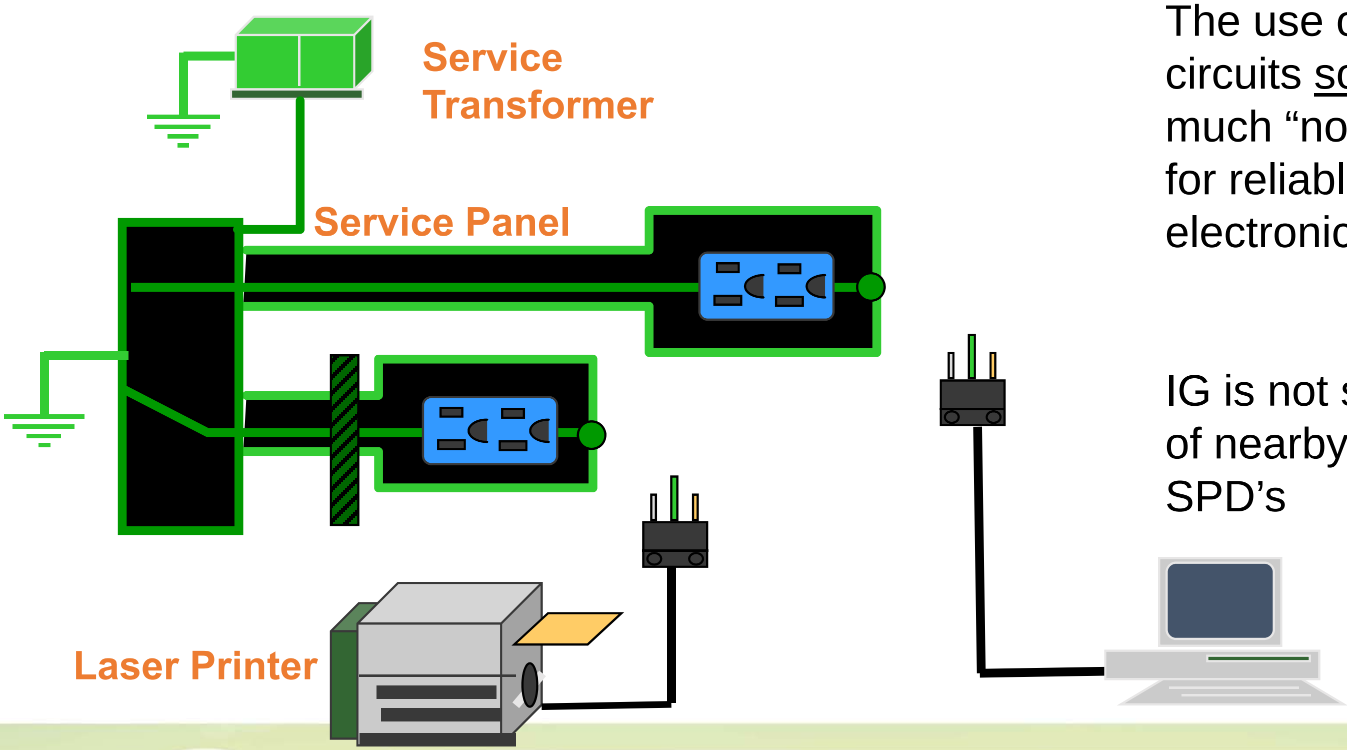


is required to be embossed on the face

IG



Why use IG?



The use of solidly grounded branch circuits sometimes results in too much "noise" on the branch circuit for reliable operation of the electronic loads.

IG is not subject to induced energy of nearby lightning, thus smaller SPD's

Isolated Grounding

CAVEAT:

- **50% of the time, IG helps situation**
- **50% of the time, IG hurts situation**
- **50% of the time, makes no difference**

Be flexible, use what works best in a particular circumstance

Let's Take a Break

After the break, John West of Power and Systems Innovation of Tampa, Inc.

Second Part

John West
Power and Systems Innovation of Tampa, Inc.

Your Job

- When your equipment is involved, you should be the expert when you walk on site.
- You are responsible to be sure all is right if not, you fix it.
- If you don't have the expertise to "fix", get an expert involved. The key dazzle with brilliance not baffle with BS.
- Learn how to recognize issues that will impact the proper installation of your equipment and its sustainability.
- Inform your customer of the conditions that can impact your installed equipment.
- Some will "ignore" and hope issues go away. Put it in writing, inform and then it is their responsibility.   Their choice.
- The customer votes with their wallet!

When You Are Not 100% Sure

- Develop a relationship with a someone that has the expertise to assist your efforts.
- Do not guess, hope or assume you are right.
- Learn from them, develop your own expertise.
- Avoid those that are just out to sell something.
- With many projects there are 6-phases.

1. Enthusiasm!	**4. Search for the Guilty!**
2. Disillusionment!	**5. Punishment of the innocent!**
3. Panic!	**6. Praise for the non-participants.**

Where to you want to be on the above list at the end of the day?

Grounding & Bonding

- Grounding, (Earthing) is the foundation of the electrical system.
- Bonding is the “rebar” that holds the foundation together.
- The electrical system is not safe or sustainable unless the grounding & bonding are completed to the highest possible standard.
- Anything built upon a flawed foundation will never be proper or sustainable regardless of the effort with which it is built.

Today’s Plan

- Understand what makes up soil resistivity.
- Know the variables in grounding conditions.
- Understand the different types of grounds.
- Understanding ground testing.
- Ground Augmentation–What works & or will not.
- Learn about high performance bonding.
- Ground Loops – Learn how to avoid them.
- Why grounding & bonding are critical for SPD.
- SPD – What you need to know about SPD.
- SPD – Your role in making sure they work.

But First

- Lets look at some examples of very poor workmanship and talk about the down side of these examples.
- Who do you blame for these?
- Who is responsible?
- Do you want your equipment connected to these grounds or ground bonds?

•Two Wires under the same lug.
•Improper lug for the wire size.
•Screwed, not bolted.
•Connected to painted steel.
•No conductive grease.
•Steel not continuous or contiguous.

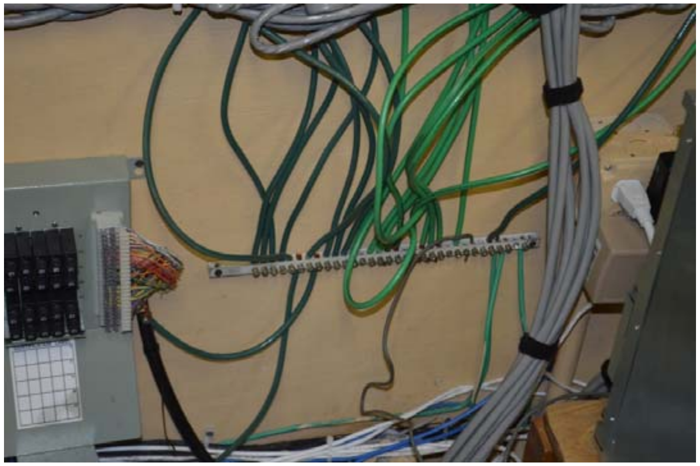
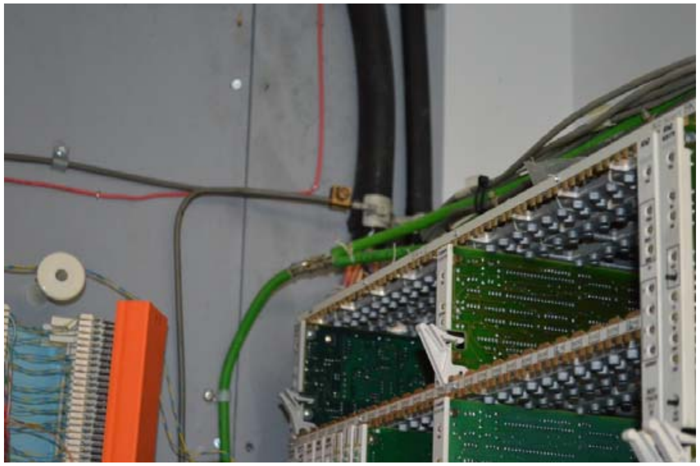
The lightning arrestors for this phone system are not bonded to a path to ground. This is a life safety issues as well as a formula for equipment damage. The client could not understand how or why his phone system would be damaged and fail during a thunder storm.

This Met Code When Installed!

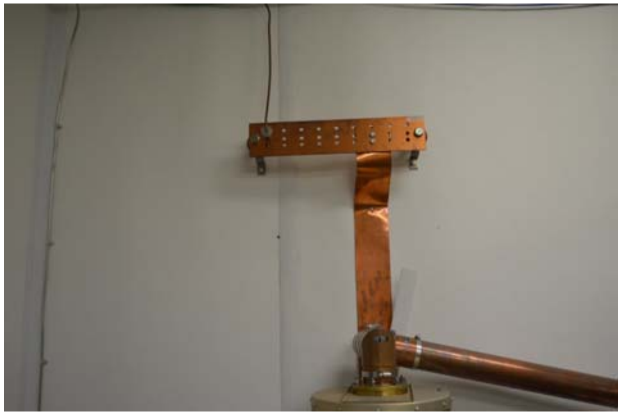
As a result it meets code today!

Want Your Name on This Job?

One of many electrical systems in a HUGE resort's in central FL. MS1's Bond is shown to the left, MS2's Bond is shown above …(missing). The customer was having big issues and had lost a significant amount of equipment. I have no idea why the inspector did not catch this.   It is now in court as the owners are not happy and they will win.

This phone system is so unreliable the company that is the owner's telecom person keeps a box full of replacement cards as they fail all the time. Annual cost? Over $100,000.00 and they thought that is normal. After the FIX, no damage in years. State of Florida agency site!



The above photo’s are from a State of Florida site (500,000 Square Foot Building) Computer Room – where all the file servers and main blade server banks are. The computer person told me that he wanted to make sure the critical equipment was grounded properly so he had additional ground rods, ground bonding bars added.

OK, start finding the errors.

#1 The difference in ground potential with the photo, a minimum of 4.
(the phone company cable has a ground reference)
#2 Look at the daisy chain connection from the telephone cabinet to the rod!
#3 Note the connections are all single lugs.
#4 No Penetrox / Noalox between the lugs and ground bonding bar.
#5 Note the bar is over and very close to a bundle of communication cables.
#6 Multiple conductors on the RHS Lug……
#7 Improper lug for the wire size on the lug in position #2 (L-R)
#8 Note the size of the ground conductor and the lug size in position #3.
The installer solved not having the proper lug, just cut some of the conductors until the wire fits the lug you have….. Oh, what quality!!!

#9 Only one lug is correct for the wire size…..
#10 The “flow” is not aimed in the direction of the ground rod (forget it is wrong to have a ground rod) the flow is wrong….. Must be from the equipment to the drain (the earth).
#11 Solid wire, not stranded is used for 4 of the 5 ground bonds.
#12 The connection to the rod is a cable that is stranded and NOT the proper size the clamp used.
#13 The clamps are exposed to physical damage.

Who Approved This Job?

Want your new HD, Smart, Flat Screen TV on this ground?

How about the fire alarm in a Children's hospital? (no, I am not kidding)

Tape Job on the Ground Bonding?

Lightning Damage to 9-1-1 Facility

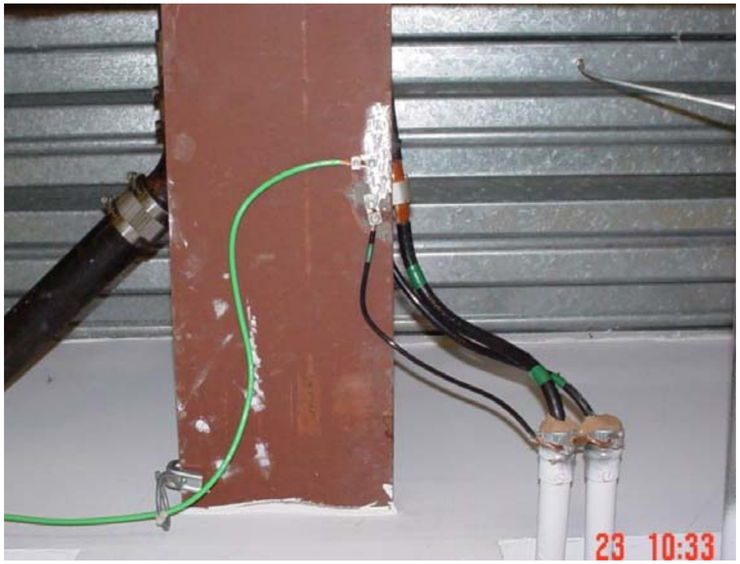
Monitor your grounding!!!

Very Expensive Copper Theft!

Nice Bonding Job….. To What?

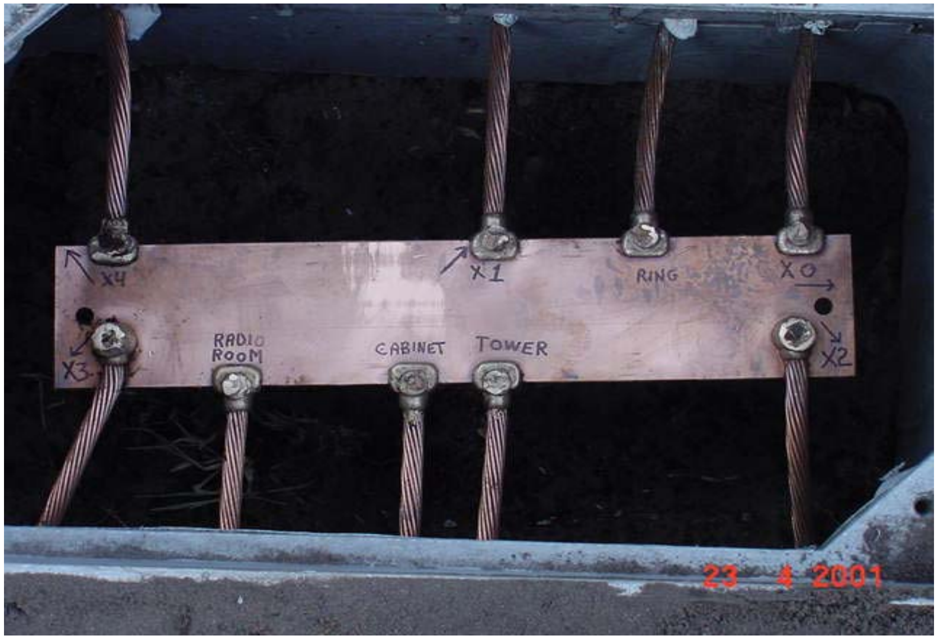
Bonding to Building Steel

The code allows it, but in a lightning prone environment this is trouble!

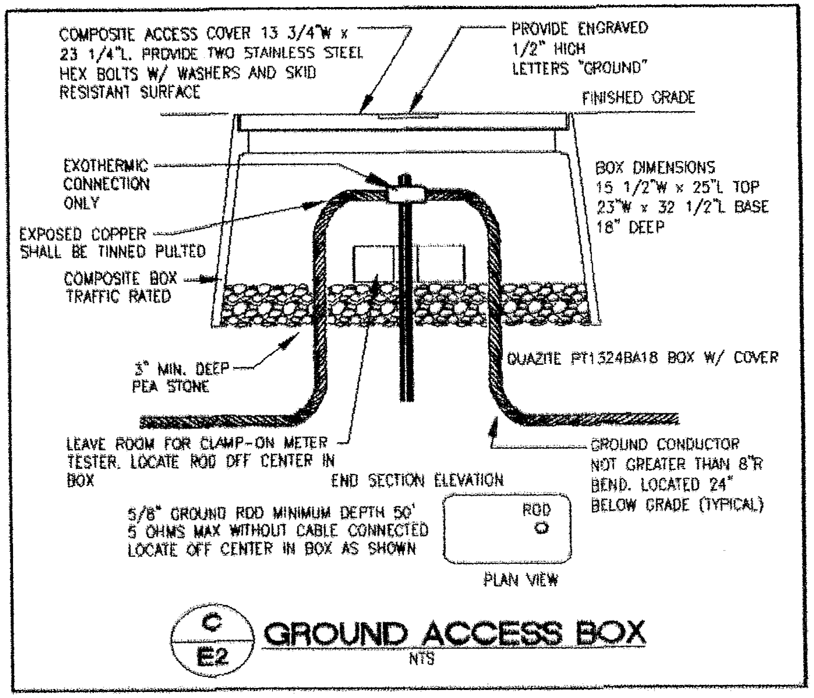


What is Wrong Here?

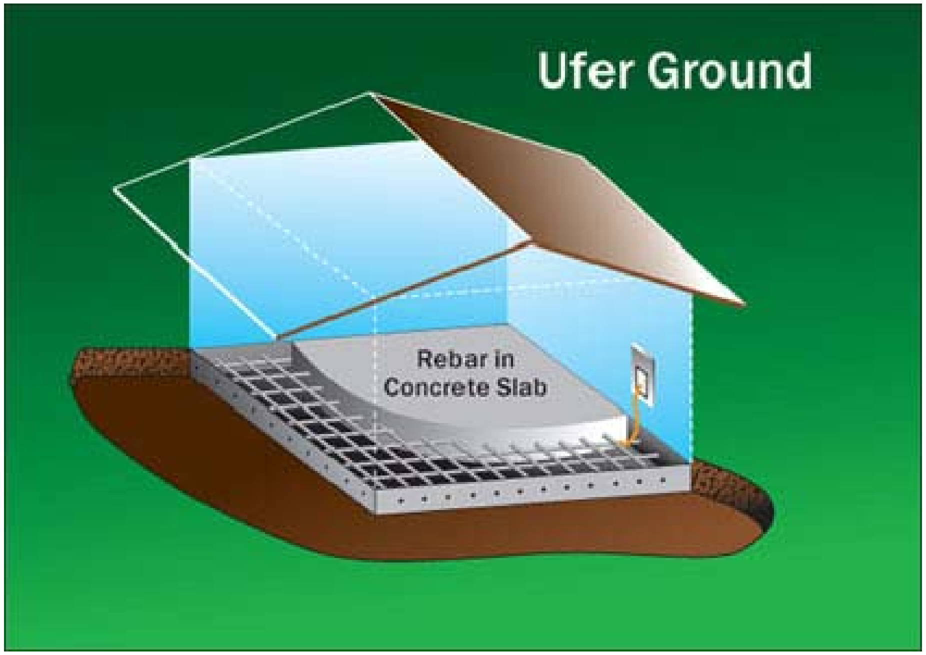
What Should Be Done Here?



A Proper Ground Test Well



What is Wrong With This Picture?



Testing Ground Systems

- NEC 250 Grounding Performance Requirements.

  None!
- NFPA 780 Grounding Performance Requirements.

  None!
- UL96A Grounding Performance Requirements.

  None!
- IEEE Grounding Recommendations.

  5-Ohms or less.

5 – Ohm Grounding

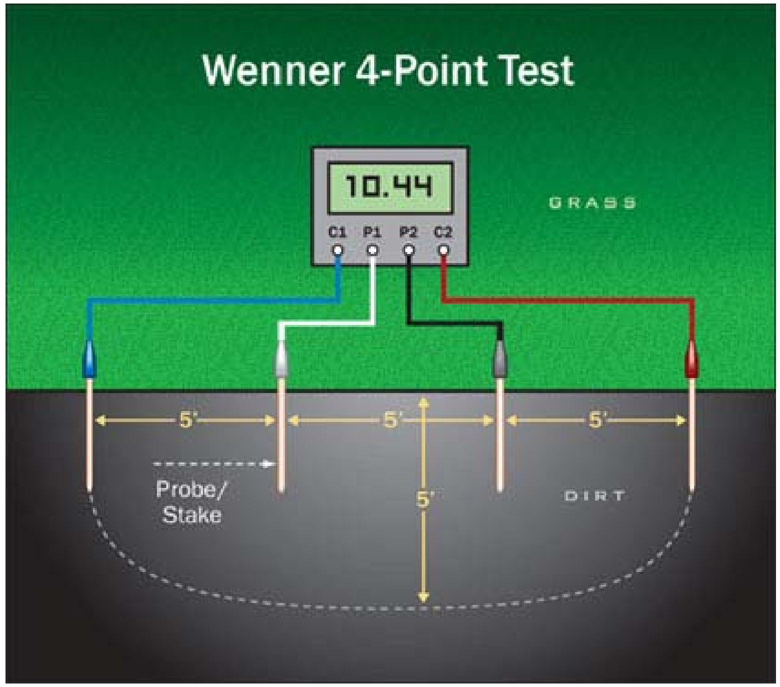
- Should be the requirement for the ground rod system of every electrical system.
- Ufer grounding & bonding is in addition to the 5-Ohm ground rod system.
- The maximum resistance of a lightning protection system ground rod should be 5-Ohms.
- All this added together, properly bonded will assure the odds of damage to the facility is VERY slim.
- Add to this a properly designed and installed surge protection system and the probability of any damage comes close to “0”.

Soil Resistivity

To determine the resistivity of the soil, the Wenner four-point measurement method (my choice of the two options), it corresponds to IEEE Std. 81.

The Wenner 4-point measurement test employs 4 test probes, spaced apart from each other at equal distances (the distance is critical).

Note the distance between probes!

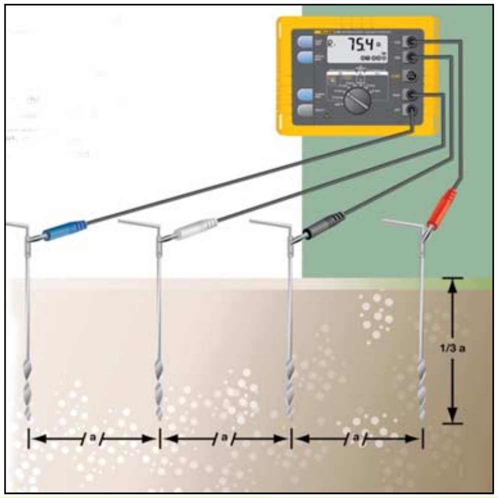


Four Point Soil Resistivity Test Layout

Wenner Method:

$$\rho_E = \frac{4 \cdot \pi \cdot a \cdot R_W}{1 + \frac{2 \cdot a}{\sqrt{a^2 + 4 \cdot b^2}} - \frac{a}{\sqrt{a^2 + b^2}}}$$

ρE = measured apparent soil resistivity(Ωm)
a = electrode spacing (m)
b = depth of the electrodes (m)
RW = Wenner resistance measured as "V/I" in Figure (Ω) If b is small compared
to a, as is the case of probes penetrating the ground only for a short distance.



Average Soil Resistivity

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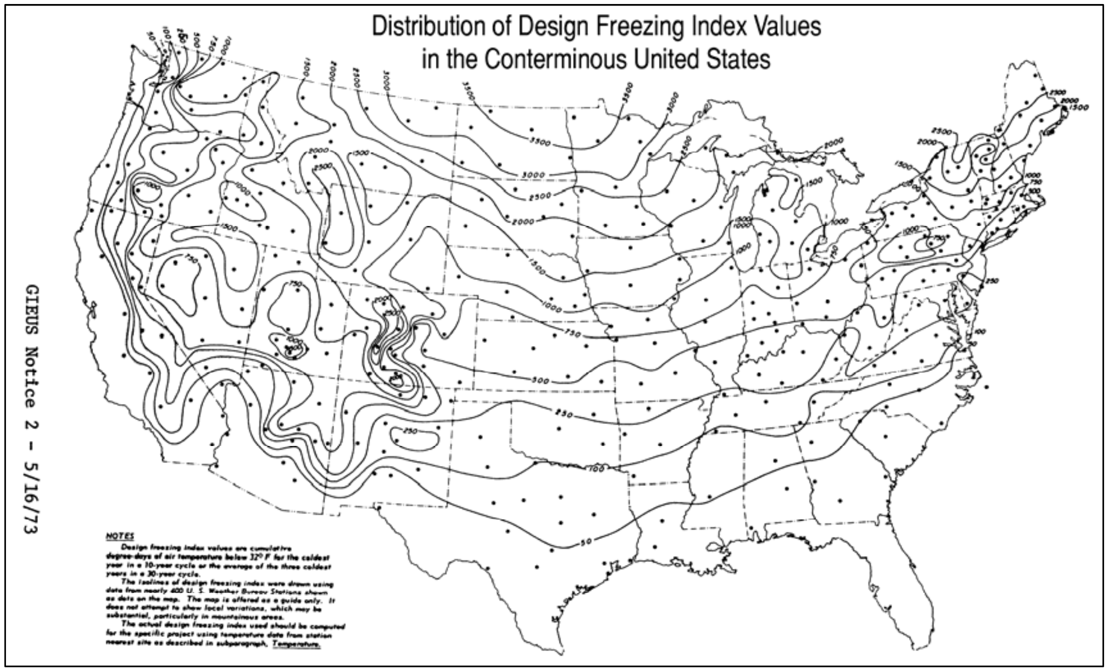
FIGURE 2

Estimated Average Earth Resistivity in U.S. (ohm·meters)

Temperature & Grounding



The “Depth” Required to Reach:

SOIL RESISTIVITY	LENGTH FOR A 5-Ohm GROUND	LENGTH FOR A 10-Ohm GROUND
50 Ω-M	33 Feet	9.8 Feet
70 Ω-M	52.5 Feet	20 Feet
100 Ω-M	85 Feet	33 Feet
150 Ω-M	145 Feet	59 Feet
200 Ω-M	207 Feet	85 Feet
300 Ω-M	344 Feet	144 Feet
500 Ω-M	636 Feet	276 Feet
1000 Ω-M	1444 Feet	636 Feet

Why Ground Testing is Critical

- Arcing ground faults can seriously damage distribution equipment, causing fires, which damage facilities and endanger personnel.
- Arcing ground faults also cause extended downtime during system repair.
- Not tested, the grounding system may not be compliant with IEEE recommendations.
- Increased exposure of personnel (life safety issues), the facility systems & equipment to damage and downtime.
- Reduced equipment life.

Fall-of-Potential Tester Checklist

- Identify and locate any and all conductive elements (wires, pipes, cables, metal fences, tree roots, etc.) or any condition or conductive element in the soil that would impact the test results.
- To insure accuracy of a “stake type” fall of potential test it is necessary to verify the test results. This is done by a completion of two additional tests that are at: 90°, 180° or at 270°.
- Do you have access to enough area or real estate to allow completion of two additional tests for the stake type tester? (Including this requirement for 4-Point soil resistivity testing is proper.)
- Verify the soil is un-disturbed and virgin soil, no fill has been added.

Fall-of-Potential Tester Checklist

- If necessary use ground penetrating radar to be sure the soil in the area can be used for testing.
- Verify the moisture content of the soil does not exceed the worst case lack of seasonal moisture.
- Test and record; the soil temperature, moisture content, PH, salt content.
- Confirm if any ground enhancement material was used when the grounding was installed. If anything other than Bentonite or conductive concrete by; “San-Earth” or “Conducrete” the testing may (will) not be accurate.

The Factors That Impact Soil Resistivity

- Electrolytes which consist of Moisture, Minerals and dissolved salts.
- Regardless of electrolyte content dry soil has high resistivity (Florida “Sugar Sand”)
- The highest resistance “normal” soil conditions are: Gravel, Sand & Stones with little or no clay and/or loam.

Formula for Ground System Impedance

Grounding System Impedance (Z) = $\sqrt{R^2 + {X_L}^2}$

Where R is the Grounding system Resistance

X_L is Grounding system Reactance given by $(XL) = 2\pi f L$

f is the frequency of current

L is the inductance offered by the installed Grounding System

Influence of Temperature and Moisture

Resistivity (approx), n-cm

Soil	Min.	Average	Max.
Ashes, cinders, brine.waste	590	2,370	7,000
Clay, shale, gumbo or loam	340	4,060	16,300
Same, with varying proportions of sand & gravel	1,020	15,800	135,000
Gravel, sand, stones with little clay or loam	59,000	94,000	458,000

Temperature and Resistivity*

Temperature		Resistivity
C	F	Ohm-cm
20	68	7200
10	50	9900
0	32 (water)	13,800
0	32 (Ice)	30,000
-5	23 (Ice)	79,000
-15	14 (Ice)	330,000

- *As temperature varies throughout the seasons therefore soil resistivity will also vary with the moisture content and the temperature. This is one of the reasons deep earth grounding is preferred in areas where the "frost line" is deep. A 10' ground rod in some areas does not provide a ground in all seasons.

Classified Water	Ω − m
Pure Water	200,000
Distilled Water	50,000
Rain Water	200
Tap Water	70
Well Water	20～70
Mixture of River & Sea Water	2
Sea Water (Inshore)	0.3
Sea Water (Ocean 3%)	0.2～0.25
Sea Water (Ocean 5%)	0.15

Table 9 : Resistivity of Water(Approx.Value)

The Impact of Temperature on the Resistivity of Soil Containing Salt

Temperature C	F	Resistivity Ohm-cm
20	68	110
10	50	142
0	32 (water)	190
-5	23 (ice)	312
-13	8.6 (ice)	1,440

*This example is sandy loam, 20% moisture content and 5% of weight of the moisture is salt.

Combined Resistance Of n No Of Electrodes

$$R_n = R\left[\frac{1 + \lambda a}{n}\right]$$

In which $$a = \frac{\rho}{2\pi RS}$$

Where

R=resistance of one rod Ω

S = distance between adjacent rods m

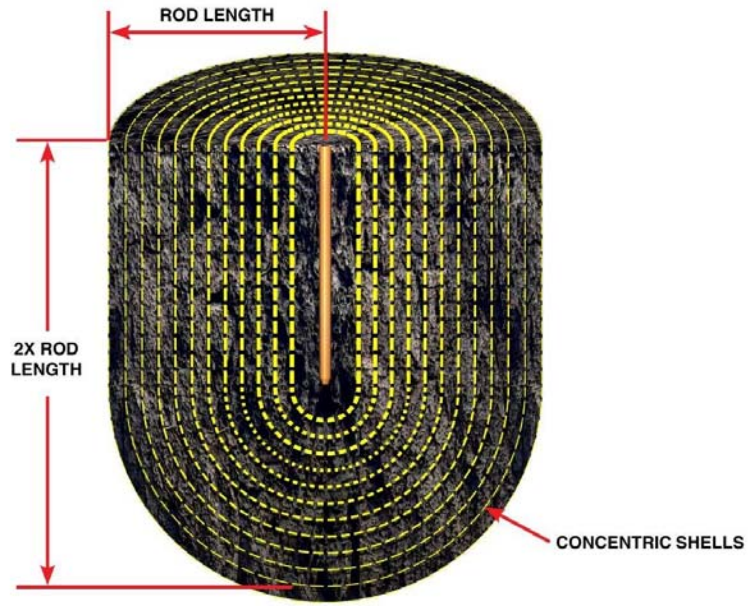
ρ = resistivity of soil Ω-m

λ =is a factor selected from Table 2 or 3 of BS 7430

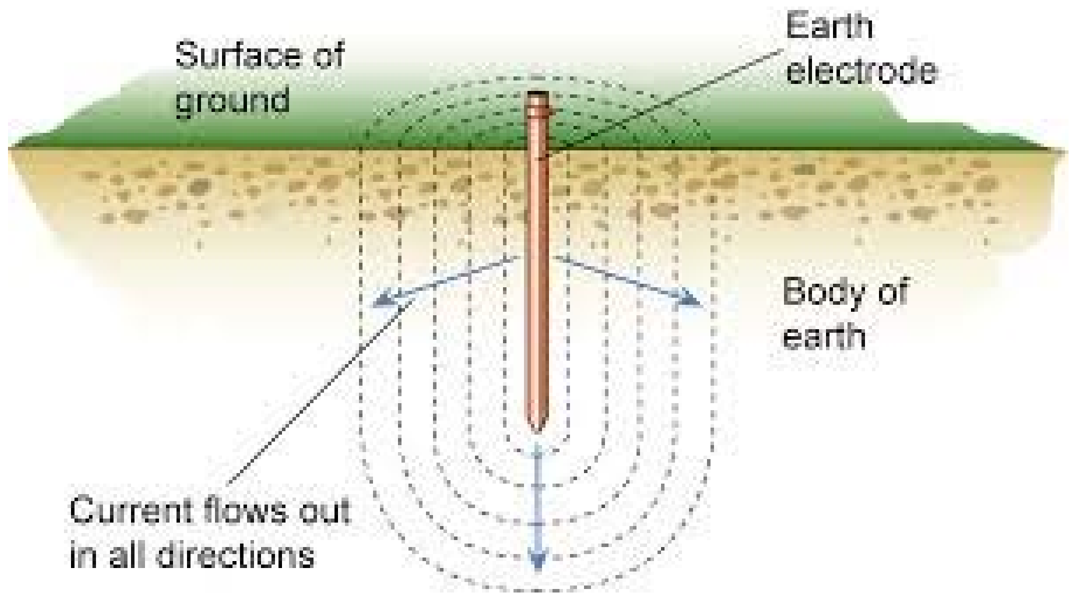
'n is the no of electrodes as given in Tables 2 and3

Concentric Shells of Earth

Dependent on rod length & soil conditions



Current=Voltage/Resistance



2X Rod Length (average) Dependent on Soil Resistivity

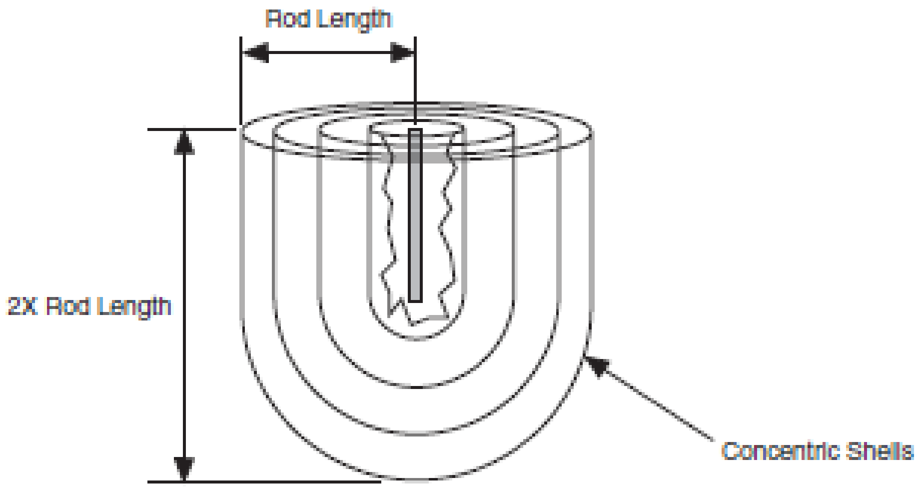
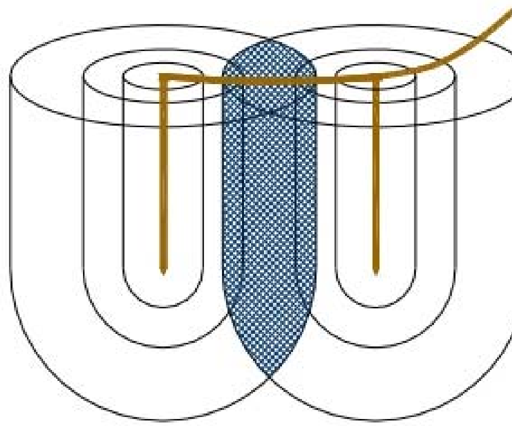


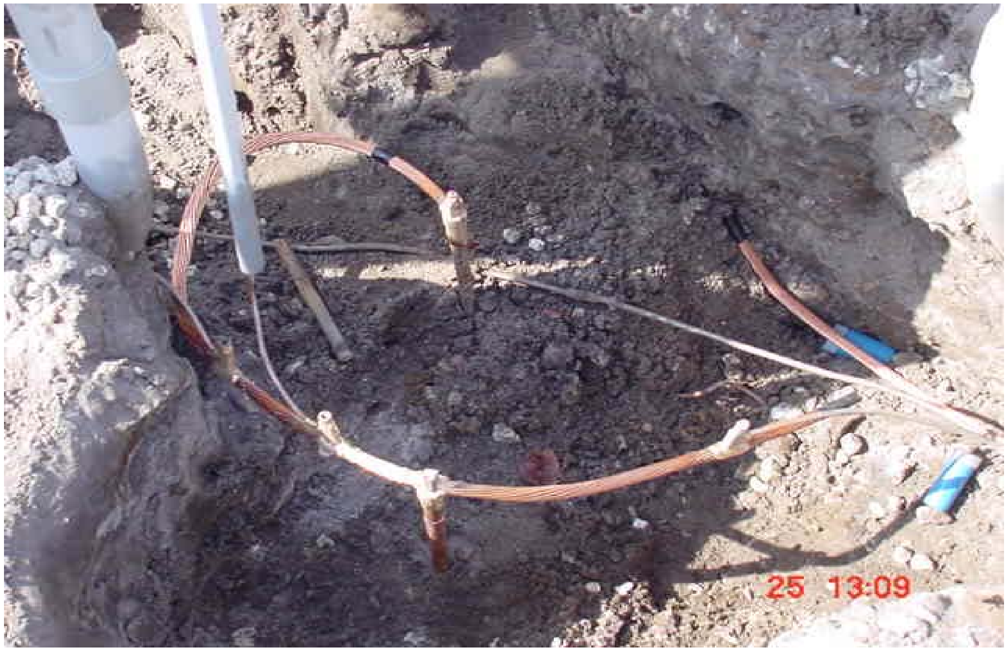
FIGURE 4-5 GROUNDING ELECTRODE SPHERE OF INFLUENCE

Lowering Ground Resistance



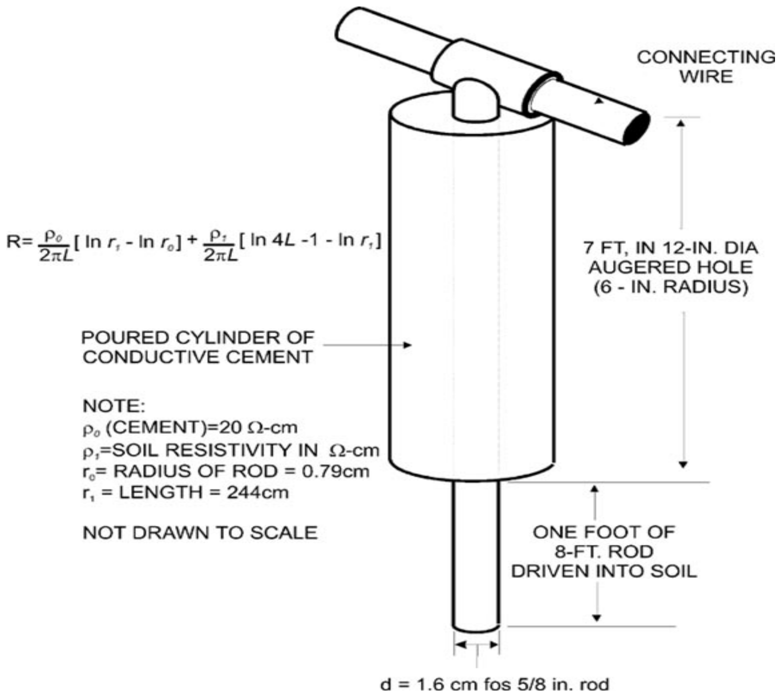
Concentric Shell
Overlap Decreases
Efficiency of
Ground Rod
Resistance

Ground Rod Spacing



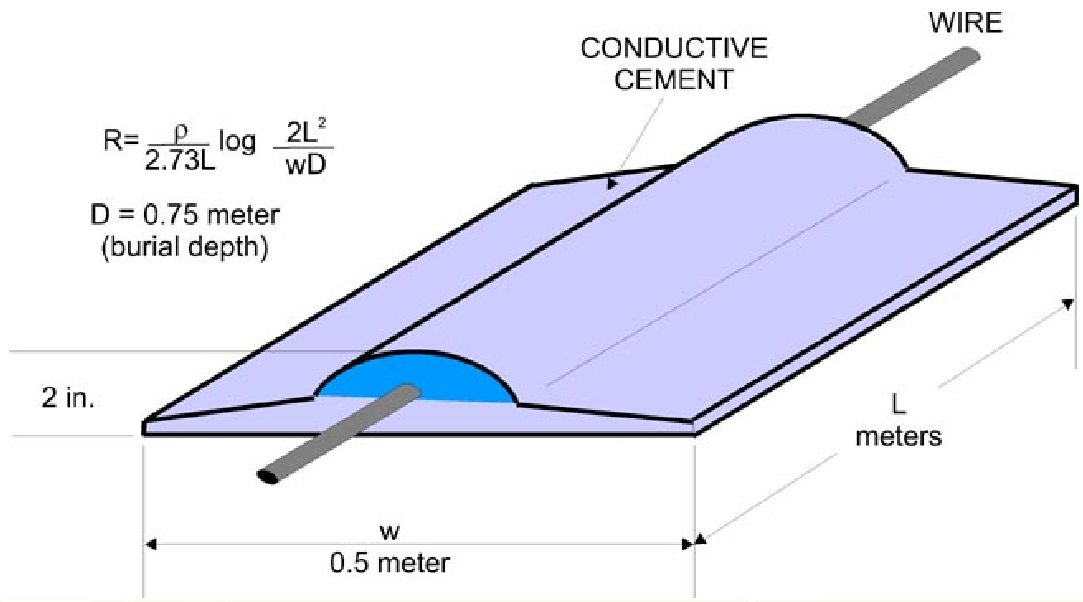
Ground Rod is Embedded in Conductive Concrete

Takes advantage of the fact 50% of the earth resistance is within 6” of the rod. (credit to gpr-expert.com)



Conductive Cement

Effectively Enlarges the Contact with the Earth of the wire.

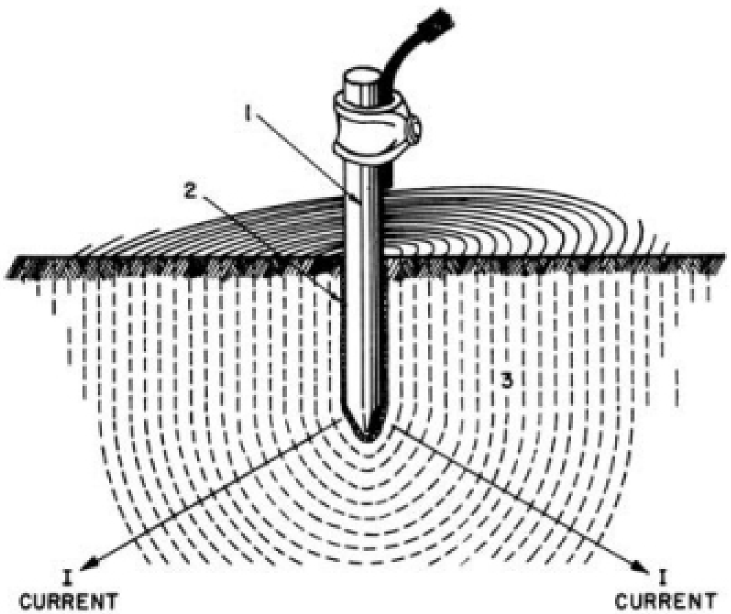


Annual Ground Testing

- The technician that completes ground testing must have been trained by the factory or their approved training representative.
- The technician MUST be certified to complete the testing.
- It is recommended the technician have a minimum of 5-years experience.
- A detailed written report with photo's must be provided.
- Anything less is NOT reliable.

If you needed brain surgery, would you go to the local supermarket butcher? NOT using a highly qualified professional for your ground testing will yield the same results. Operation was a success, but the patient died.

I=E/R



Ohms Law

- Current is “I”
- Voltage is “E”
- Resistance is “R”
- I = E/R
- 0 = 1,000,000,000,000,000,000,000,000/ 0
- So you can have all the voltage you can imagine and if the “R” is “0” you have “0” damage. Current, the “I” causes damage.

Real World

- 1 Trillion Volts with a 1000 Ohm Ground = One Billion Amps.
- 1 Trillion Volts with a 5 Ohm Ground = 200 Billion Amps.
- Do the math if that is your ground rod resistance. Where does the 199 Billion amps go with the 1000 Ohm Ground? Try your electrical system!!!
- Prove my math wrong! Go ahead, take your time!

Ground Rod Resistance & Rod Size

Increasing the diameter of the ground rod does little to reduce the resistance to earth.

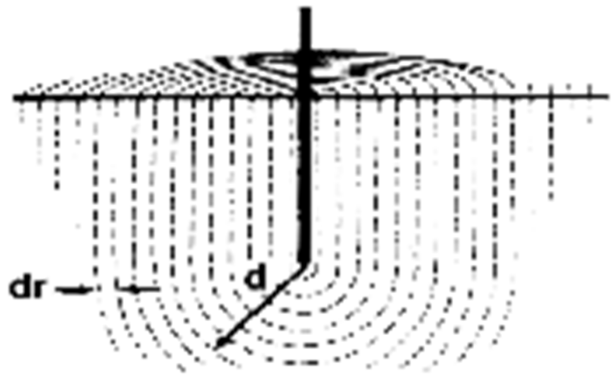
Doubling the diameter reduces the resistance by less than 10%.

The only logical reason for a larger rod is the soil conditions (aka: Conditions require a ¾" or larger ground rod so the rod can be installed. It is not unusual to have to "drill rock" or other hard earth structure.

Single 10' Ground Rod

The resistance of this ground rod on a home and is lower than the ground of many critical facilities.

The Formula for Rod Length & Diameter



$$\frac{dR}{d} = \rho \frac{d}{dr}\left[\frac{l}{A}\right]$$

l = length
A = diameter

Which Ground Tester(s) Will Meet Your Needs & Testing Requirements?

- Ground testers come is two version. Stake type testers & clamp-on ground testers.
- Before you decide which style will meet your needs understand the benefits & limitations of each tool.
- In order to understand your needs you should have the knowledge of both tools and how to properly use and operate them.
- Take the training to use both types. Understand how to use both testers properly.
- Then you are ready to make a decision of what you need and make the investment in Fall-of-Potential Ground Rod Tester(s).   NOT Before then.

After Training on Both Types: The Fall-of-Potential Checklist

- Identify and locate any and all conductive elements (wires, pipes, cables, metal fences, tree roots, etc.) or any condition or conductive element in the soil that would impact the test results.
- To insure accuracy of a “stake type” fall of potential test it is necessary to verify the test results. This is done by a completion of two additional tests that are at: 90°, 180° or at 270° from the initial test. This confirms there is no conductive elements.

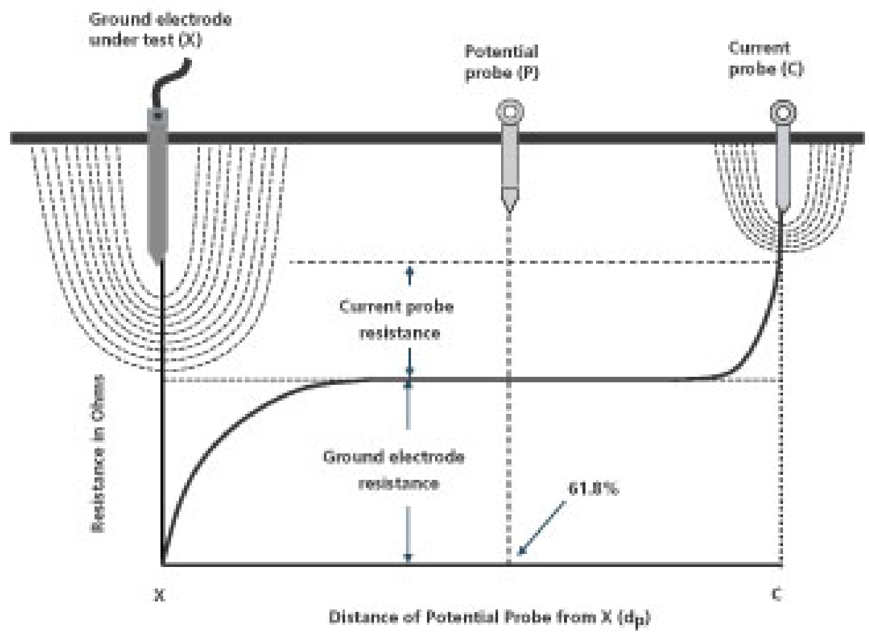
After Training on Both Types: The Fall-of-Potential Checklist

- Do you have access to enough area or real estate to allow completion of two additional tests? If you cannot do both you don't have a reliable initial test.
- Verify the soil is un-disturbed and virgin soil, no fill has been added.

The Fall-of-Potential Checklist

- If necessary use ground penetrating radar to be sure the soil in the area can be used for testing.
- Verify the moisture content of the soil does not exceed the worst case lack of seasonal moisture. Test soil moisture “volumetric water content in soil” if it exceed the “norm” then the test is invalid in “moist” soil conditions.
- Test and record; the soil temperature, moisture content, PH, salt content on the testing report form.
- Confirm if any ground enhancement material that was used when the grounding was installed. If anything other than Bentonite or conductive concrete the testing will not be accurate.

Ground Rod Fall of Potential Testing & Concentric Shells of Earth



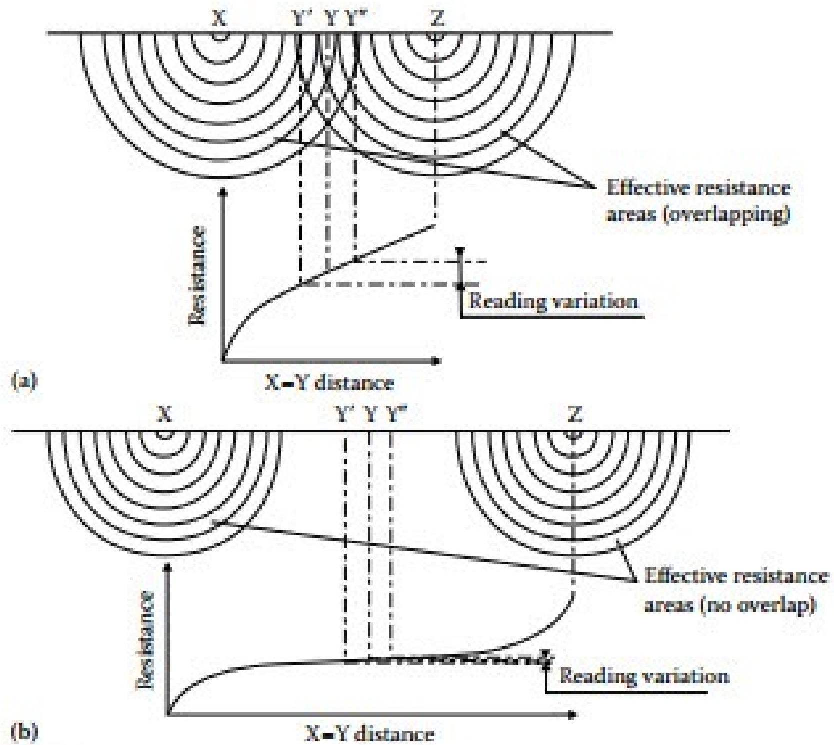


FIGURE 11.17
Effective resistance areas (cylinders of earth) (a) overlapping and (b) not overlapping.

Fall-of-Potential Ground Testing

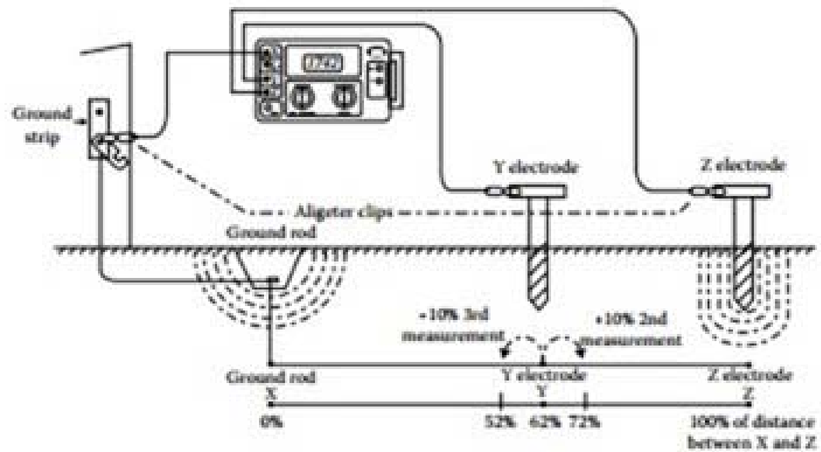


FIGURE 11.18
Fall-of-potential method showing potential rod location at 62% distance from the electrode under test.

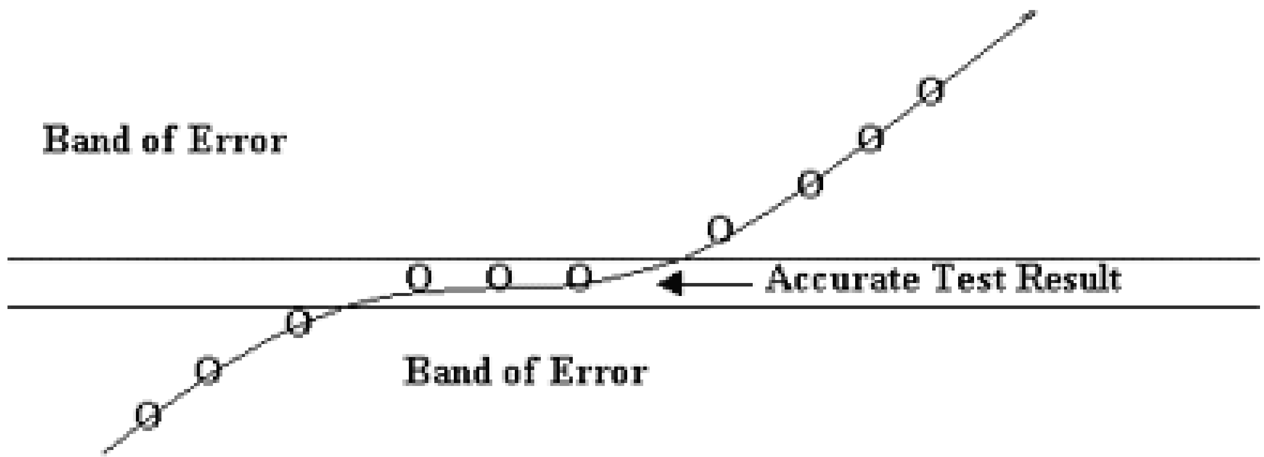
Distance in Feet to the Auxiliary Electrodes Using the 62% Method**

Depth Driven	Distance to “Y”	Distance to “Z”
6	45	72
8	50	80
10	55	88
12	60	96
18	71	115
20	74	120
30	86	140

** The above is for “average” conductive soil with a 5% moisture content. The distances will triple if the soil has 10% moisture content and increase 12 times if the soil has 20% moisture content.

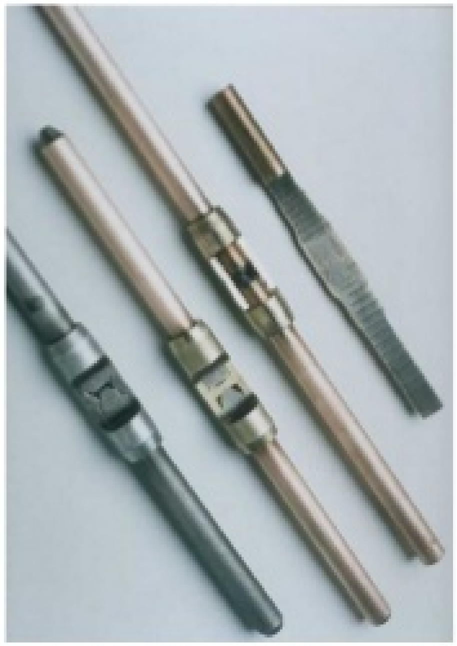
Multiple Electrode System		
Max Grid Distance	Distance toY	Distance to Z
6 ft	78 ft	125 ft
8 ft	87 ft	140 ft
10 ft	100 ft	160 ft
12 ft	105 ft	170 ft
14 ft	118 ft	190 ft
16 ft	124 ft	200 ft
18 ft	130 ft	210 ft
20 ft	136 ft	220 ft
30 ft	161 ft	260 ft
40 ft	186 ft	300 ft
50 ft	211ft	340 ft
60 ft	230 ft	370 ft
80 ft	273 ft	440 ft
100 ft	310 ft	500 ft
120 ft	341 ft	550 ft
140 ft	372 ft	600 ft
160 ft	390 ft	630 ft
180 ft	434 ft	700 ft
200 ft	453 ft	730 ft

Band of Error
Fall-of-Potential



Lowering Ground Resistance

- Add More Rods
- Deep Driven Rods
  - Threaded Couplings
  - Compression Couplings
  - Exothermic Ground Rod Splice



Bentonite

- Bentonite is a Ground Improvement Material.
- Bentonite is not a Ground Enhancement Material. (There is a difference.)
- GIM is:
  - Naturally Inert.
  - Compactable & soil compacting.
  - Have low and stable resistivity.
  - Able to maintain low resistance with minimal fluctuations.
  - Does not leach with time.
  - Economically viable.

Sodium Bentonite

- Sodium Bentonite has superior swelling capacity when compared to Calcium Bentonite.
- Sodium Bentonite has extremely low hydraulic conductivity to water.
- Sodium Bentonite has a “valence” of +1. (Calcium Bentonite +2)
- Sodium Bentonite can absorb up to 5-times it weight in water.
- Sodium Bentonite can swell up to 13-times it dry volume.
- Sodium Bentonite (30%) can be mixed with concrete to lower the resistance of a Ufer ground.

Calcium Bentonite

- Calcium Bentonite has a lower swelling capacity when compared to Sodium Bentonite (10-20%).
- Calcium Bentonite has 15% higher hydraulic conductivity to water than Sodium Bentonite.
- Calcium Bentonite has a “valence” of +2)
- Calcium Bentonite can absorb less than 5-times it weight in water.
- Calcium Bentonite can swell up to 11-times it dry volume.
- Calcium Bentonite is superior to Sodium Bentonite in corrosive soil conditions.
- Calcium Bentonite can be mixed with concrete to lower the resistance of a Ufer ground.

Augured Hole with Rod & Bentonite

- A hole is augured into the soil.
- The hole is filled with Bentonite.
- A ground rod is installed into the center of the augured hole and the conductor is exothermically wielded to the rod.
- Water is added, the Bentonite swells and fills all the voids.

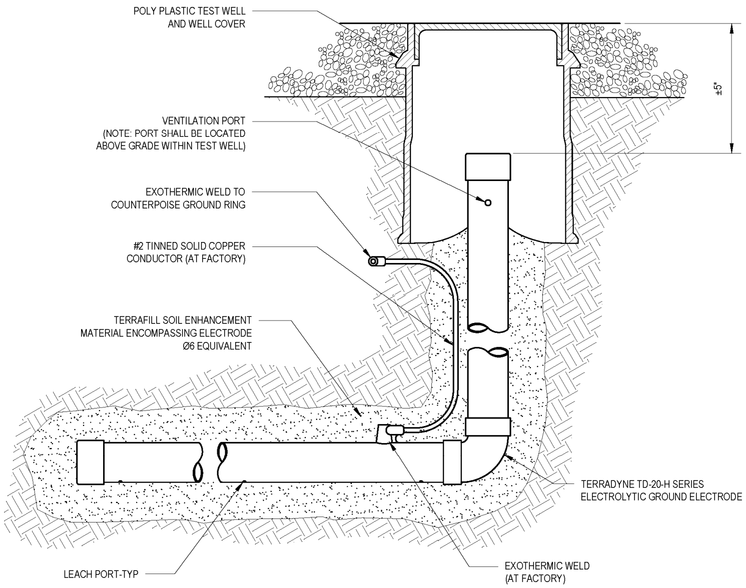
Benefits of Bentonite

- The formation of an electrolyte when Bentonite is ionized by water & this layer around the grounding electrode serves as a pathway for dispersion of lightning charges.
- Increased current dispersion of lightning when compared to installations lacking Bentonite.
- Bentonite is the only Ground Improvement Material approved and recommended by the Copper Industry. (re: copper.org)

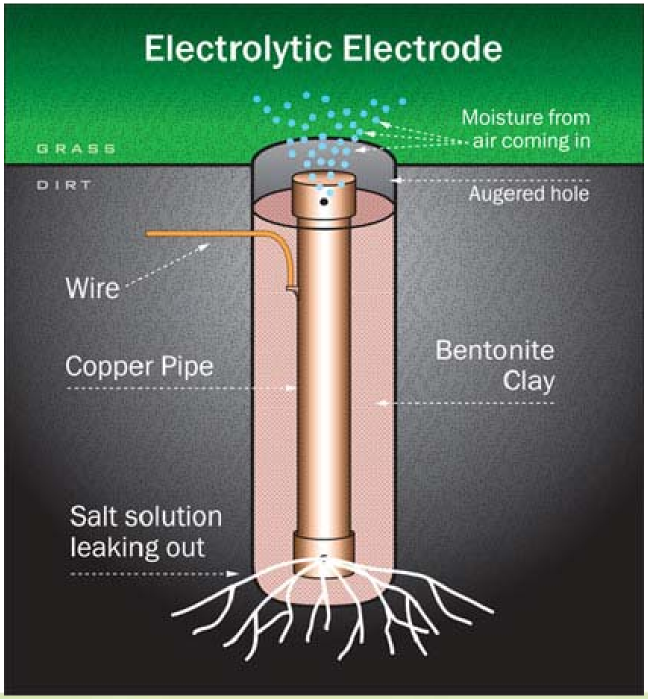
Chemical Ground Rods

- Sustainable grounding is installation to a high standard and maintenance.
- You can use disposable technology such as chemical ground rods if you are aware of the limitations and recognize what must be done to use them.
- If you make the choice to use "chemical ground rods, ground enhancement material or any other "alternative" option.
- You must have a testing plan in place and a program to make sure what you have is working.
- Lacking that, you should not use any technology including chemical ground rods, GEM, etc.

Chemical Ground Rods



A Chemical Ground Rod in Action



A copper pipe full of salt will last how long?

Chemical Electrodes

Salt-filled pipe after 7 years

What is a Chemical Ground Rod?

- Simple version: Salt in a Copper pipe with holes drilled into it that is installed in the earth where the moisture will cause the salt to leach into the soil.
- The truth, it is a very viable grounding solution “IF” you understand what it is, what is needed to maintain it (AKA Replace it in time).
- The bottom line is what works in one environment may or may not work in another.
- Use what is most cost effective, sustainable and reasonable in cost for your application.

Ground Enhancement Material

- GEM is marketed as the best way to lower the resistance in difficult grounding conditions.
- GEM is a by-product of a manufacturing process, may not be subject to a quality control process or procedure that would insure it is not corrosive.
- If you wish to ignore the issue with corrosion, just use the “cheap version” of GEM, Rock Salt or fertilizer of some type.
- Carbon “enhanced” or based products are know to be corrosive and not recommended.

Grounding & Bonding for Lightning

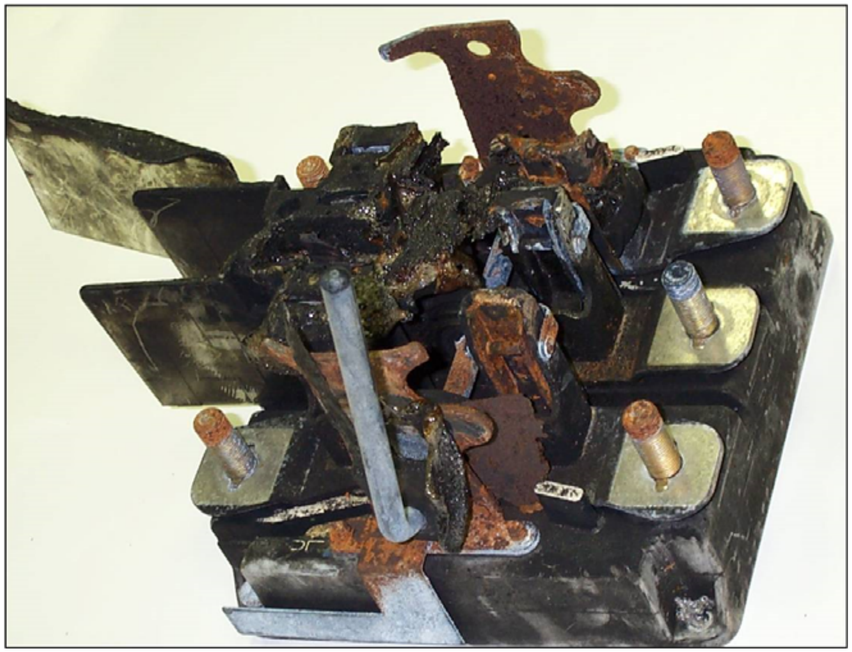
- Lightning strikes most often occur to outside wiring.
- Grounding & bonding the electrical system will assist the flow of lightning into the earth.
- The electrical system is a calibrated spark gap.
- Over voltages will arc to a lower potential.
- If the lower potential is capable of handling the current that will develop you divert what would otherwise be trouble.
- Low resistance & impedance ground paths facilitate that to happen…. Doubt that statement? See the next slide.

SunCoast Federal Credit Union

Data Center Inside

Lightning Hit Service Drop

SunCoast Credit Union's Data Center
480Y/400-Amp Meter Base Disconnect



Lightning vs. The Meter Base

- The meter base took the brunt of the lightning damage.
- The meter base housing was “bonded” to the ground system.
- The impedance of the path to the switchgear higher than the path to the ground rod system.
- Nothing inside the data center was damaged.
- The ground resistance of the service: 4.3 Ohms (Fall-of-Potential) tested.

Lightning vs. The Meter Base

- The most robust was a SPD was rated at 120 kA per mode.
- The lightning energy imposed on the electrical service went to earth ground on the conductor that bonded the meter base and other metal cases of the electrical system to the ground rod system.
- The only damage was to the "outside" elements of the electrical service. (Meter base, gutter work, pole, transformer, utility wires, etc.)

7 Levels of SPD's

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Bonding to the Highest Level!

- Bonding should be designed and installed to a level that will provide a very low impedance path to the facilities electrical system earth ground.
- Bonding must be robust, use stranded cables and have a “flow” to the earth ground.
- Bonding must not have hard bends.
- Bonding must be installed with the capability to channel the flow of lightning energy to earth ground with no equipment damage.
- Bonding must be logical…. It is not just a green wire connected to something. NO cross contamination.

Bonding Installation

- Electrical service entrance ground bonds should be to a common bonding bar that is both robust and provides a low impedance path to earth ground.
- All bonds should be exothermic wields or double lugs and made using conductive grease and robust hardware. (lock washers, double nuts, etc.)
- This bonding bar should be the common point of all bonds: Neutral, plumbing, water, gas pipe, lighting protection, Ufer, building steel, all metallic elements of the electrical panels, conduit, etc.

Bonding Installation

- Allow for the flow of lightning energy imposed on any and all elements of the electrical system.
- Bonding must be "serviced", verified, checked, etc.

Improve Bonding Installations

- Bring footer rebar out of the footer in an 18" radius bend to 1' above the floor adjacent to the service entrance.
- A minimum of two 20' sections of rebar should be 1' apart. (more is better)
- The Ufer bonds to be exothermic wields with 4/0 bare copper.
- Connect the 4/0 copper bonding bar with high compression double lugs (or exothermic wields).

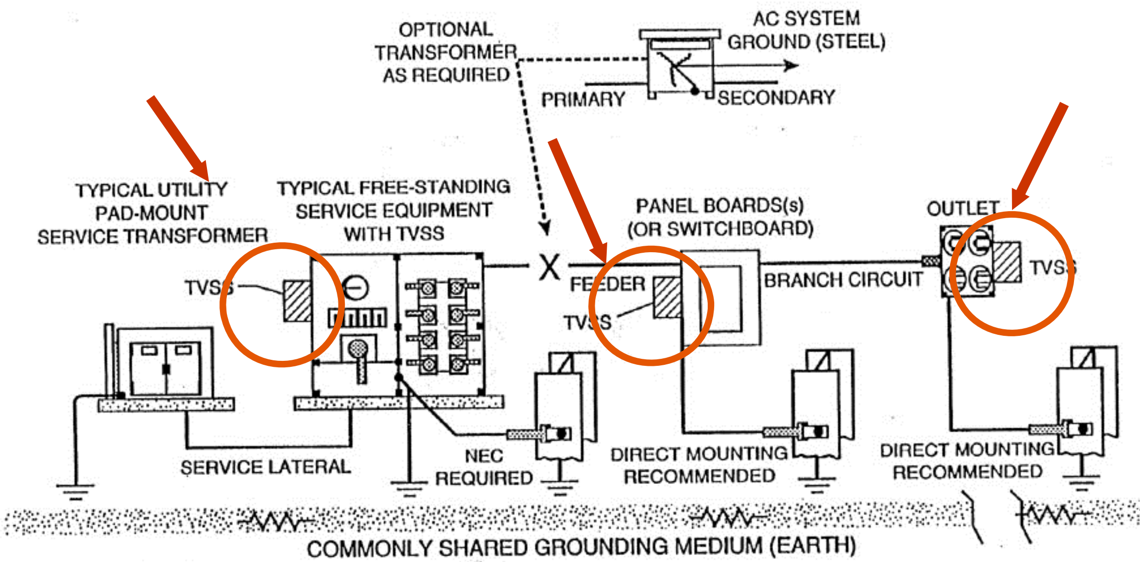
Improve Bonding Installations

- Connect the X/O bond to the bonding bar.
- Connect all outside services (CATV & Telecom) bonds with home runs to the bonding bar.
- Bond: plumbing, water, gas pipe, lighting protection, building steel, standpipe(s) or fire sprinkler piping, static bonds (computer room), etc. to this bonding bar.
- Make all bonds to flow to the earth; ground rod system (plate, mesh, etc.) and the Ufer bond. (Flow to earth is down & out)

SPD (TVSS) Placement

Use Surge Suppressors in a “system" approach.

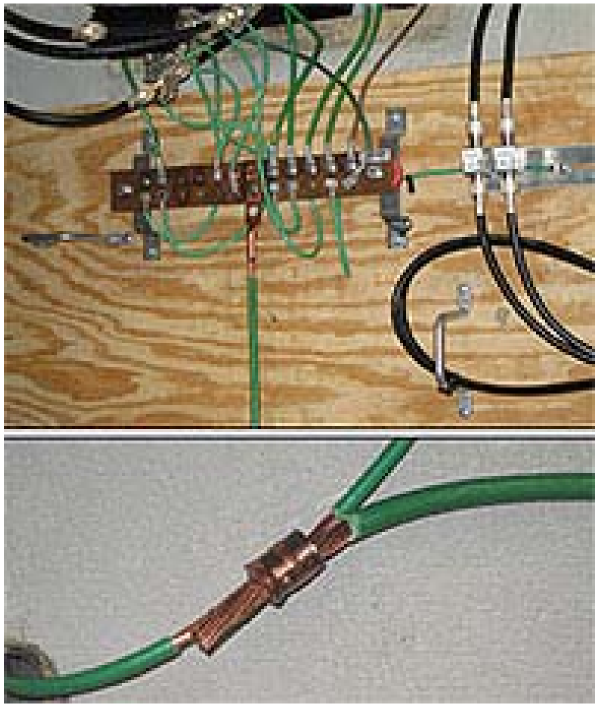
C B A



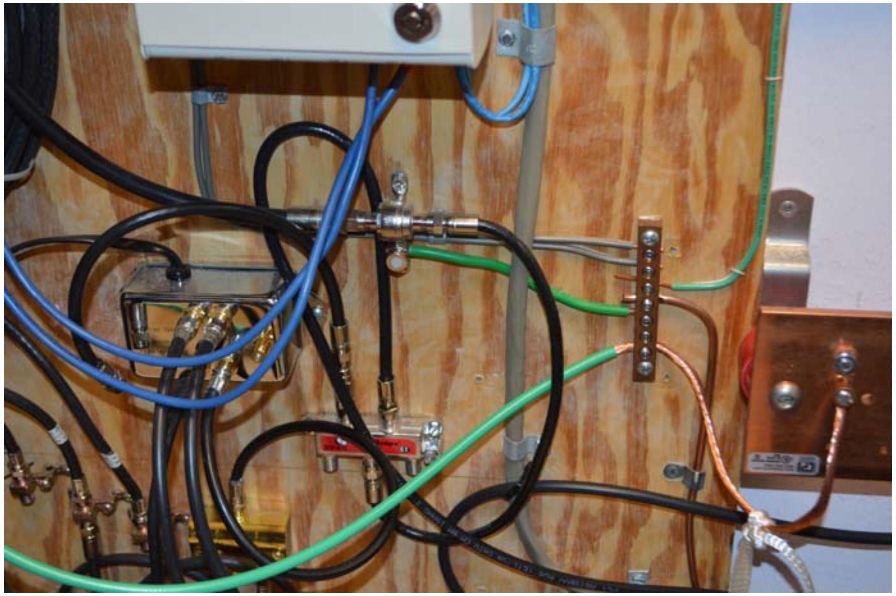
Ground Bonding

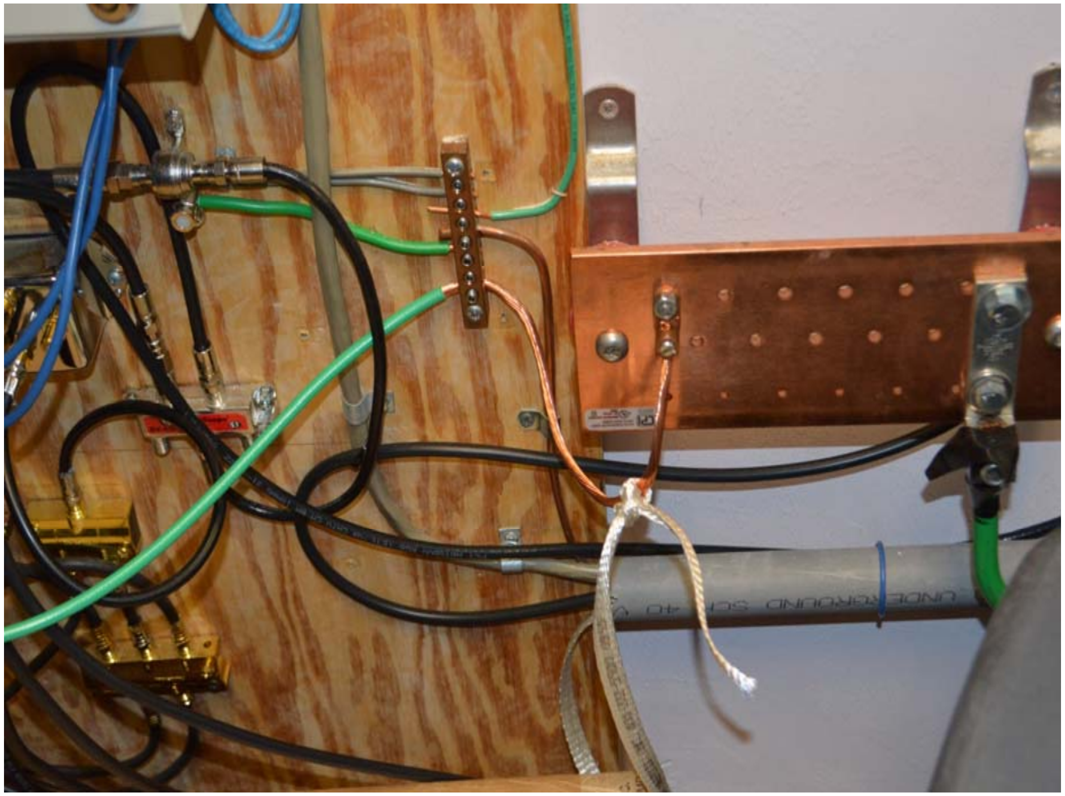
The next series of slides will give you answers to some of the questions you have on the why some of your equipment may have been damaged by lightning.

What is Wrong in the Photo?



What is Wrong in this Picture?





Can you find more?

Ground loops between devices.
Coax ground bonds…. 11 are missing.
Sweep bends are missing.
Most wire is solid, not stranded.
Single lug bonds, no surface area.
Telecom & coax bonds are mixed.
Grounding and no conductive grease.
Daisy chain method of ground bonding.
How many wires don't go to the ground bonding bar???
Ground bonds to not "flow" to the grounding system…change directions.
No labels to know which ground bonding wire goes to what.
Critical equipment ground bonds mixed with coax and Telcom bonds.
(The above is a formula for lightning to damage equipment!!!!!)

Remember the two types of "Grounding"

- **System Grounding**

- **Equipment grounding (bonding)**

Causes of PQ Problems

INTERNAL:

- Poor electrical system design and layout
- Lack of or inadequate electrical system maintenance
- Shared mixed load distribution panels
- Too many outlets per circuit
- Mixed load use on circuits
- Inadequate and shared neutrals
- Poor, inadequate and shared grounding
- Intermittent connections
- Standard equipment and wiring

Transformers

- NEC requires transformers ground bonds be made to building steel and pipe systems.
- NEC requires the steel or pipe system be continuous and contiguous.
- Networked systems ground reference will be to the same “pipe” or “steel”.
- The only exception is when the ground bonding path is not continuous and contiguous.

Lightning Protection Systems

- The codes and standards for lightning protection systems allow building steel to be used as the “down conductor”.
- Simply put the steel framework of a building becomes the conductor for lightning.
- What happens to the metal conduit that is in contact with the building steel?
- What impact will this have on your systems?

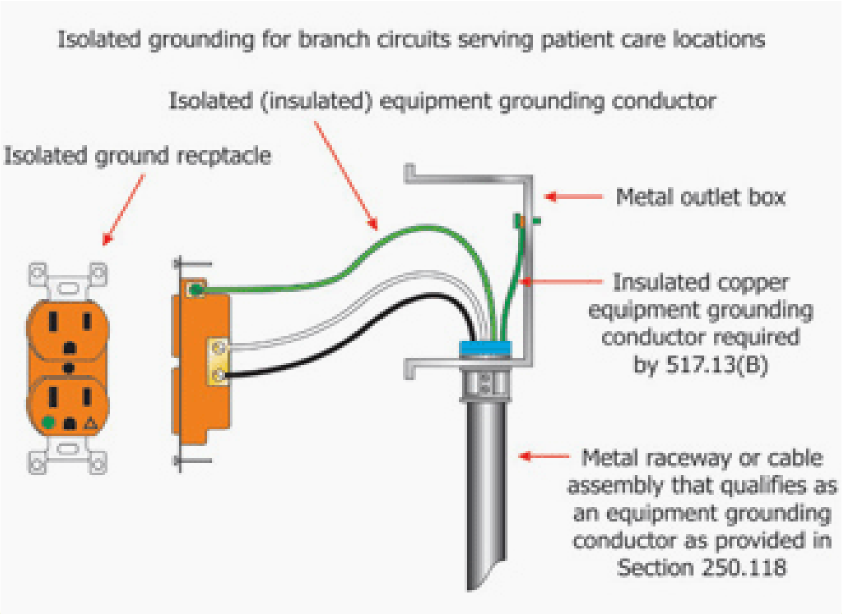
Improper Bonding

- The buildings metal studs are a ground reference path for the metal equipment cabinet of the system to attach to them.
- The case ground wire connects the control board to the ground reference of the metal studs.
- The electrical ground and the metal studs become a ground loop.
- Lightning strikes the building or nearby the building and electrical energy flows between the grounds.
- ZAAAAAP! System(s) down!

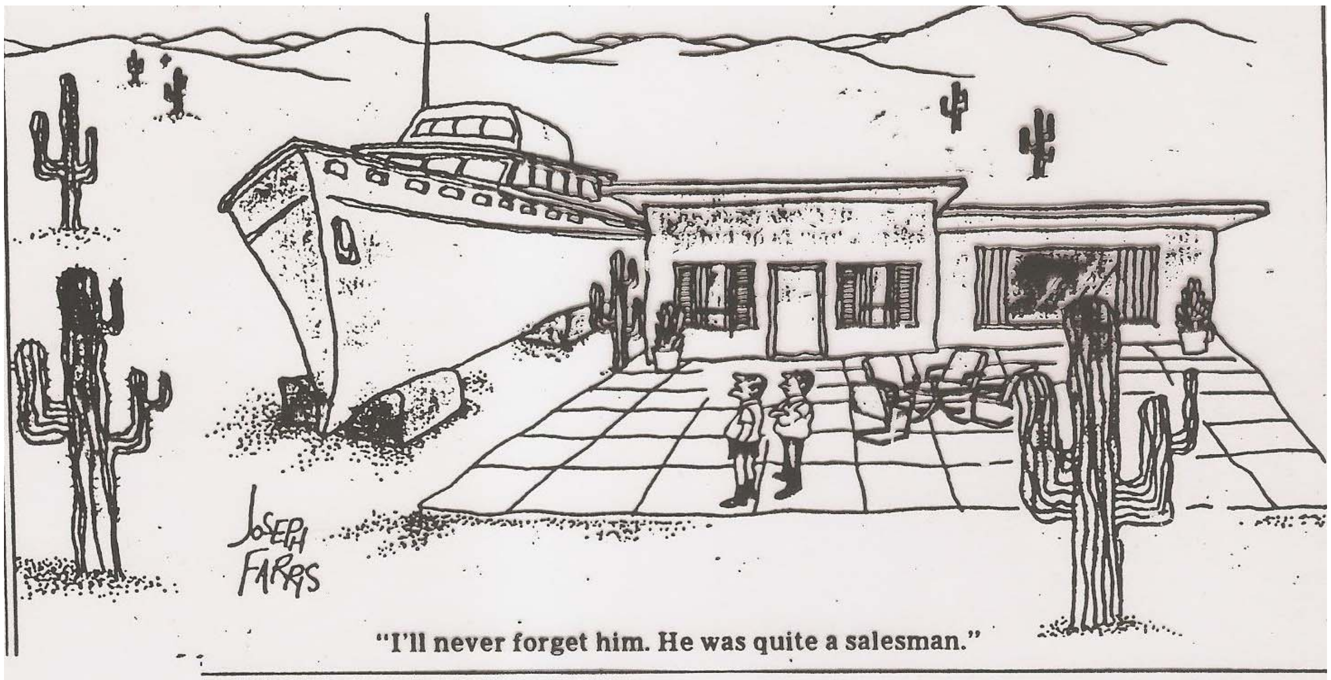
How Will IG Circuits Help?

- Case ground is also the ground reference of your installed systems.
- In addition to protecting the wire conduit is also a shield from EMI & RFI.
- Building steel, conduit and all other metal objects in a facility can become charged and become a current path during a lightning strike.
- IG ground along with the phase and neutral conductors are protected from this induced energy by the conduit, gutter work and metal housing of the electrical system. The case ground wire is not bonded to the IG wire except at the X/O (neutral / ground) bonding point.

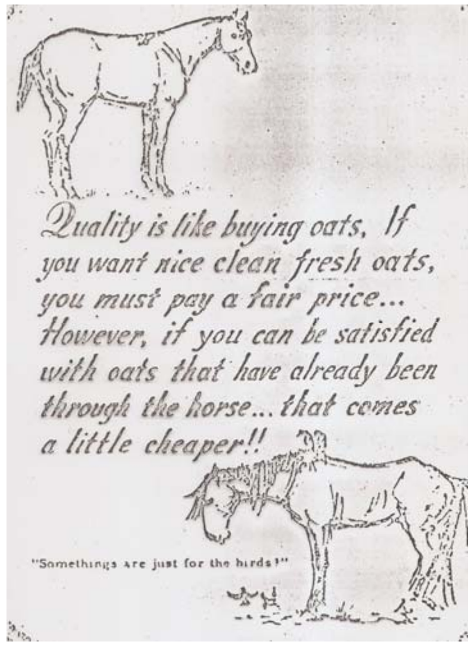
- As permitted by **NEC 250.146(D)** and **NEC 408.40** Exception, consider installing an isolated grounding system to provide a clean signal reference for the proper operation of sensitive electronic equipment.



Surge Protection Devices (SPD)



Quality = Performance



_AC Power Surge Protection Devices

- SPD are classified by UL based upon how they are installed and their installation.
- Type "1" – Hardwired ahead of the main means of disconnect.
- Type "2" – Hardwired after the main means of disconnect.
- Type "3" – Cord connected or direct plug in devices.
- Type "4" – Component Assemblies – One or more components that are listed as part of Type 5.
- Type "5" – Individual components such as MOVs.

What to Use Where

- Service Entrance – 100kA to 300kA.
- Primary Distribution – 100kA to 200kA.
- Distribution “outside loads” – 100kA to 200kA.
- Distribution panels – 50kA to 100kA.
- Sub Panels – 40kA to 50kA.
- Outside Loads – 40kA to 50kA series device.
- Critical Loads – 50kA series device.
- Point of use – Cord connected 10-20kA.

Rating SPD – What is Important

- NEMA LS-1 1992 Testing.
- Rated kA per mode rather than by phase.
- SPD Noise Filters are rated in dB.
- SPD manufacturer reputation for SPD.
- Expert application support.
- SPD manufacturers field support.
- SPD manufacturers warranty policy.

The SPD Layered or System Installation

- Ahead of the main means of disconnect.
- Automatic transfer switch both line & load.
- To protect the main
- To protect all distribution panels.
- To protect critical circuits.
- To protect circuits that exit the facility.
- To protect elevators.
- To protect point of use devices.

Installing Hardwired SPD What is Important

- Location of the SPD.
- Position of the SPD.
- Wire length between the SPD & connection.
- Wire type, stranded vs. solid wire.
- Wire installation – no sharp bends.
- Conductor twisting - lower wire impedance.
- Breaker or fuse ratings.
- Proper torque for all connections.
- Connections - *NO WIRE NUTS*!!
- Written inspection, testing and maintenance program.

General Wiring Practice

Surge Suppressors should be connected to a <u>full size</u> grounding conductor

Minimal Wire Length is Critical as is Proper Connection

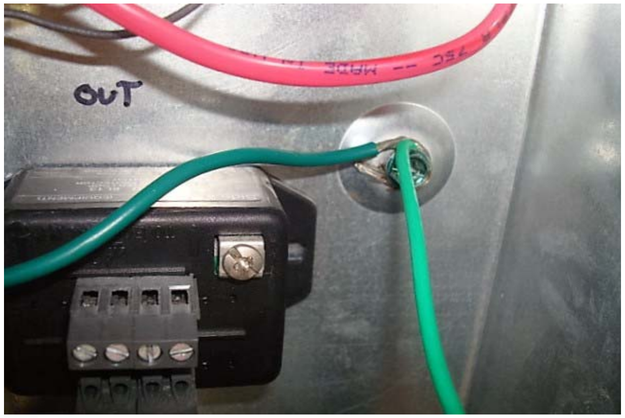
But NOT a Local Ground Rod!

Wire Length is DELAY!

Code Violation & More!

Only One Ground Reference

- Systems must only have one ground reference.
- NO passive grounds.
- You have to love the "out" marked on the can. It should say "incoming!!!!"
- Allow me to explain.

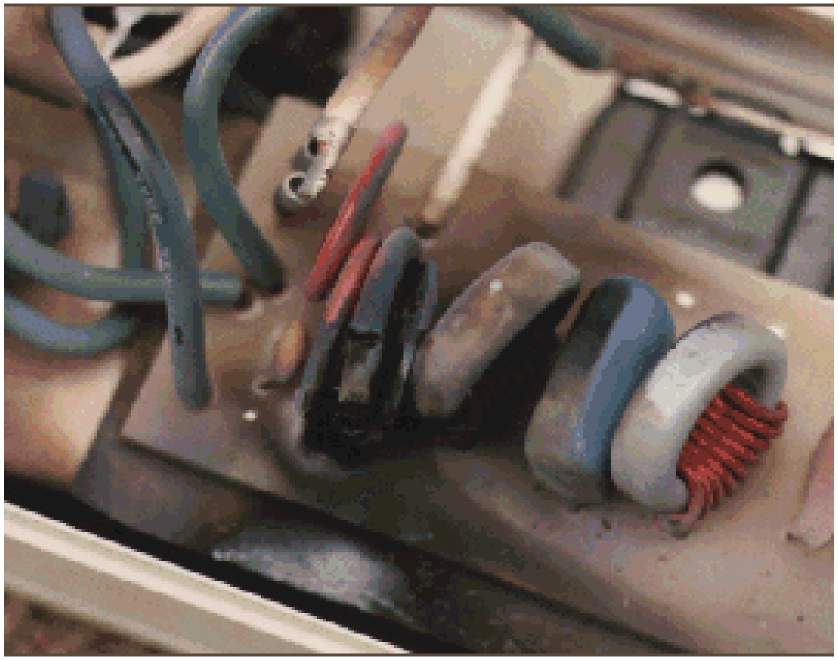


MOV Based SPD

- SPD “must” have a ground to be UL Listed.
- That is true of all “low voltage SPD”
- Low voltage defined as listed to UL-497.
- Some UL listed AC Power SPD do not have a ground connection. They are “Type 1” as their “drain” is neutral…. And there is no ground involved….Yes, Neutral is utility ground.
- Sorry, don’t intend to confuse you.

MOV

A Failed MOV



MOVs

- MOVs are bi-directional components.
- So if one is on a line (AC Power, System, etc.)

  it will be connected to another "reference".
- That reference could be neutral, ground, another line, etc.
- Simply put: A surge can come from any of those connections!!!! (Bi-directional)

SPD Inspection & Testing

- Most SPD lights only mean you have power.
- Industry people call SPD lights, “idiot lights”.
- Some SPD lights are diagnostic.
- Ask the company how their lights know there is a change in the status of the SPD.

SPD Testing

AC Power SPD & Facility Protection

- Proper “facility” protection is much more than the installation AC power SPD.
- Coordinate with other service providers: CATV, Telecom, etc.
- Be sure they have connected properly to the ground bonding system.
- Be sure they have also protected their services.

AC Power Source

Is the electrical system serviced annually?

Is the power source stable enough for proper equipment operation?

Is a power backup system needed?

Any disruptive circuits on your power panel?

Any outside circuits powered by your panel?

Is the panel surge protected properly?

Are the upstream panels surge protected?

Low Voltage SPD Installations

- All low voltage SPD should have a common ground reference or they must be isolated from any ground reference.
- Wire length as well as impedance issues make a “common or single ground reference, difficult at best.
- The option is low voltage SPD that does not require a ground reference.
- That option will not be MOV based.

Access – Video – Fire – Security - Environmental

- To the customer, all are critical systems.
- All should have the highest level of protection possible.
- Protection starts with a proper installation.
- The installation should be flexible, as technology changes so should the system.
- Technology must be proper & sustainable for the application and installation.
- The system must be installed so it can be serviced.

Systems Installations

- Installation Conditions
- System Power Options
- System Installation Options.
- System Communication Options.
- Connections to communication utilities.
- Inter system connections.

Installation Conditions

- Geographic Considerations.
- Building Construction.
- System Topology.
- Power distribution system configuration.
- Control cabinet or equipment location.
- Interface considerations.
- Customer specific requirements.

System Installation Options

- Geographic conditions should be considered when connectivity of devices within a system is determined.
- Distance of the connection must be considered.
- Device location (inside or outside) the facility will impact the connectivity option considerations.
- System expansion plans will impact the initial system installation.

System Power Options

- AC Power Source, should be a dedicated, isolated ground circuit from a clean power panel if a 120VAC system.
- What do you do if it is not?
- Is a back up power source required or needed.
- Is there a generator involved.
- Is the system smart and does it communicate?
- Is the system network based.

System Topology - Communication

- System component or device communications.
- Inter system communications.
- Connections to the outside world.
- Shielded vs. Unshielded wire.
- RF Communications.
- Fiber Optics.
- Cellular
- Phone lines

Connection to Communication Utilities

- Phone lines, what you need to know to avoid the worst possible problems they can cause.
- Cellular Communications, good, bad and ugly.
- RF to a central station. Is the option available locally. What is involved.
- Networked devices, options and considerations.
- WiFi – the good, the bad & the ugly.

Inter System Connections

- Integration is the watchword in the security industry.
- Network applications continue to be introduced and in the long term it will be how security is controlled. It will also be the notification method of choice once the “flaws” are worked out.
- The term you need to be aware of is “the bleeding” edge of technology

Access Control

- Controllers & Dialers
- Keypads & card readers
- Driveway loops
- Gate motors.
- Telecom Lines

Challenges in Access Control

- Devices are installed on the perimeter and outside of facilities.
- RFID systems are high cost and require significant facility and equipment modifications.
- Long wire runs are very often the norm.
- Standards are lacking and most have little or no line security.
- Networked systems will soon be the norm.
- Networked systems have security issues.

Access Control - Check List

- Single power source. (AKA, single ground)
- Shielded wire for all system wiring.
- Device isolation (mag lock / metal door frame)
- Encrypted “RF” where wires should not go.
- Local power = RF, Fiber or WiFi.

Fire & Security Alarms

- Plan the layout – consider wire run options.
- Networks are nice, however long wire runs increase exposure to lightning damage.
- Avoid problems – use shielded wire.
- Understand how to bond the shield.
- Avoid ground loops – know your connection.
- Isolate if you are not 100% sure.
- Select the right technology.

Video Security Systems

- Stand Alone Systems
- Networked Systems
- RF Systems
- WiFi Systems
- Hybrid Systems
- Camera Options
- Connectivity Options

Camera Options

- Coax
- Twisted Pair Video
- POE Mode A
- POE Mode B
- Fiber Optics
- RF Transmission
- WiFi

Coax Systems

- With RG-59U - 800 feet coax limit.
- With RG-6U - 1,100 feet coax limit.
- With RG-11U – 1,600 feet coax limit.

Twisted Pair Video

- Passive systems to about 1000 feet.
- Combination to about 1500 feet.
- Active systems to about 3000 feet.
- The low cost option if “wired” is required.
- The key is the UTP baluns.
- Shielded wire used for TPV must have low parasitic capacitance, below 20pF per foot.

POE Mode A & Mode B

Pins at switch	T568A color	T568B color	10/100 mode B, DC on spares		10/100 mode A, mixed DC & data		1000 (1 gigabit) mode B, DC & bi-data		1000 (1 gigabit) mode A, DC & bi-data	
Pin 1	White/green stripe	White/orange stripe	Rx +		Rx +	DC +	TxRx A +		TxRx A +	DC +
Pin 2	Green solid	Orange solid	Rx −		Rx −	DC +	TxRx A −		TxRx A −	DC +
Pin 3	White/orange stripe	White/green stripe	Tx +		Tx +	DC −	TxRx B +		TxRx B +	DC −
Pin 4	Blue solid	Blue solid		DC +	Unused		TxRx C +	DC +	TxRx C +	
Pin 5	White/blue stripe	White/blue stripe		DC +	Unused		TxRx C −	DC +	TxRx C −	
Pin 6	Orange solid	Green solid	Tx −		Tx −	DC −	TxRx B −		TxRx B −	DC −
Pin 7	White/brown stripe	White/brown stripe		DC −	Unused		TxRx D +	DC −	TxRx D +	
Pin 8	Brown solid	Brown solid		DC −	Unused		TxRx D −	DC −	TxRx D −	

POE Mode A & B

- POE & lightning prone environments.
- Cable limitations.
- Shielded cable.
- How to connect shielded cable.
- Powered splitters.
- Wireless access points.
- Wired Limits – with passive baluns 3,000 feet.
- Wired Limits – with active baluns 8,000 feet.

Fiber Optics

Down side:

- Not always cost effective.

Upside

- Very secure, frequency & type of signal
- Multiplexing
- High Resolution
- Distance is not an issue.

RF Transmission

- Low cost compared to wired systems
- Significant distances, 3 miles or more
- 2.5GHz can transmit up to 40 miles
- High data transfer rates 150Mbps+
- Security issues, jamming.
- System limitations.

WiFi

- Advantages: low cost, simple installation & mobility.
- Primary disadvantage: low security.
- Unsecured unless encryption devices added.
- Secured systems are still a hackers dream.
- Interference issues.
- Slower speeds / resolution issues.

Environmental Systems

- Environmental controls have the same issues as security systems.
- Environmental systems can be connected to other systems and networked.
- All connections to your system can be problematic. (the why)
- Before you connect know your options.
- If the connection will be problematic consider some “non” wired connection.

We Took a Hit, Now What?

- When you are ask to respond to a customer that has (they think) been struck by lightning or has suffered lightning damage what do you say or do?
- What do you do when you arrive?
- What questions do you ask?
- What do you look for?
- How best to find the “smoking gun”.

The First Steps After a "HIT"

- Talk to the client and ask questions.

- ❑ Why do they think they were "hit"?
- ❑ In their words what happened?
- ❑ Was equipment lost or damaged?
- ❑ Make a list of everything that was impacted.
- ❑ Now compare that to the electrical distribution system.
- ❑ Find out where in the electrical system was the majority of the damage or impact of the event.

The First Steps After a "HIT"

- Test the grounding!
- Inspect the lightning protection system (if installed).
- Inspect every SPD installed.
- Gather information and then call an expert in lightning damage mitigation.

Another Break

After the break, David Brender of
Copper Development Association Inc.

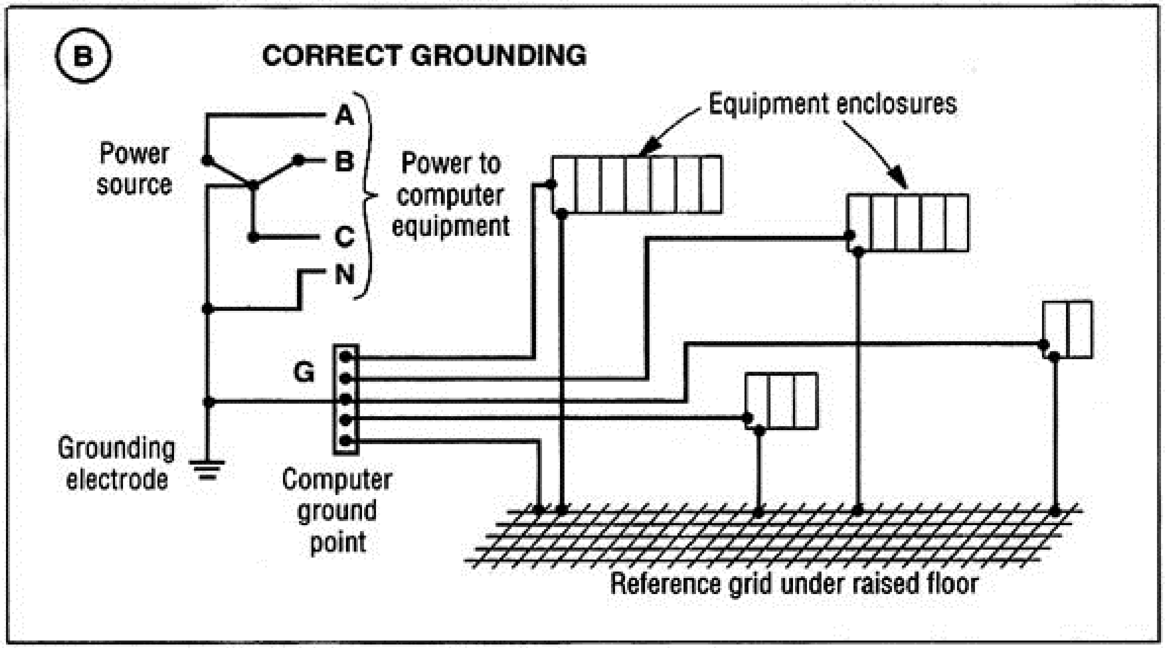
Part 3

David Brender
Copper Development Association Inc.

General Guidelines

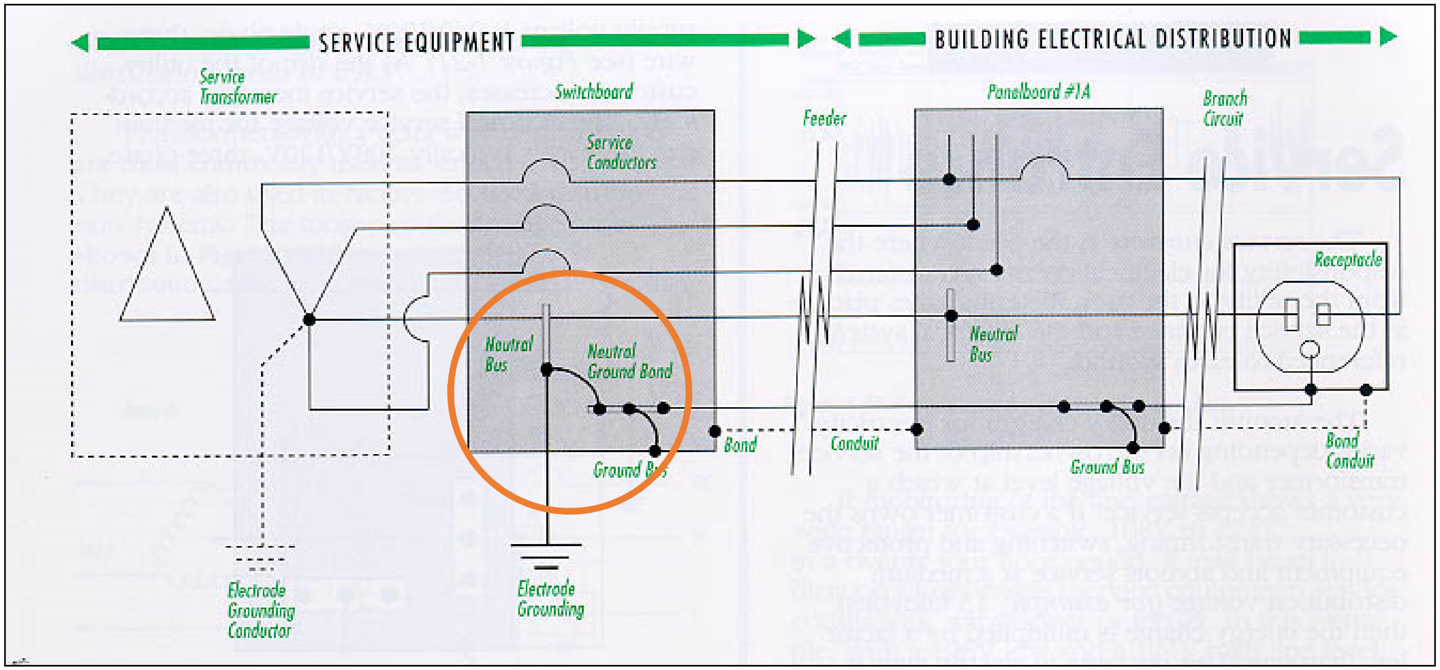
Circuitry
Voltage Drop
Full Size Conductors
General Principals

Example of “Star” Grounding



Source: EC&M Guide to Quality Power

Only N-G Bond is at Service (or separately-derived system)



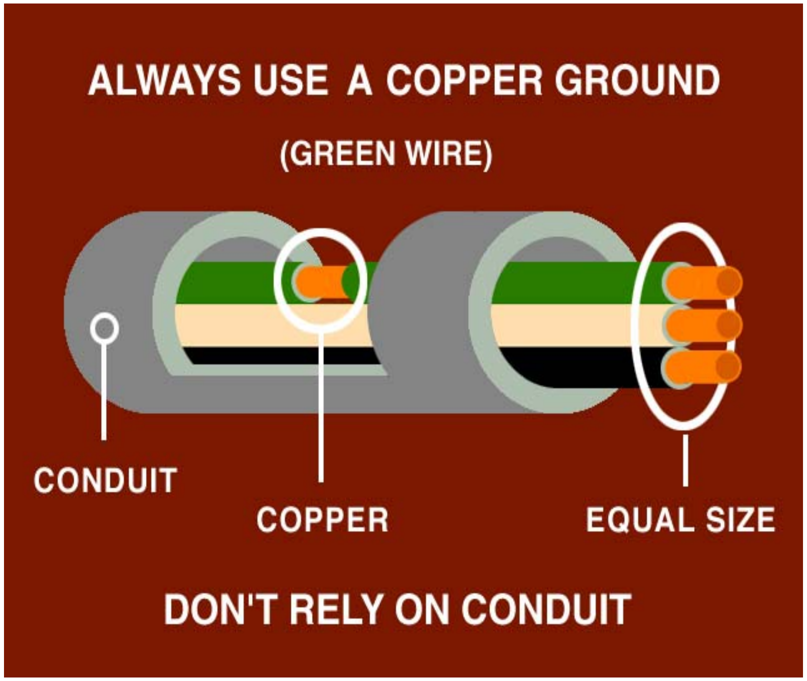
• Source: Dranetz Field Handbook

Series Installed Surge Suppressors for critical circuits!

Avoid Conduit as a Ground Path

Can you imagine a joint every 10 feet?

Full Size Equipment Grounding

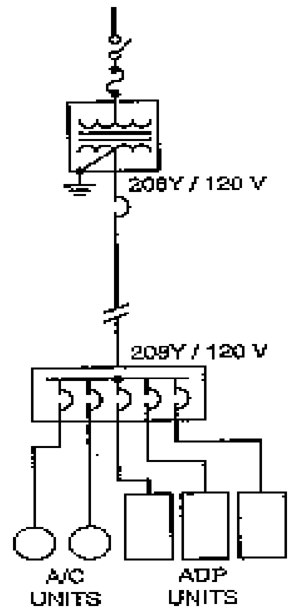


Will That Conductor "Fuse"?

General Wiring Practice

- **Sensitive loads should be separated:**
- **Separate branch circuits**
- **Separate panelboards**
- **Separate feeders**
- **Separate transformers**

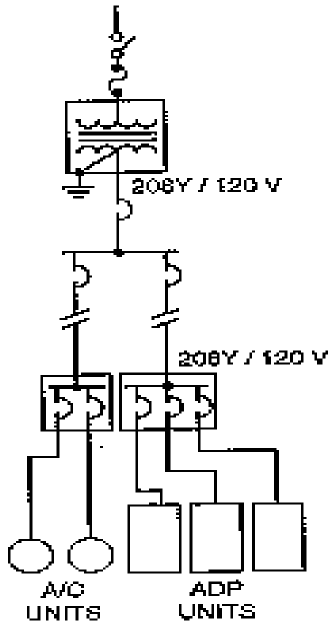
Typical Wiring Method



a) WORST!

source: IEEE
Emerald Book

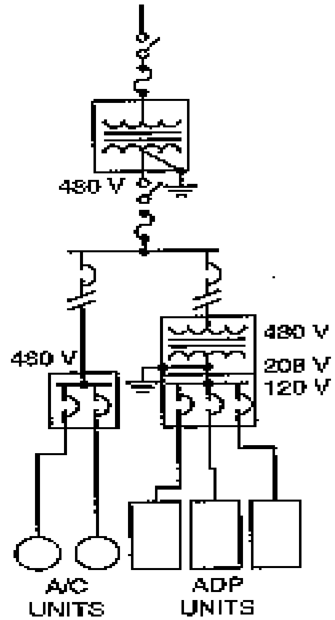
Slightly Better Wiring Method



b) FAIR!

source: IEEE
Emerald Book

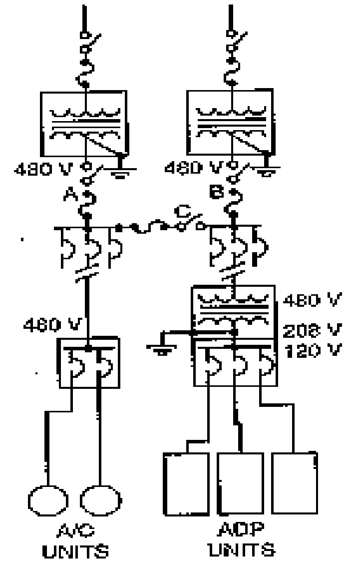
Much Better Wiring Method



c) BETTER!

source: IEEE
Emerald Book

Optimal Wiring Method



d) BEST!

source: IEEE

Emerald Book

Limit Voltage Drop

- Code alludes to a 5% combined limit (feeder plus branch)
- If utility is allowed a 4% swing, plus 5% on the circuit, already up to 9%
- 3% or less recommended

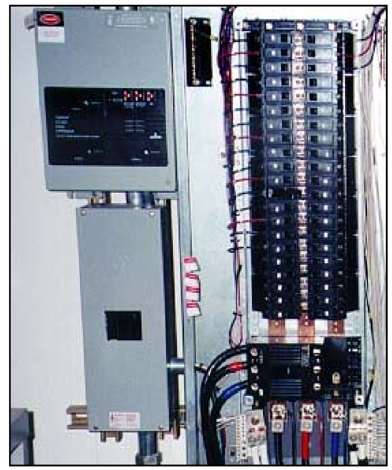
How to Limit Voltage Drop

- Limit the number of outlets per circuit
- 3-6 max. per 20 amp. branch circuit
- Prevent interaction among loads
- Exceed minimum size for conductors
  - Use #10 where #12 will do
  - MIT never exceeds 6 outlets
- Side benefit, voltage drop = wasted energy

General Wiring Practice

- **Use Surge Suppressors, connected to a <u>full size</u> grounding conductor**

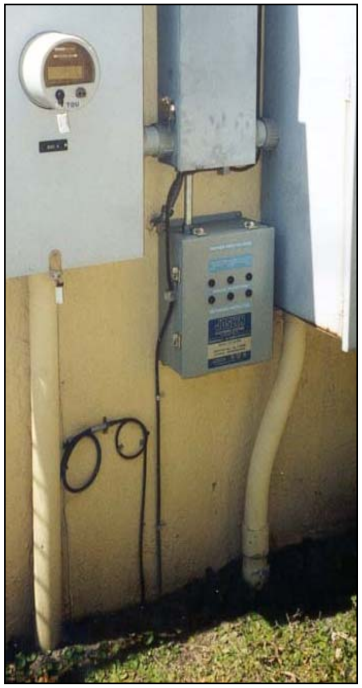
- **- at the service**
- **- at the panelboard**
- **- at the load**



General Wiring Practice

Surge Suppressors:

Must be well-grounded to work



General Wiring Practice

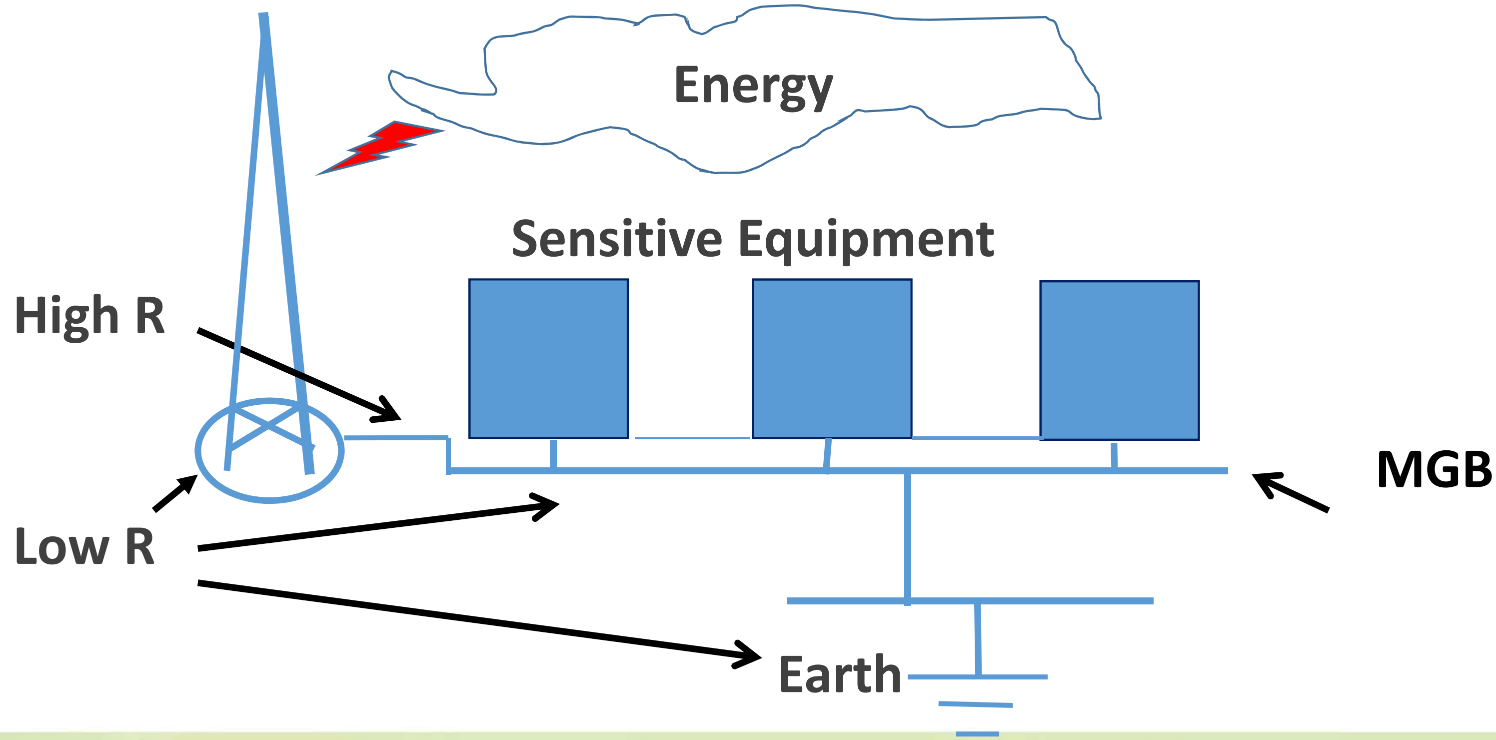
Surge Suppressors Should Have:

- All-mode protection: ϕ-ϕ, ϕ-G, ϕ-N, N-G
- Listed to UL 1449, Version 3
- High Joule (W•Sec) rating
- Have filtering, fuses, indication
- Must be well-grounded to work

Caveat

MOV's can degrade with use!

Think of a “current divider”



Desired Grounding

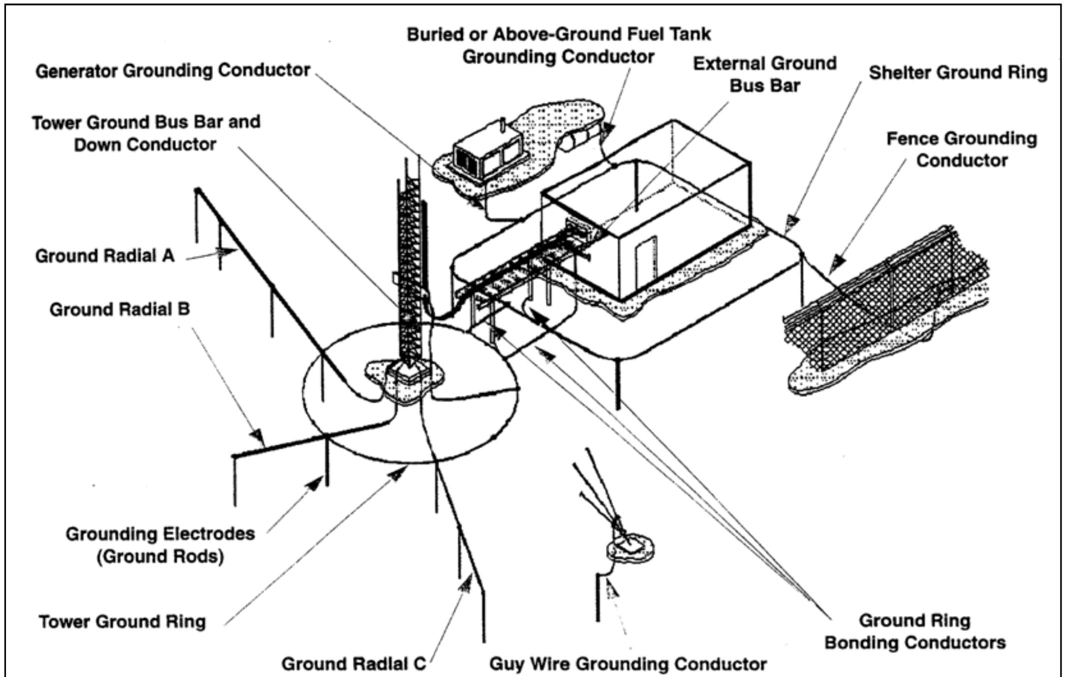
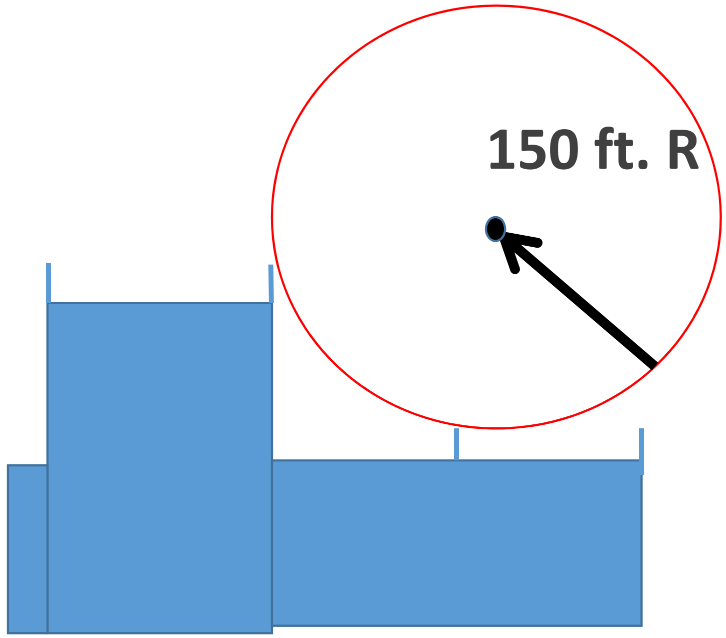


FIGURE 6-1 TYPICAL TYPE B EXTERNAL GROUNDING ELECTRODE SYSTEM

Rolling Ball

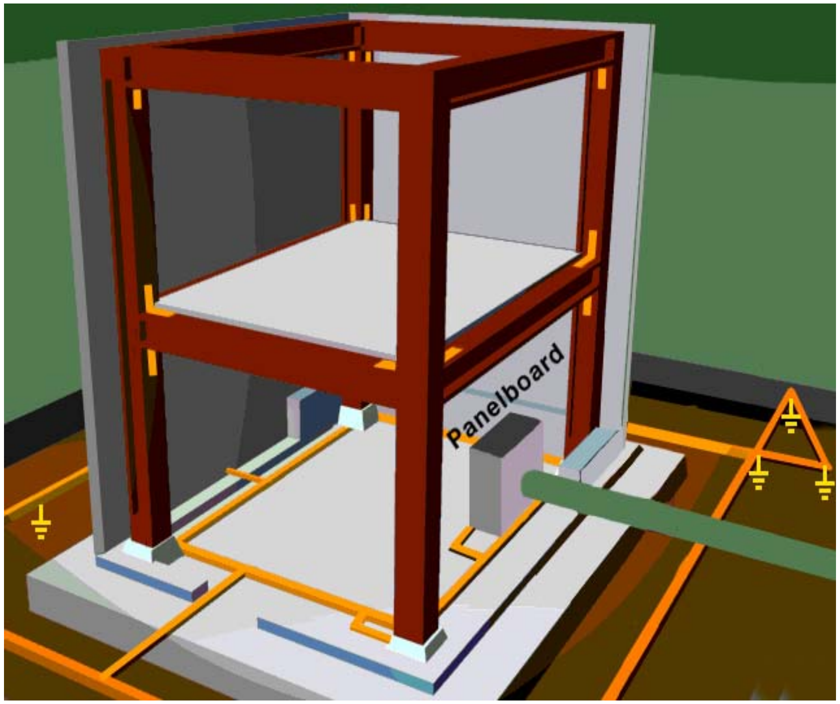


Costs

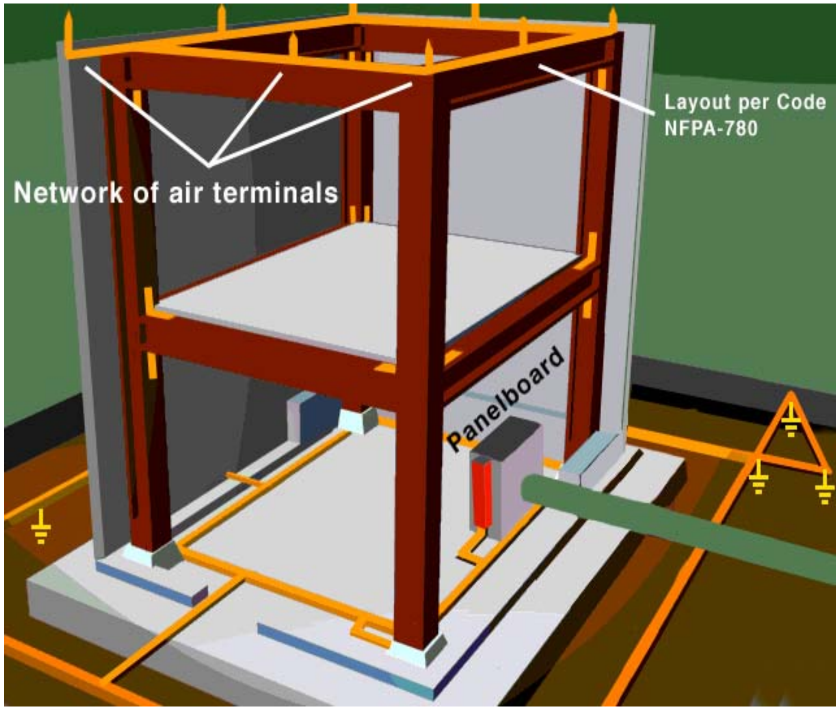
- Cost of materials is CHEAP compared to labor, equipment, downtime
- Cost for all PQ improvements:
- Adds about 1 to 1-1/2% to the overall cost of construction, but….

- Never have to revisit infrastructure for foreseeable future

Start With Ring Ground

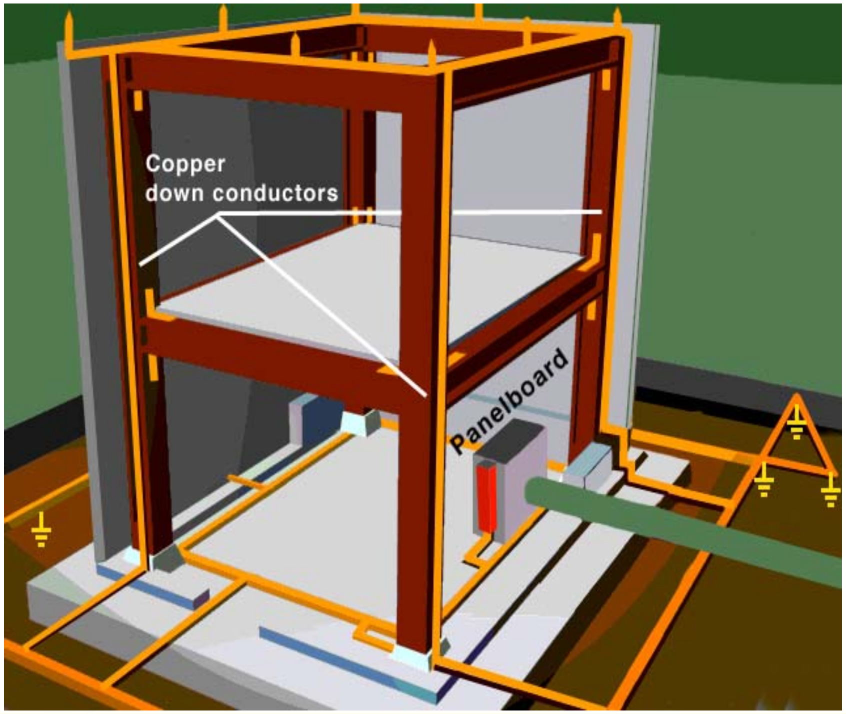


Network of Air Terminals



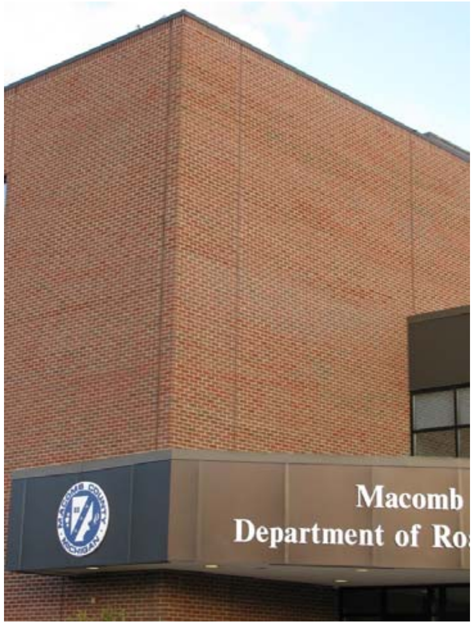
Heavy Duty Down Conductors

Not steel framing

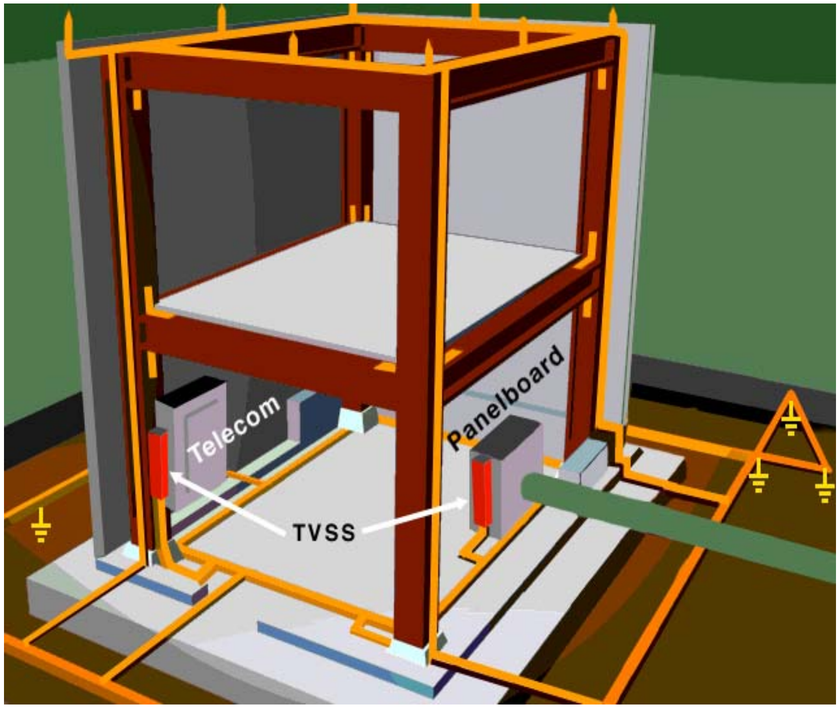


Do Not Use Steel Framing as Conductor

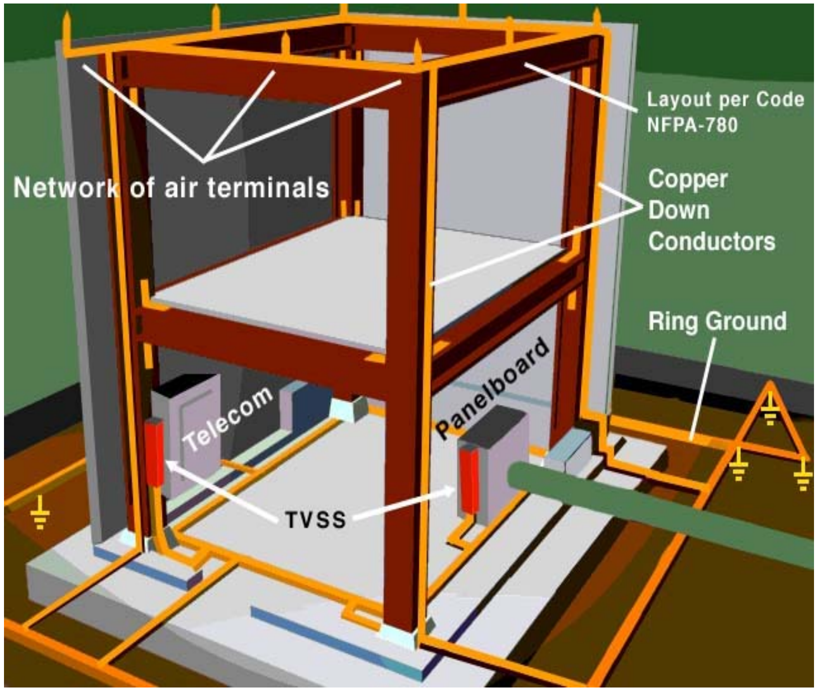
9-1-1 Uptime was more important than appearance



Surge Suppression



Overall Result

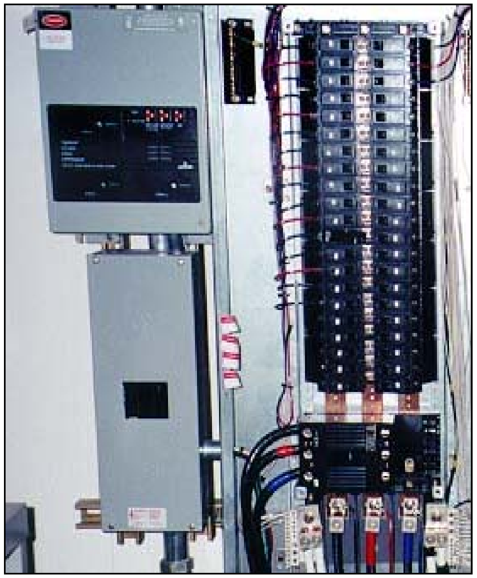


Surge Suppressors

Keep leads as short as possible

Surge Suppressors (SPD’s)

- at the service
- at the panel board
- at the load



At the Service Level

Type 1 devices

150 kA per mode minimum

At the Feeder Level

Type 2 devices

75 kA per mode minimum

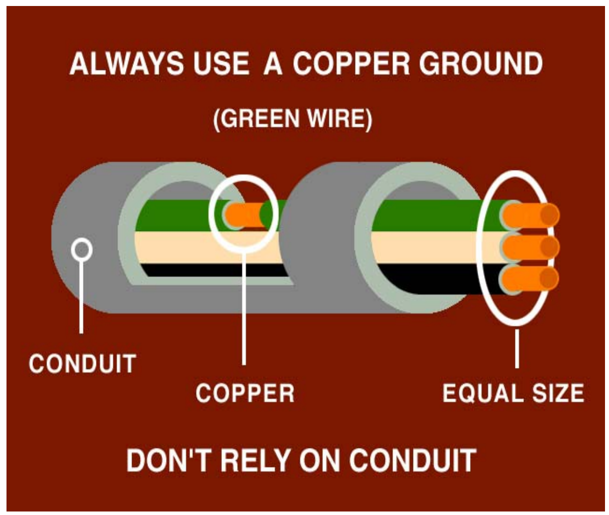
At the Device Level

Type 3 devices

25 kA per mode min.

Use Grounding Conductor

Always use a full size copper equipment grounding conductor – do not rely on conduit

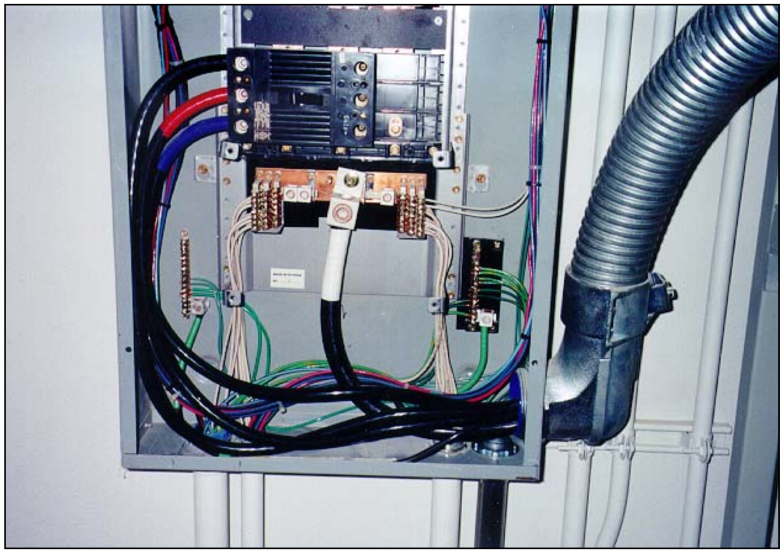


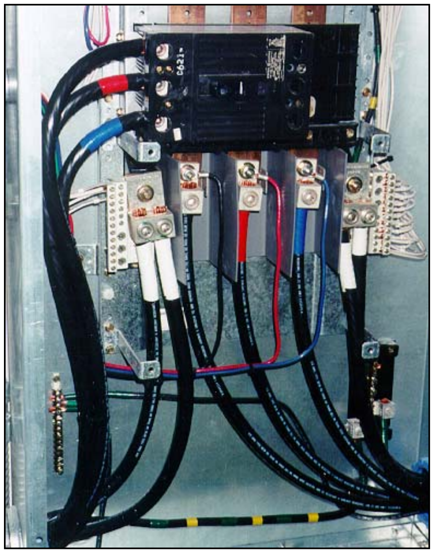
Trap Harmonics

Shielded isolation transformer sometimes helps

To Handle Harmonics

Use a 200% rated neutral or separate neutrals per phase



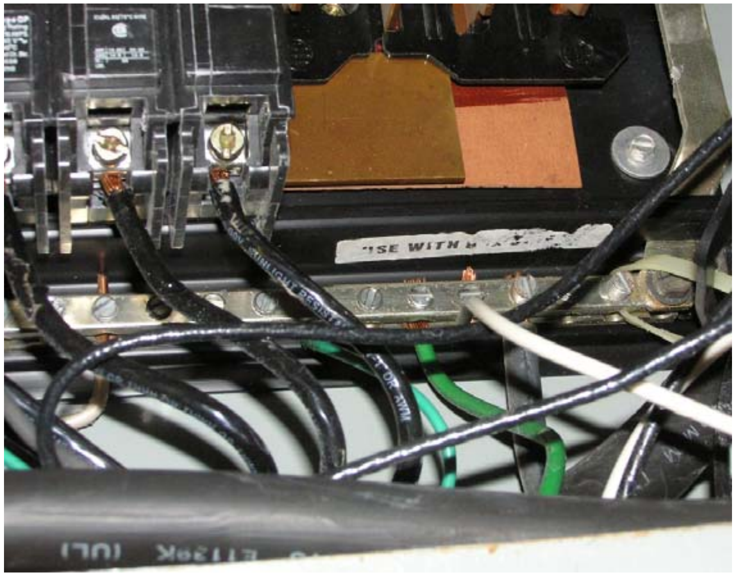


N-G Bonds

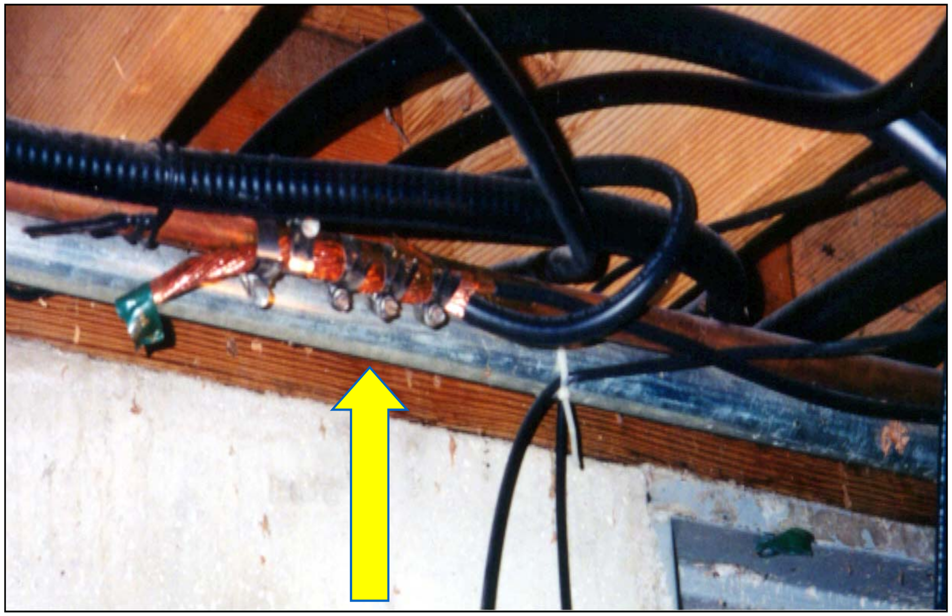
Interior:

- Check neutral – ground voltage
  - could mean harmonics

- Check for ground current
  - illegal N-G bonds



Use Only Listed Connectors



- Automotive hose clamps
- Water tube conductor

Rusty Water Pipe Bonding

- Automotive hose clamps
- Undersize conductors

Connection to Ground

- Plumber’s tape
- Unlisted U-bolts
- Steel all-thread rod

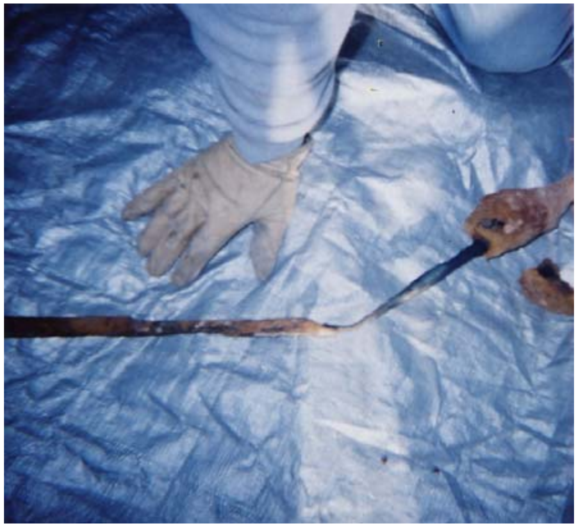
Choice of Rod Types

Pick the right rod for the
soil conditions

Galvanized Rod After 7 Years

Galvanized Rod

¾ inch to pencil-thin

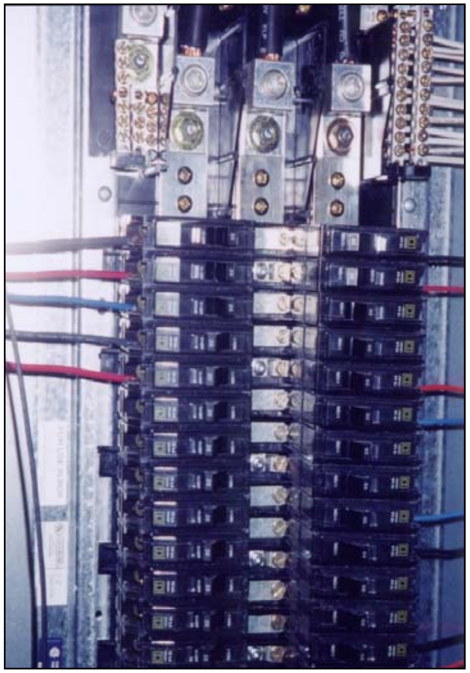


Chemical Electrodes

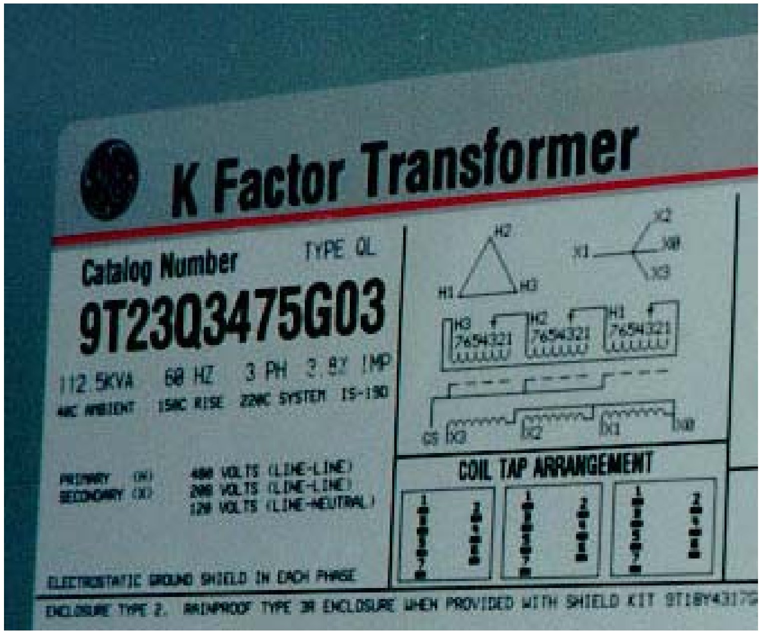
Salt-filled pipe after 7 years

Use Bolt-in Circuit Breakers

Use twist-lock plugs/receptacles



Use Harmonic Rated Panels and Transformers



First Step

Get the wiring and grounding right

This may solve the problem at minimum cost!

Backfill

Bentonite is the recommended backfill

Be wary of anything

containing graphite (very corrosive)

Grounding System Must be Checked

Check resistance of grounding electrode system annually (or more often as conditions dictate).

Examples

"We like to maintain a

maximum of two ohms … and that's checked once a year to make sure it hasn't risen." – CoSentry Data Center

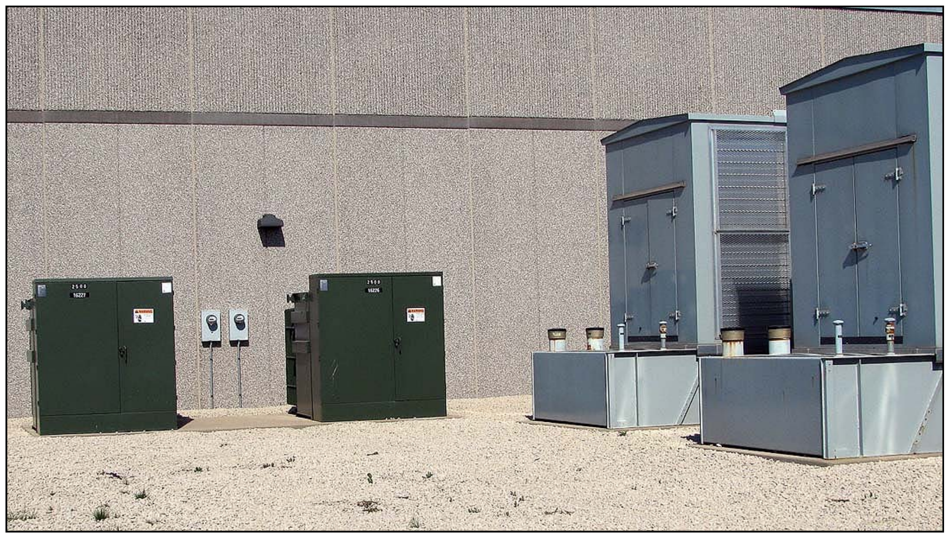
500 kcmil Ground Ring Surrounds Building

Inspection well about every 100 feet with 10 ft vertical electrode

Dual Electric Circuits

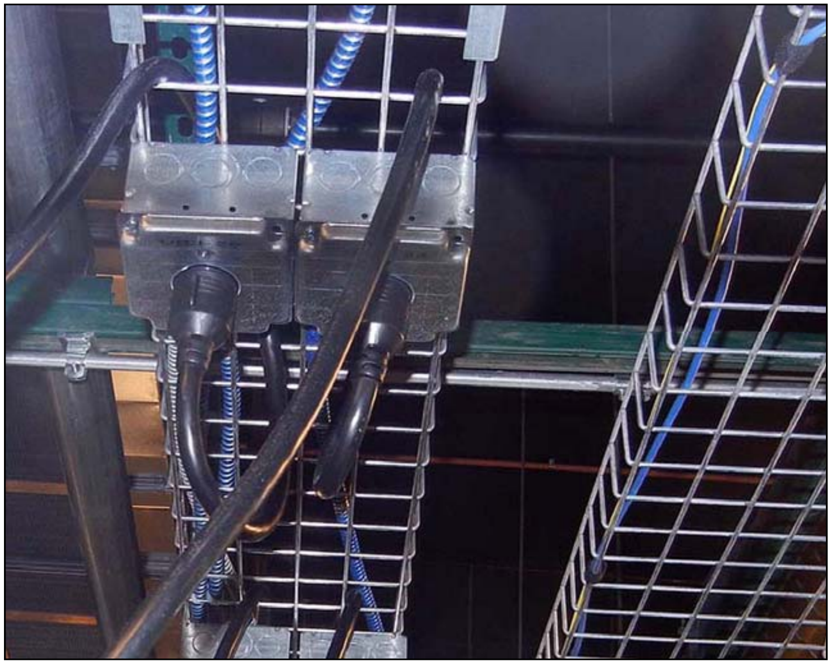
Dual utility feeds, 2- 2500 kVA transformers, 4- 750 kVA generators,

A&B circuitry



A and B Circuits

Dual Feed to Cabinets



Cabinets to Overhead Bus

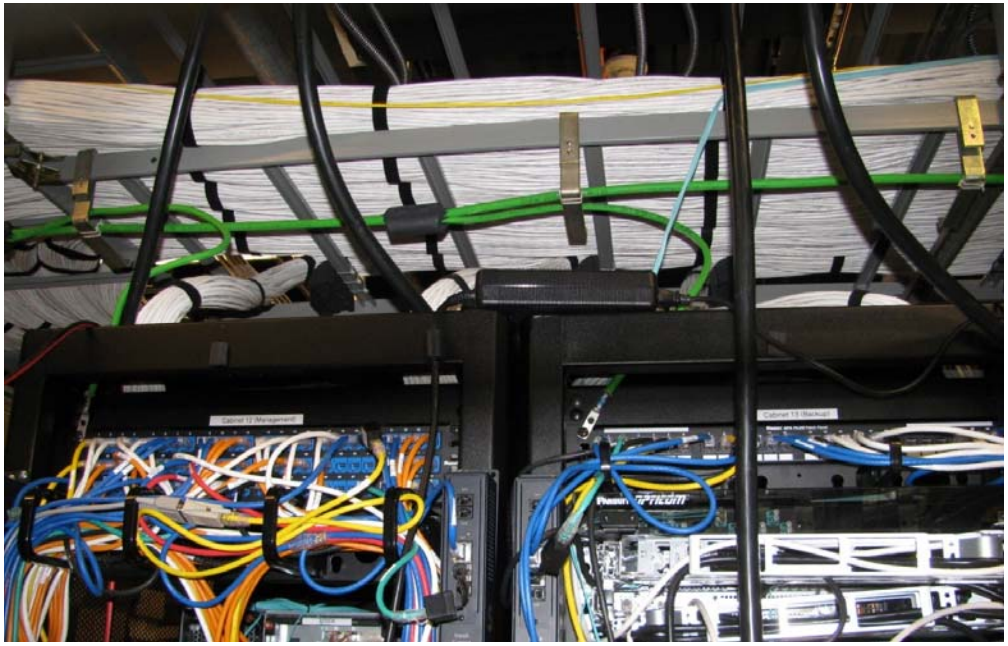
Bus Grounds Collected at SGB

From SGB to MGB

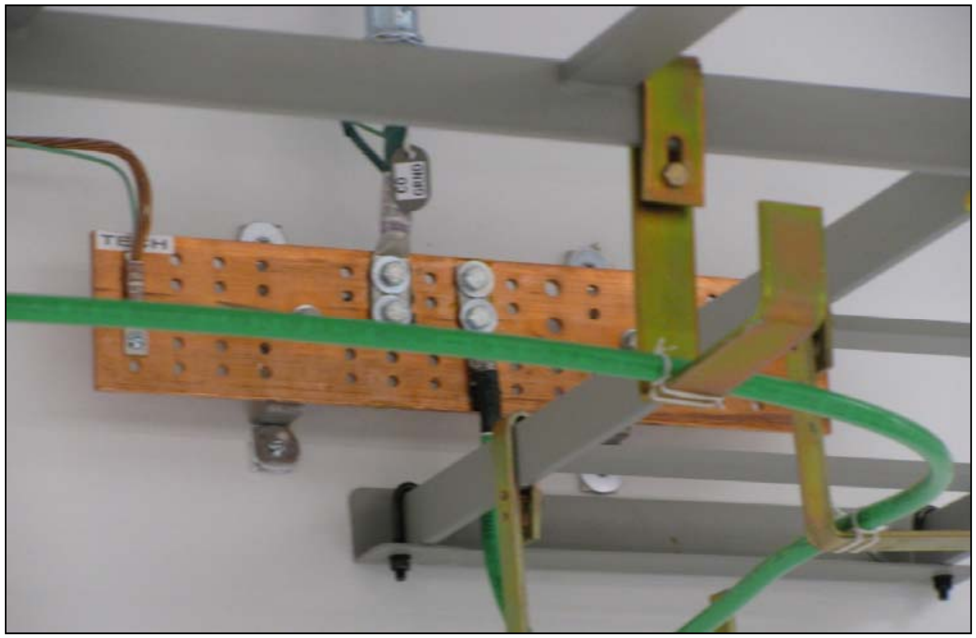
Markey Data Center

2 Vaults, 5 MVA each

Each Rack Tied to Overhead Bus



Rows of Racks to Ground Bus



Separate Conduits to Master Ground Bus

Master Ground Bus (MGB)

- Note that all conduits are labelled.
- MGB located at lowest point in building.

Never Rely on Conduit for Ground

Always use a full-sized separate copper ground conductor

Separate Circuits

Sensitive loads should be separated:

- Separate branch circuits
- Separate ground conductors
- Separate panelboards
- Separate feeders
- Separate transformers

BUT everything must be bonded together

Takeaways

1. Exceed the Code, but don’t violate the Code!
(Code minimum is one step above “illegal”)

2. You don’t get what you expect,
you only get what you inspect.

3. Have a written plan and procedures.
Insist contractors follow it.

3. Get the grounding and bonding right before anything else. Most lightning and transient problems can be cured at minimal cost.

Tips

This stuff isn't taught in school.

"A man's got to know his limitations."

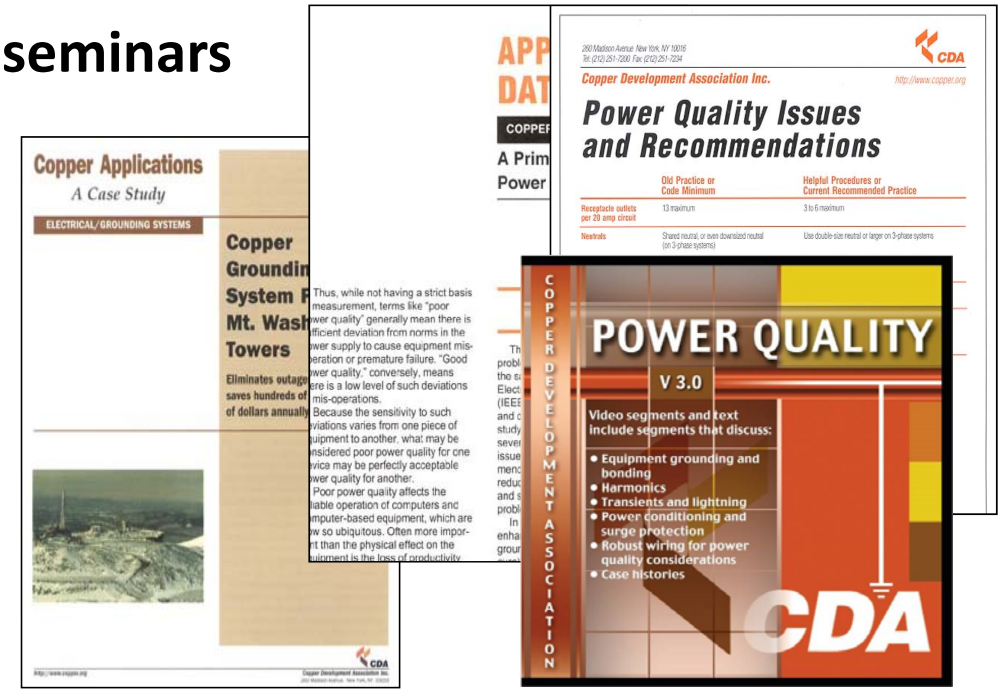
- Clint Eastwood as Dirty Harry

Call in a professional when there is doubt.

Free Educational Seminars

- **www.copper.org/electricalseminars**

- **Case Histories**
- **Recommendations**
- **Bibliography**
- **CD-ROMs, DVDs**



Thank You!

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