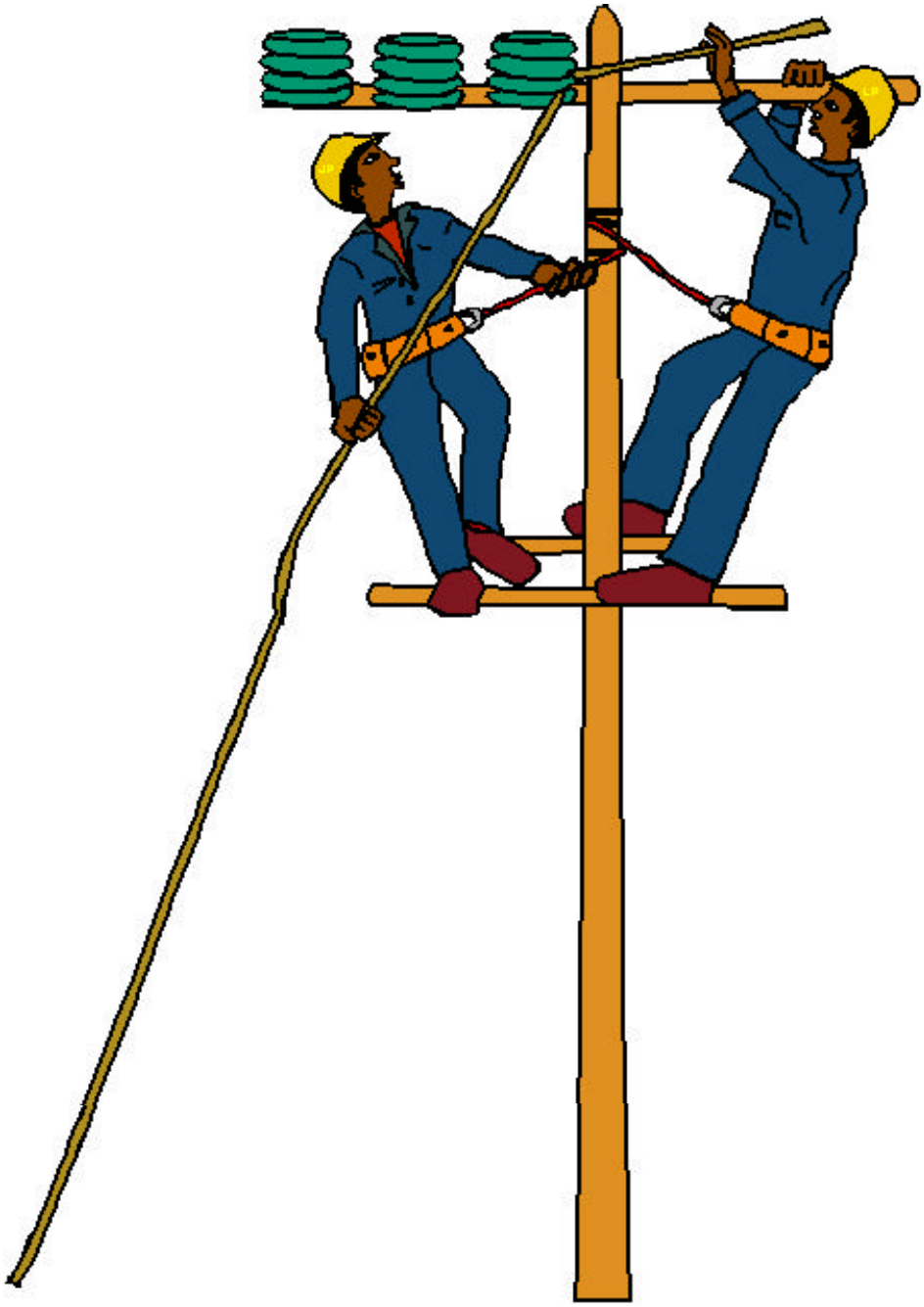
DOE ELECTRICAL SAFETY MEETING

1999



1999 DOE ELECTRICAL SAFETY COMMITTEE

Electrical Safety Committee Meeting
Tuesday, June 22

Introduction

At the beginning of the meeting, a brief introduction was held, and people in attendance were asked to introduce themselves. Larry Perkins told the attendees that approximately 130 people attended last year's meeting in Las Vegas, Nevada. The topics from the 1998 annual meeting were reviewed as follows: Electrical Statistics, 1000 Volt Insulated Tools, Electroshield, PVC, Rubber Blankets, FermiLab Accident, 99 NEC Code Changes, NESC, Extension and Flexible Cords, Electrical Meter Safety, WAPA Electrical Accident, ASTM Update, 1000 Volt Tools and Testing, OSHA Update, Grounding, Load Breaking Receptacles, Lightning Protection, Hazards of R&D Power Sources, Training the R&D Electrical Worker, Electrical Safety Handbook Process, Future, and Closure.

Meeting June 23 - 25 Agenda

The topics to be discussed at this year's meeting were reviewed and the agenda follows:

ELECTRICAL SAFETY MEETING
AGENDA

Monday -	**Travel**	**Planning Meeting (2:00 – 4:00 pm)**
Tuesday -	**7:30 - 8:00**	**Registration**
	8:00 - 8:15	**Welcome - Pat Tran**
	8:15 – 8:30	**Electrical Statistics - Janice Nelson**
	8:30 - 10:30	**High-Voltage Grounding Practices Based on Fault Studies – Gary Zevenbergen**
	10:30 – 10:45	**Break**
	10:45 - 12:00	**Electrical Meter Safety - Harvey Trager**
	12:00 - 1:00	**Lunch**
	1:00 – 1:30	**International Electrical Standards Update (June 99 Mouloose France Meeting of IEC TC78) – Allen Bingham**
	1:30 – 2:00	**Face and Eye Protection from Electrical Arc's – (ASTM Task Force Progress) – Jack Hirschmann, Jr.**
	2:00 – 2:15	**Break**

	2:15 – 2:45	**NFPA70E/OSHA Electrical Clothing Requirements (June 99 ASTM Meeting in Boston) – Allen Bingham**
	2:45 – 3:15	**Arc Resistant Rainwear – Bill Snyder**
	3:15 - 5:00	**Underground Detection Update - Jerry Phillips**
Wednesday -	**8:00 – 10:00**	**Grounding of Electrical Systems and Associated Problems – Mark Regan**
	10:15 – 11:15	**Drillco Devices - Nick Lacey**
	11:15 – 12:00	**Grounding of Generators Below and Above 5KW – Gordon Johnson**
	12:00 – 1:00	**Lunch**
	1:00 – 1:30	**Electrical Safety During D&D Activities – Jim Craven**
	1:30 – 2:00	**Intrinsically Safe Equipment – Doug Lovette**
	2:00 – 4:00	**R&D Is It Really Different - Lloyd Gordon**
	4:00 – 4:30	**Interactive Electrical Safety Course for Researchers**
	4:30 – 5:00	**Electrical Inspection Program – Terry Fogle**
Thursday -	**8:00 – 8:30**	**Idaho Fatality – Jack Jacobson**
	8:30 – 9:15	**Alternate Methods to Meet NEC Requirements – Ernie Garcia**
	9:15 – 10:00	**Applied Integration Principles to Electrical Construction Safety – Bryan Drennan**
	10:00 – 10:15	**Break**
	10:15 – 11:00	**Approval of Unlisted Equipment – Grant Guymon**
	11:00 – 12:00	**Calculations Based on the 1999 NEC – James Stallcup**
	12:00 - 1:00	**Lunch**
	1:00 – 2:00	**Calculations Based on the 1999 NEC – James Stallcup**
	2:00 – 4:00	**Electrical Burn Update – Dr. Mary Capelli-Schellpfeffer**
	4:00 – 4:30	**Ground Problems at the Y-12 Plant - Richard Goins**

4:30 – 5:00 Future and Closure – Larry Perkins/Pat Tran

Friday 8:00 – 12:00 Steering Committee Meeting – Larry Perkins/Pat Tran

Future Surveys

A request was made for people to submit subject that they would like to see as survey topics during the upcoming year. Two topics planned are the use of electrical gloves without leather protectors and the use of proximity devices.

Commitments and Assignments

Appendix E of the handbook was discussed and the Chairpersons for the potential future chapters provided a brief status of each chapter:

Underground Utilities Detection Equipment During Excavation- Chairman - Larry Perkins

First Draft reviewed in Monday meeting will be sent to the DOE complex for further review.

Arc Flash Protection - Chairman - Bill Marsh

First Draft reviewed in Monday meeting will be sent to the DOE complex for further review.

Proper Use of Electrical Test Equipment - Chairman - Doug Lovette

First Draft reviewed in Monday meeting will be sent to the DOE complex for further review.

Portable and Vehicle-Mounted Generators - Chairman -Chuck Monasmith

No report

Electrical Hazards During Decontamination & Decommissioning (D&D) Activities

Chairman - Orville Paul No report

Electrical Hazards During Welding Activities - Chairman - Bryan Drennan

No report

Proposed time frames for the next review of the three chapters and the development of the other three chapters were established.

ELECTRICAL SAFETY COMMITTEE MEETING

Tuesday, June 23

Registration (Janice Nelson)

Participants at the meeting were registered and given names tags. Approximately 80 people attended the meeting.

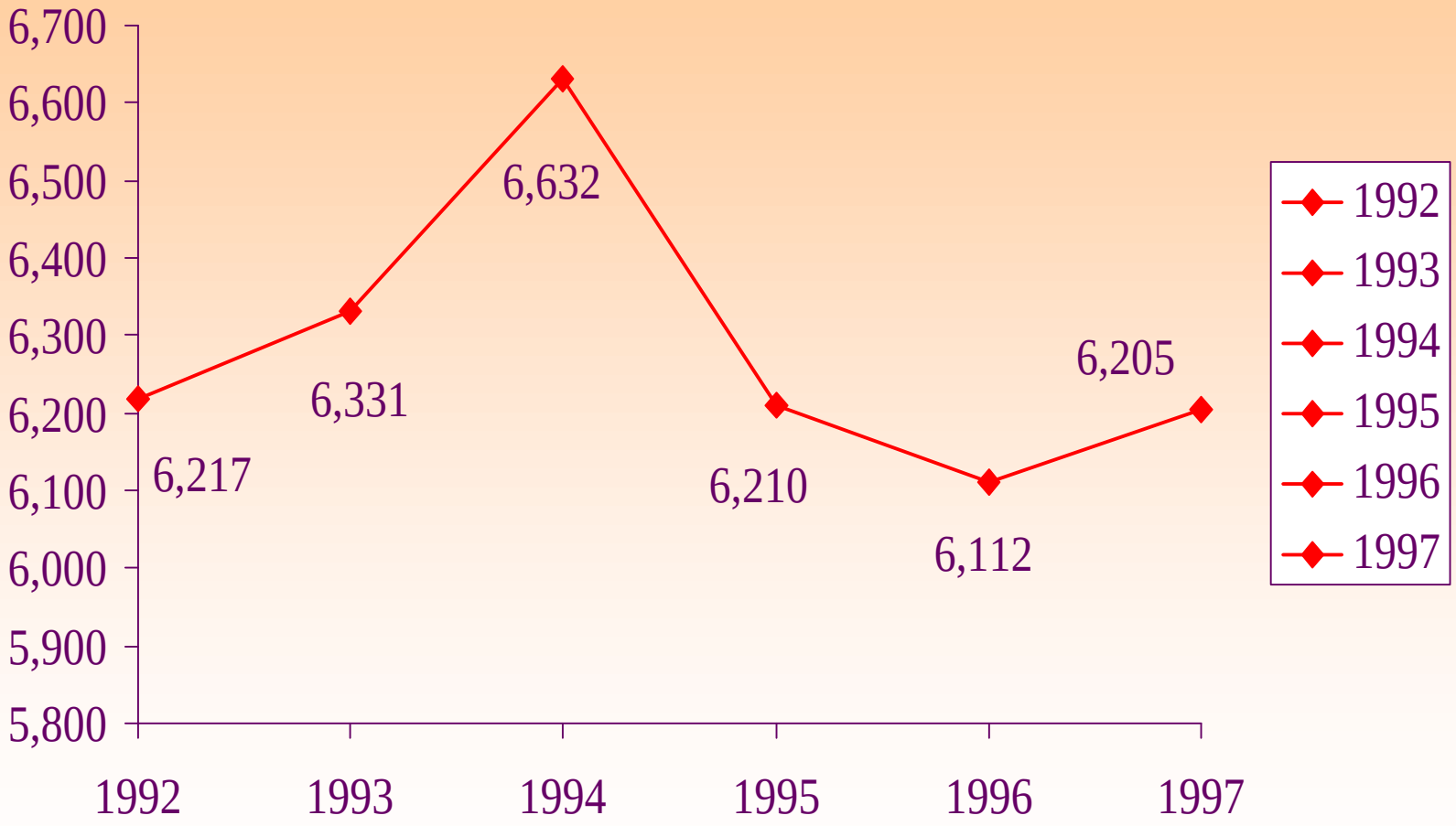
Welcome (Pat Tran)

Pat Tran from EH-51 welcomed the participants to the annual meeting. The attendees introduced themselves and identified the locations they represented.

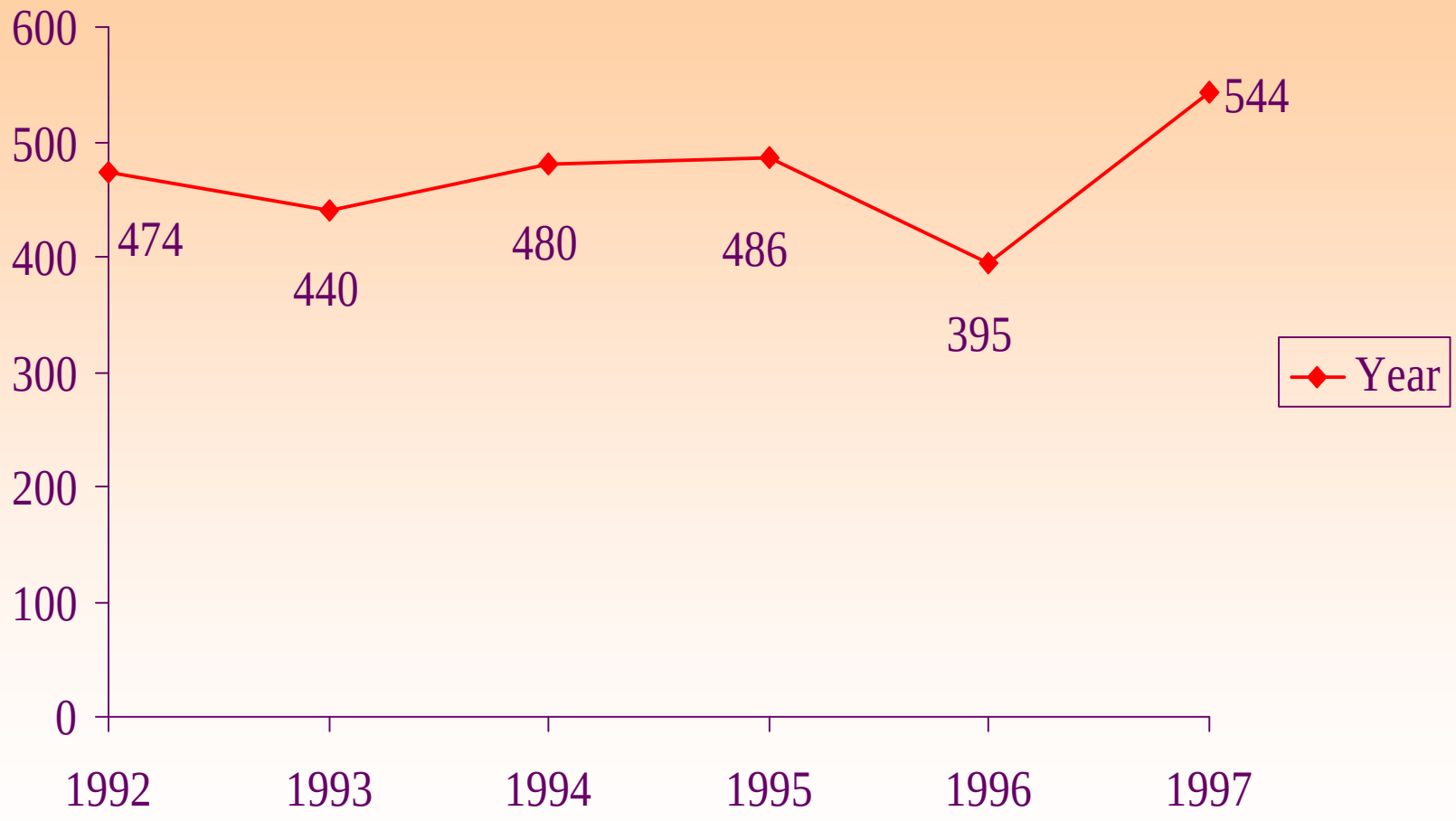
Electrical Statistics (Janice Nelson)

Janice discussed the BLS statistics related to electrical incidents. The bad news was that the numbers of fatalities in the work place are on the increase (both general fatalities and electrical fatalities). Similarly, the number of electrical-related occurrences in the DOE Complex are also on the increase.

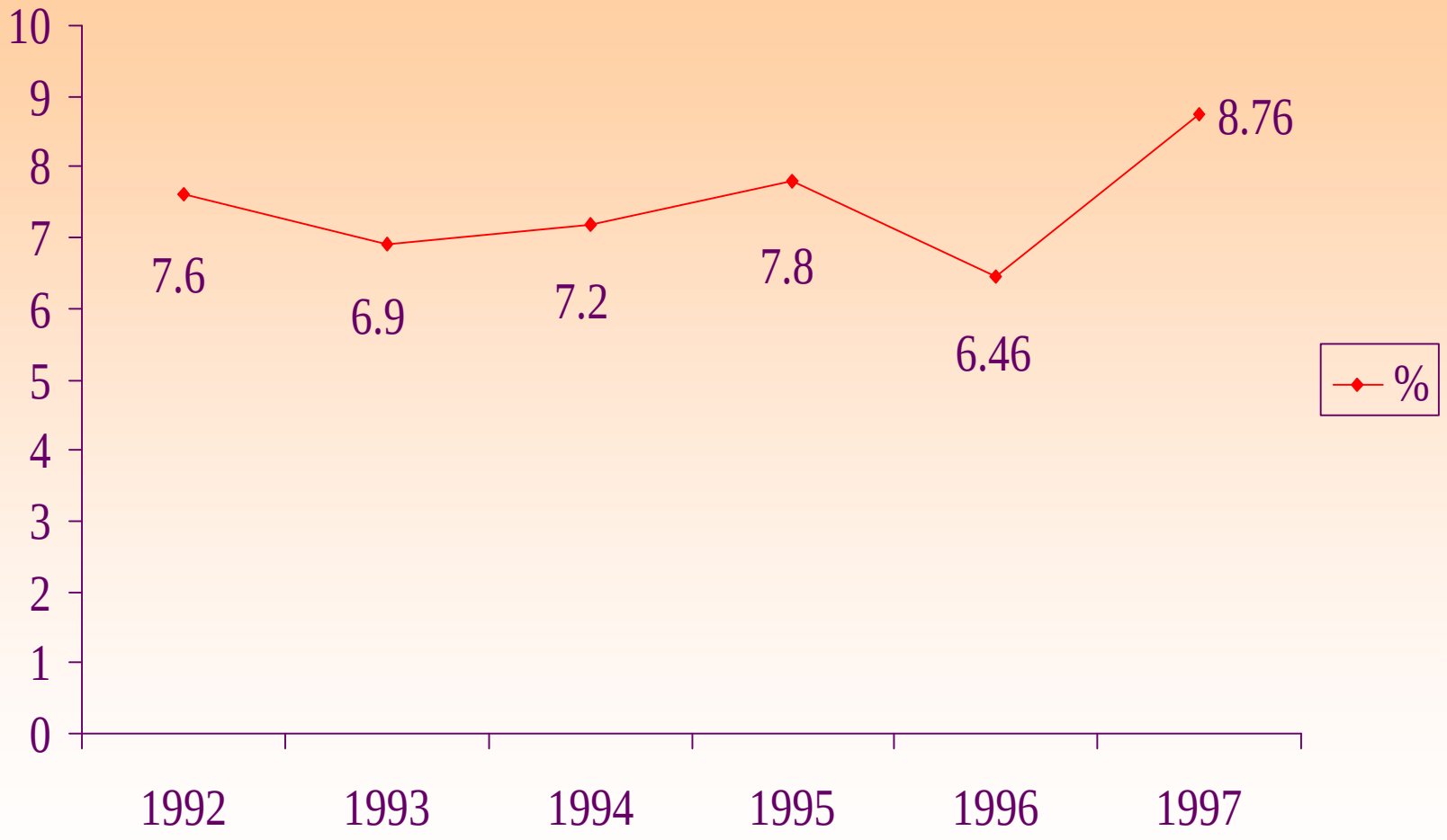
TOTAL FATALITIES BY YEAR



Electrocutions By Year



Percent of Total Fatalities By Year



High-Voltage Grounding Practices Based on Fault Studies (Gary Zevenbergen)

High-Voltage Grounding Practices Based on Fault Studies

Gary Zevenbergen
Western Area Power Administration
Golden, Colorado
303-275-1664
zevenber@wapa.gov

High Voltage Grounding Practices

- Purpose:
  - Prevent accidental death or injury from electrical shock by providing...
    - a safe work location
    - a safe work site
- Primary Use:
  - Minimize risk while working on electrically isolated equipment.

High Voltage Grounding Practices

- Safe grounding accomplished by:
  - Proper application of personal protective ground cables (Work Location)
  - Adhering to proper clearances and work procedures (Work Site)

Safe Work Location

- Objective
  - prevent injury or death to the worker from electrical shock.
- Implementation
  - Minimize the voltage appearing across the workers body.

Sources of Voltage

- Lightning
- Induced Voltages
  - Static Voltage
  - Capacitive coupled voltage
  - Electromagnetic coupled voltages
- Accidental Energization

Controlling Voltage at Work Location

- Install properly designed protective ground cables between isolated equipment and ground.
  - Creates an equal potential zone at the work location
  - Current flow through cables results in voltage across workers body
  - Maximum voltage associated with accidental energization

Acceptable Maximum Voltage

- Based on research of Charles F. Dalziel
  - minimum 60 Hz. Current causing ventricular fibrillation proportional to body weight and inversely proportional to the square root of the shock duration.
  - developed empirical formula relating current magnitude and duration

Acceptable Maximum Voltage (Cont)

- For Power systems, duration defined by protective relays and circuit breaker operating times
  - Substations
    - $t = 15$ cycles, $I \approx 200$ mA
  - Transmission Lines
    - $t = 30$ cycles, $I \approx 150$ mA

Acceptable Maximum Voltage (Cont)

- Voltage determined by Ohm's Law
  - V = I * R
    - I = maximum fault current
    - R = Resistance of Human Body
- Large variation in R values
- Western's convention is
  - R = 500 Ohms

Acceptable Maximum Voltage (Cont)

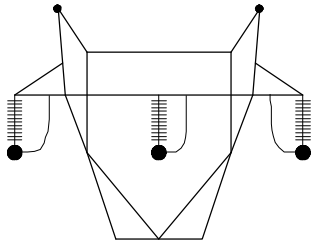
- Maximum Acceptable Voltage
  - For Substation:
    - V = (0.200)(500) = 100 Volts
  - For Transmission Lines
    - V = (0.150)(500) = 75 volts

Protective Ground Cables

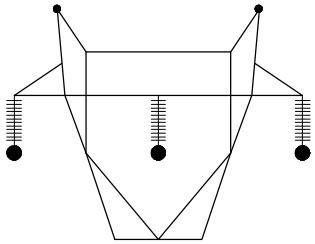
- Maximum length for ground cables
  - Given:
    - Maximum Allowable Voltage (75 Volts)
    - Ground cable size and characteristics
      - Resistance/foot
      - Fault current capability
  - Western's standard ground cable is 2/0 copper
    - Maximum length = 40 ft.

Typical Ground Cable Installations

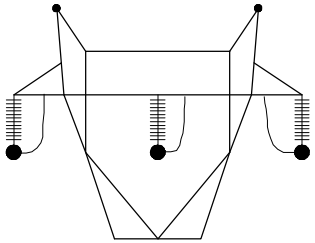
Three-Phase Bracket Grounding



Adjacent Tower



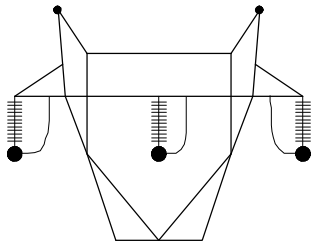
Work Site



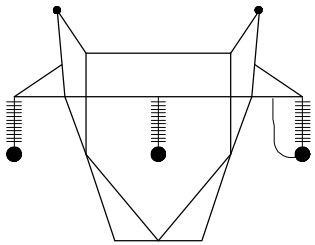
Adjacent Tower

Typical Ground Cable Installations

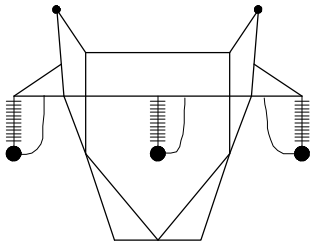
Combination Grounding



Adjacent Tower



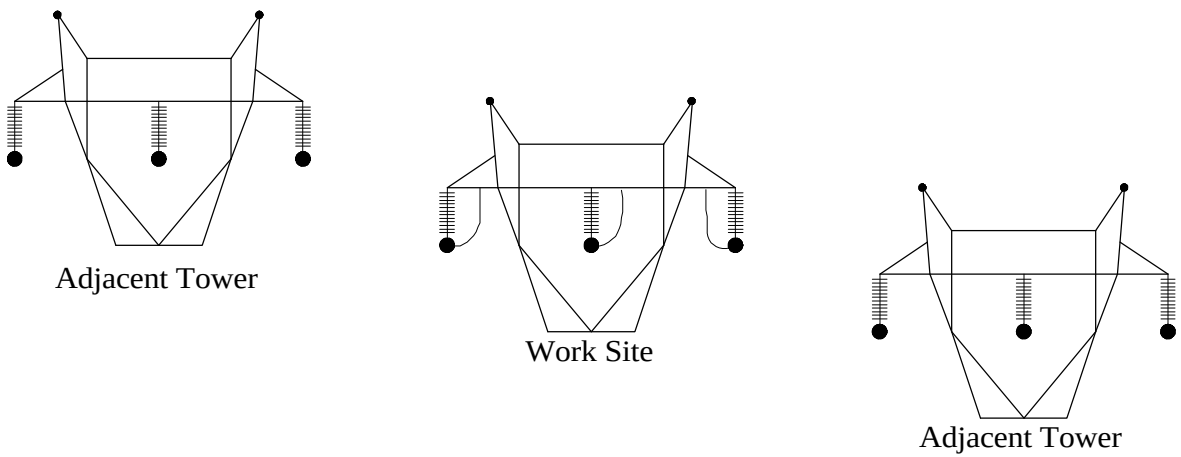
Work Site



Adjacent Tower

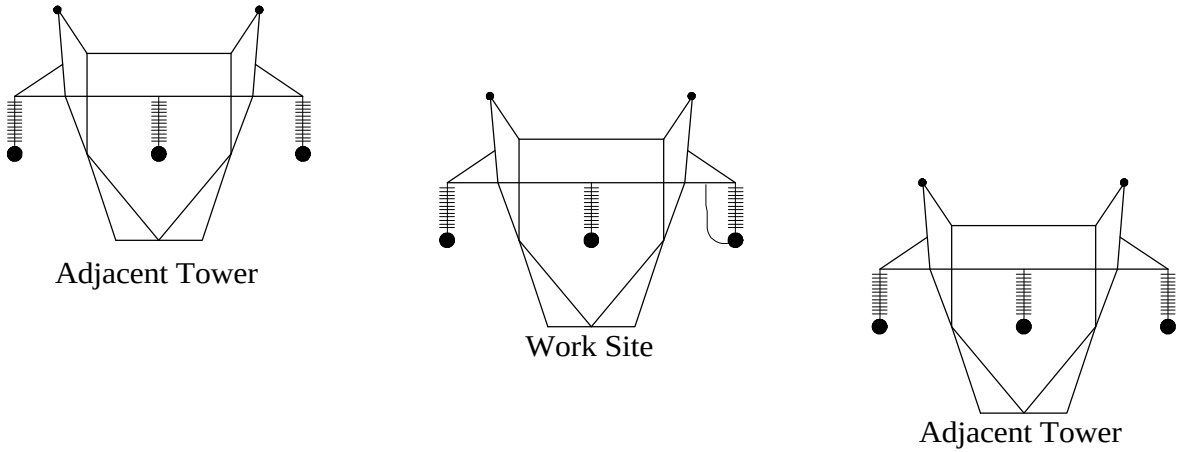
Typical Ground Cable Installations

Three-Phase Work Site Grounding



Typical Ground Cable Installations

Single-Phase Work Site Grounding



Safe Job Site

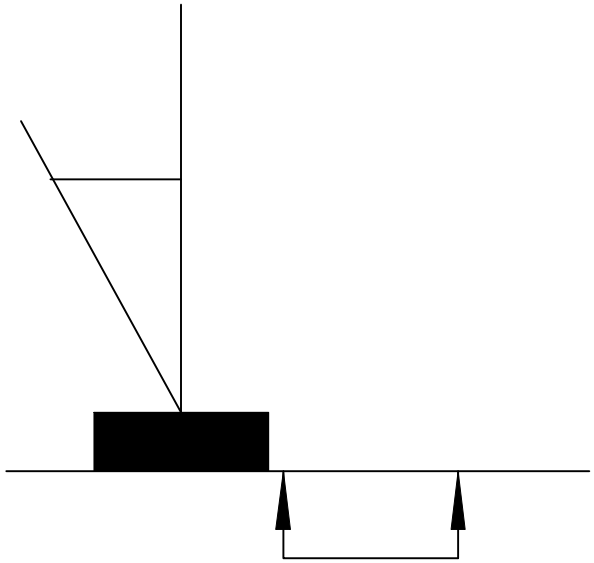
- Objective
  - prevent injury or death to personnel at job site.
- Implementation
  - Minimize exposure to hazardous voltages.

Job Site Hazardous Voltages

- Ground Potential Rise (GPR)
  - Result of injecting current into the ground.
  - Manifestations
    - Step Potential
    - Touch Potential
    - Transfer Touch Potential

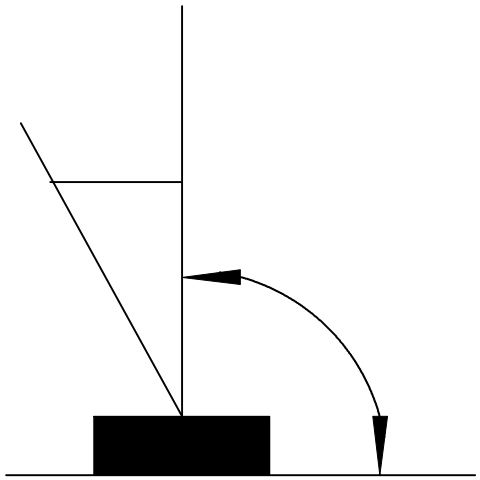
Job Site Hazardous Voltages

- Step Potential
  - Potential difference between two points on the earth 1 meter apart.



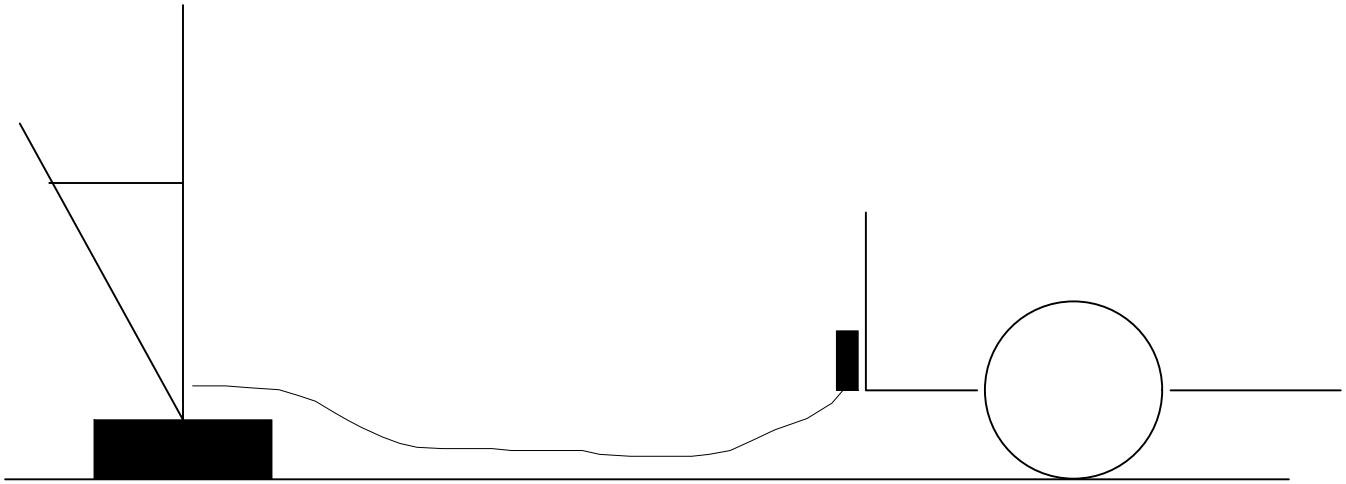
Job Site Hazardous Voltages

- Touch Potential
  - Potential difference between grounded object and point on earth's surface separated by normal reach



Job Site Hazardous Voltages

- Transfer Touch Potential
  - Potential difference between object connected to grounded system and earth.



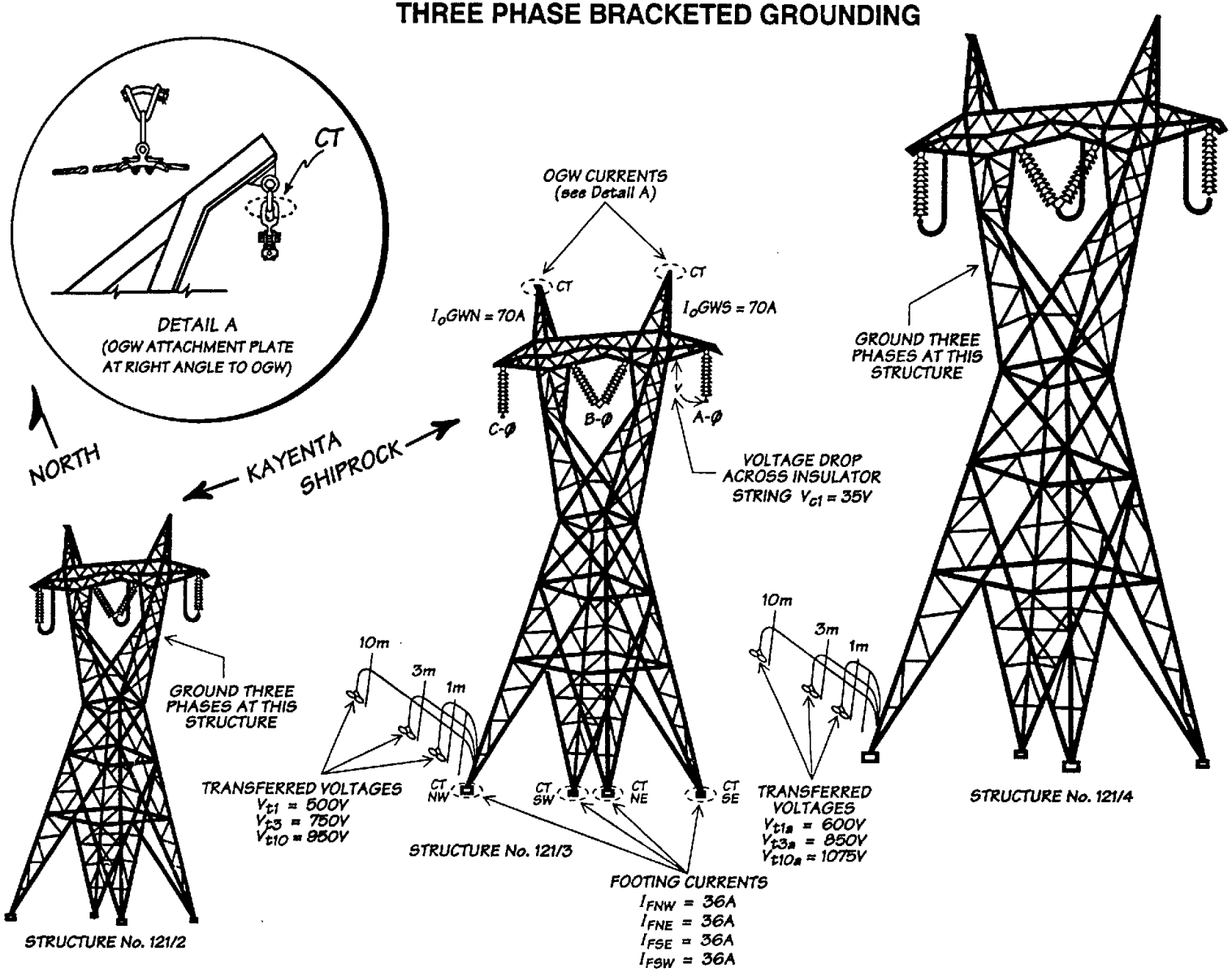
Evaluation of Grounding Practices

- Stage Fault Test Results
  - Shiprock - Kayenta 230-kV Line (March 1995)
  - Evaluate effectiveness of all four grounding methods

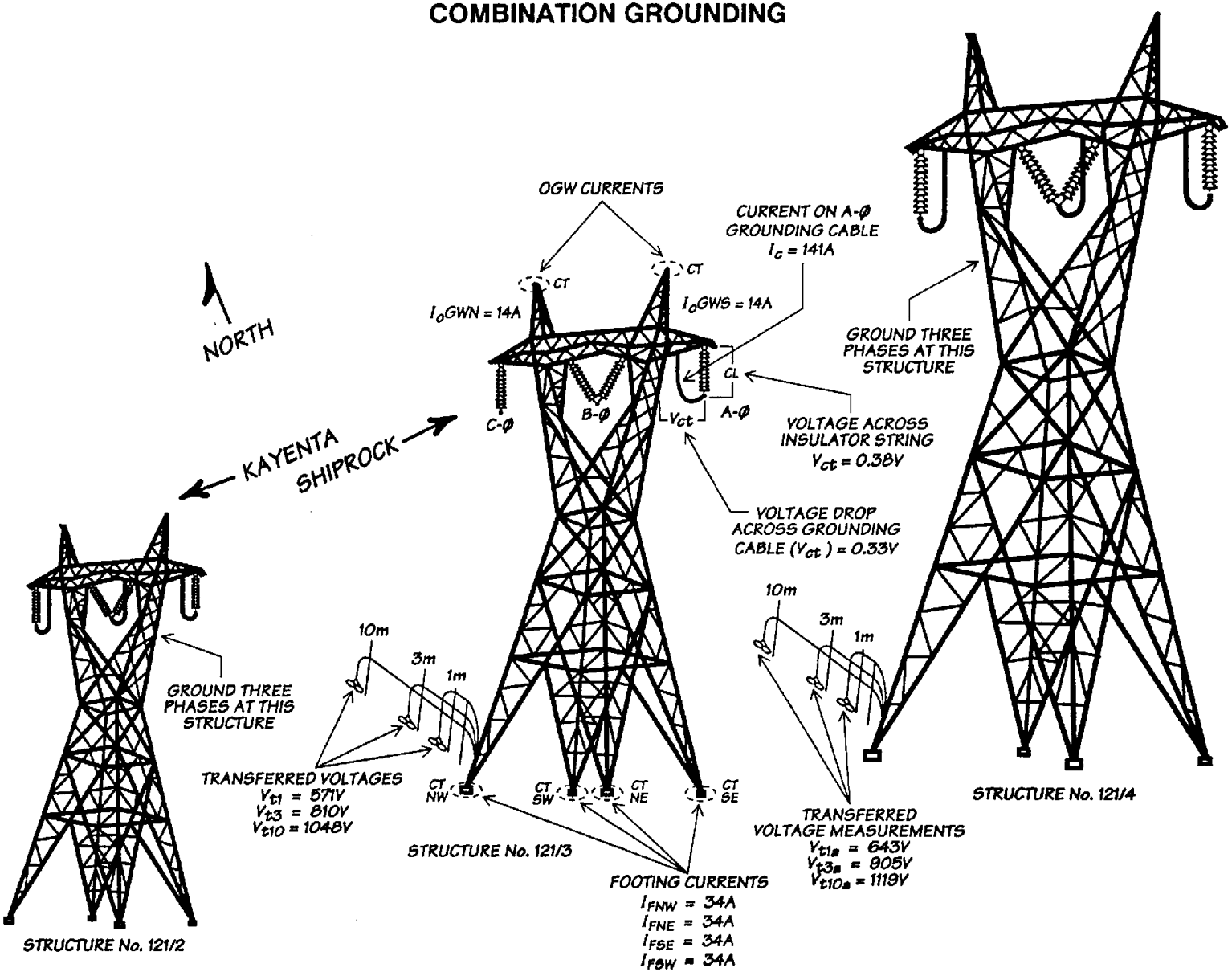
Evaluation of Grounding Practices

- Instrumentation
  - OGW Current Transformers
  - Tower Footing Current Transformers
  - Voltage Drop Across Insulator
  - Voltage Drop Across Ground Cable
  - Transfer Touch Potential

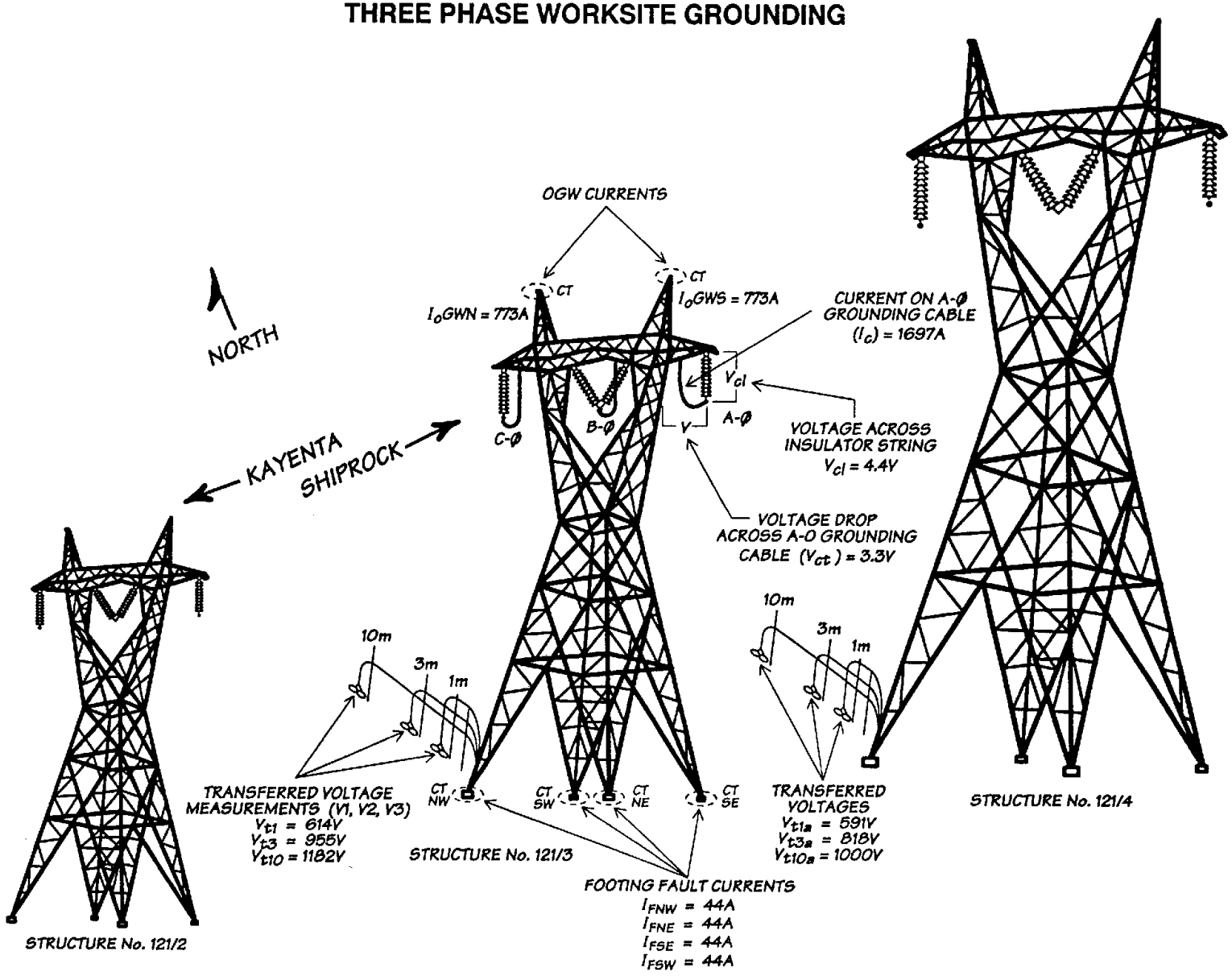
THREE PHASE BRACKETED GROUNDING



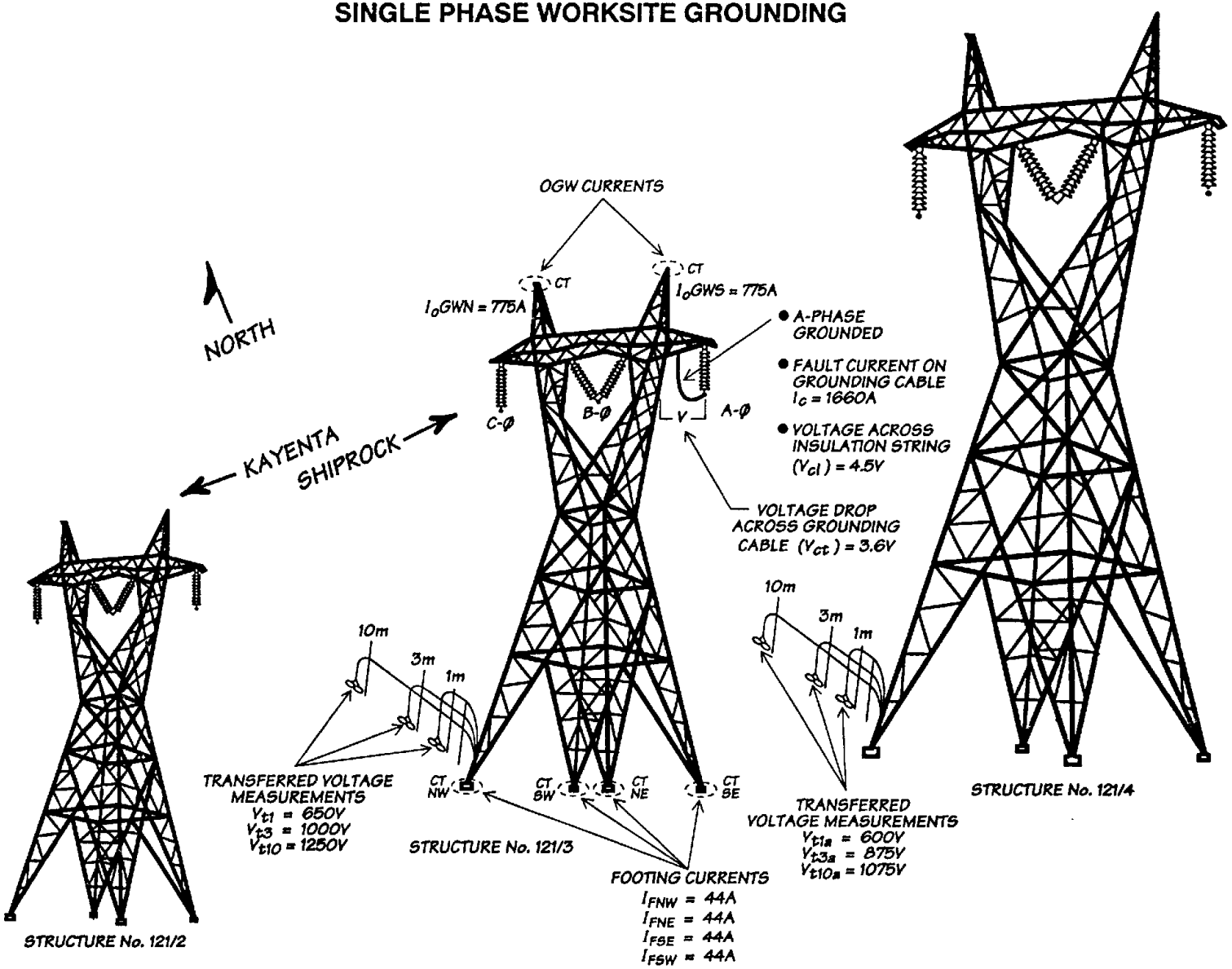
COMBINATION GROUNDING



THREE PHASE WORKSITE GROUNDING



SINGLE PHASE WORKSITE GROUNDING



Conclusions

- Transfer Touch Voltages for each grounding method were high (500-1250 Volts)

- Work Location Voltages were low (0.33-4.5 Volts)

Conclusions (cont.)

- Higher Work Location voltages were measured for 3-ph bracket grounding.
  - Could exceed 75 Volt limit under higher fault conditions
- Using bracket or combination grounding adjacent to parallel energized line may result in hazardous circulating currents

Conclusions (cont.)

- Installing properly rated personal ground cables at work location removes hazardous voltages, however, hazardous voltages still exist for personnel at ground level.

Conclusions (cont.)

- Mitigating Hazardous Voltages at ground Level
  - Avoid contacting any grounded structure or grounding system
  - Use insulated footwear or insulated mats.

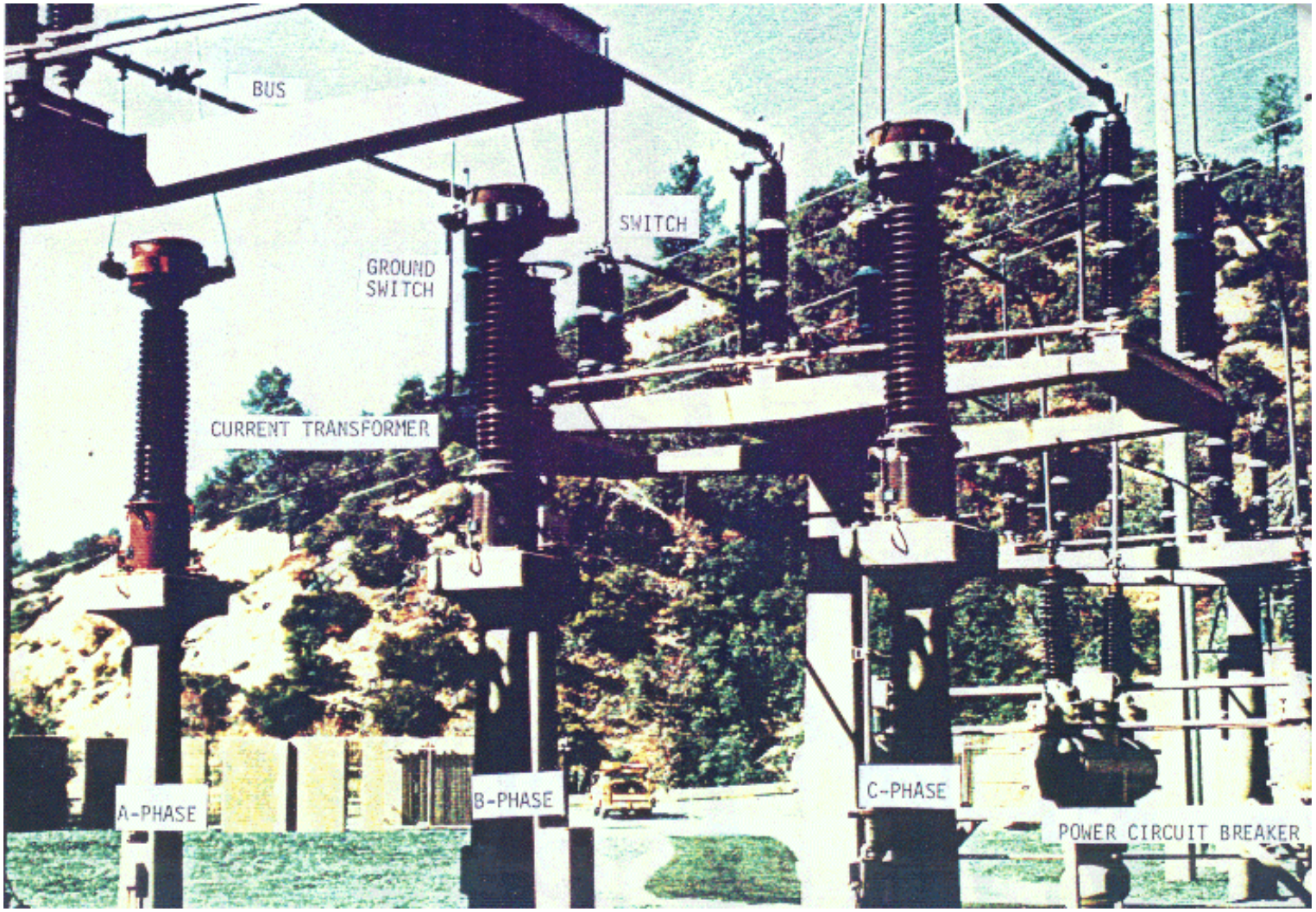
Case Study

- Incomplete Ground cable installation
  - Installation of Current Transformer

New Melones switch yard Accident Summary

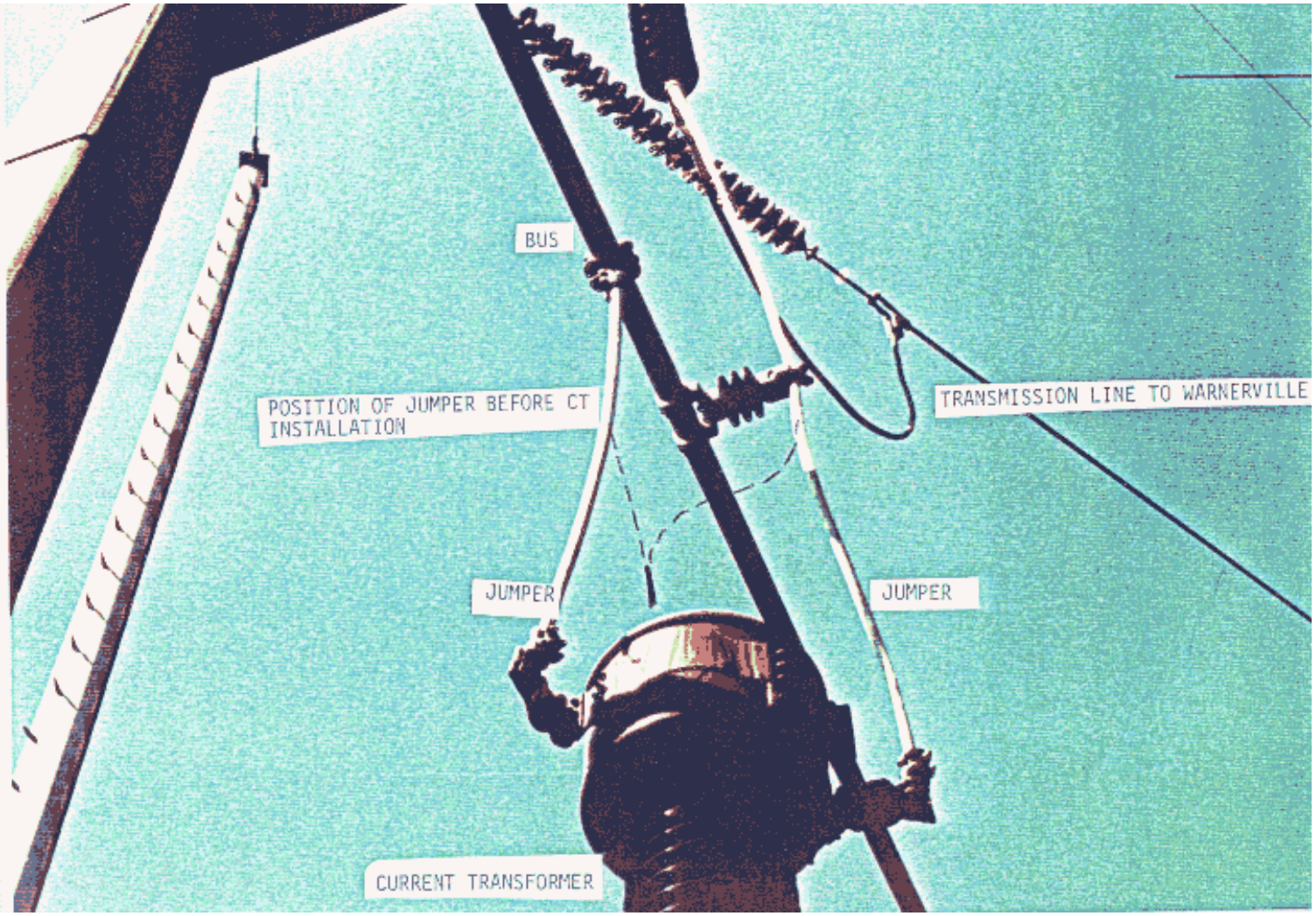
- A Western line crew was installing a current transformer.
- A personal ground was installed on the interconnecting bus only.
- The employee was in the process of disconnecting jumper leads from the t-line and the switchyard bus from a bucket truck.

New Melones switch yard

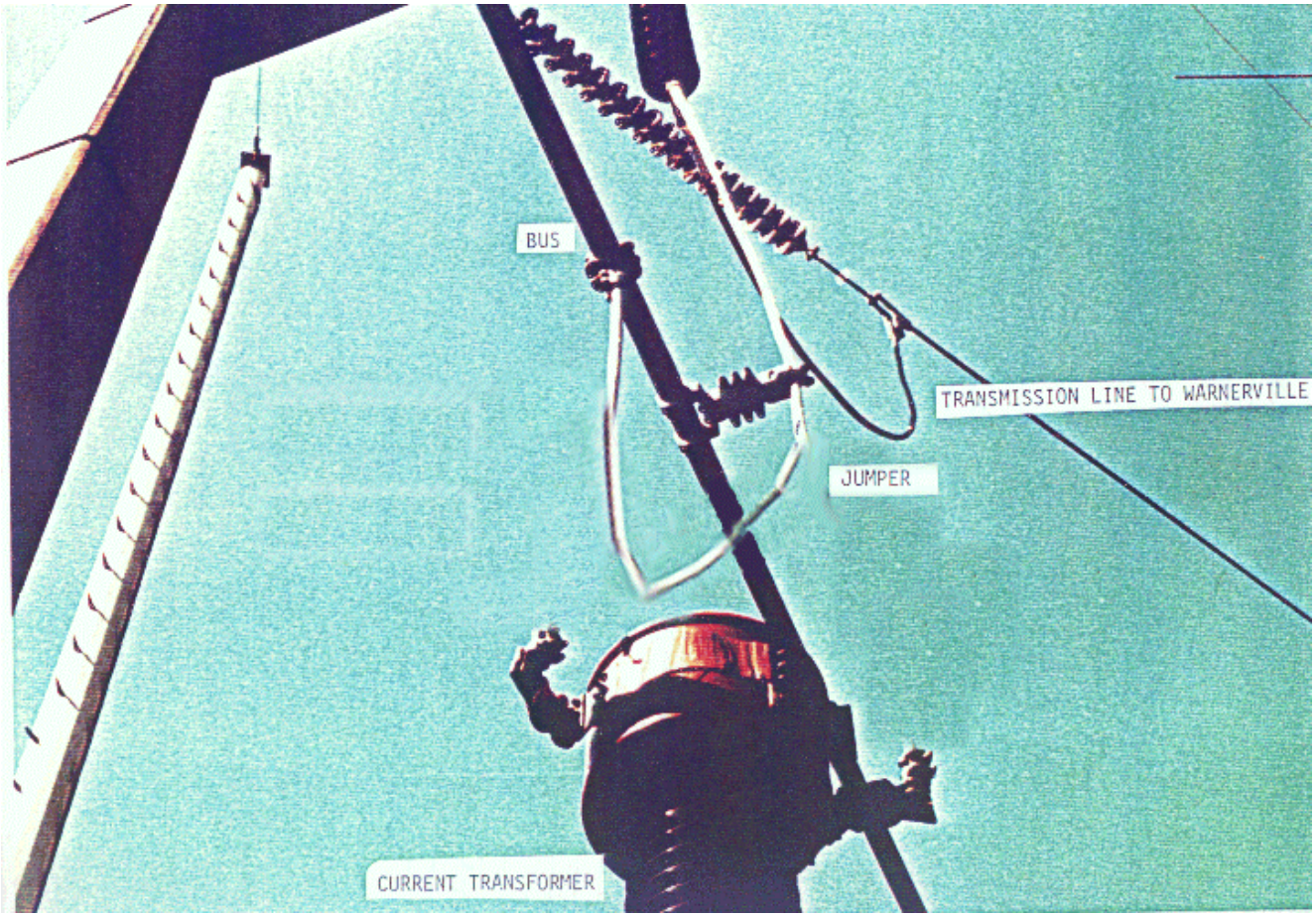


New Melones Switch Yard

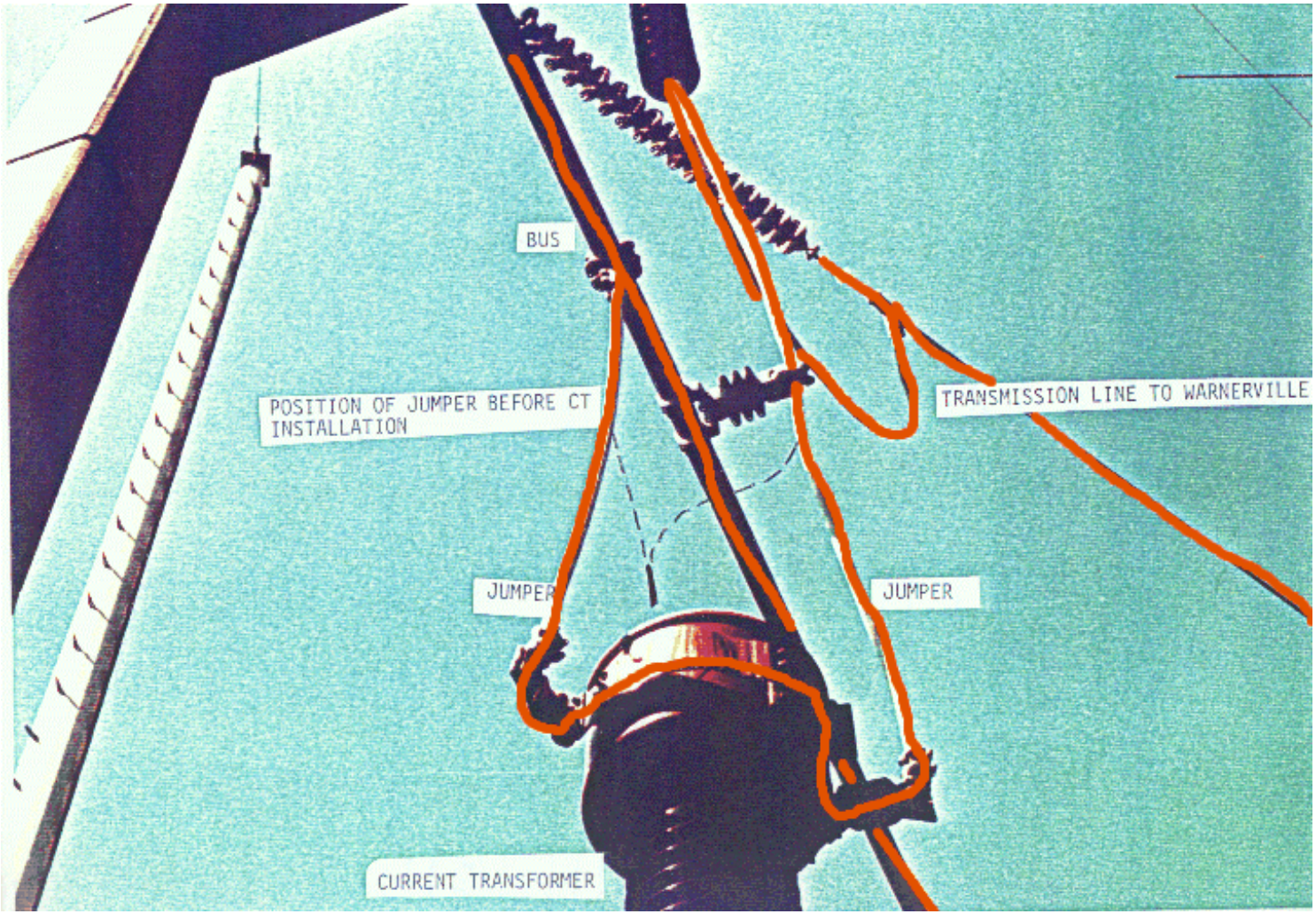
CT With Jumper Assembly



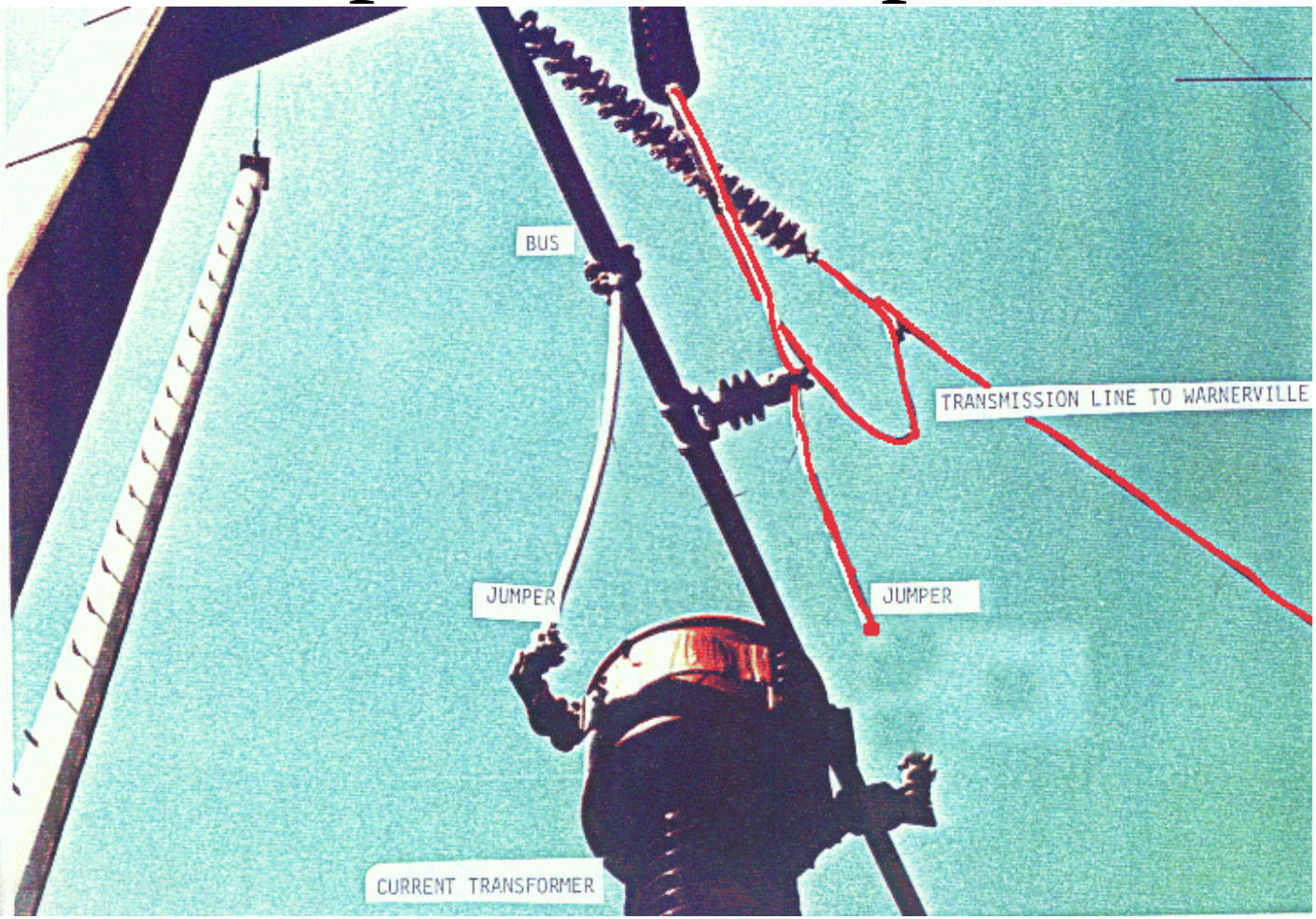
CT Disconnected from Jumper Assembly; Bus or Line Grounded



CT in Service



Bus Side Grounded With Separated Jumper



Grounding Rules of Thumb

- Always ground (close as practical) at worksite.
- Personal protective grounding means creating only **<u>one</u>** personal protective grounding path for fault, static, and induced current (worksite-rated).
- “Bonding” means placing yourself and or equipment in “parallel” with the *one* personal protective grounding path (not rated).
- All equipment and hardware within a worker’s possession or reach must be *bonded* to the *one* personal protective grounding path.

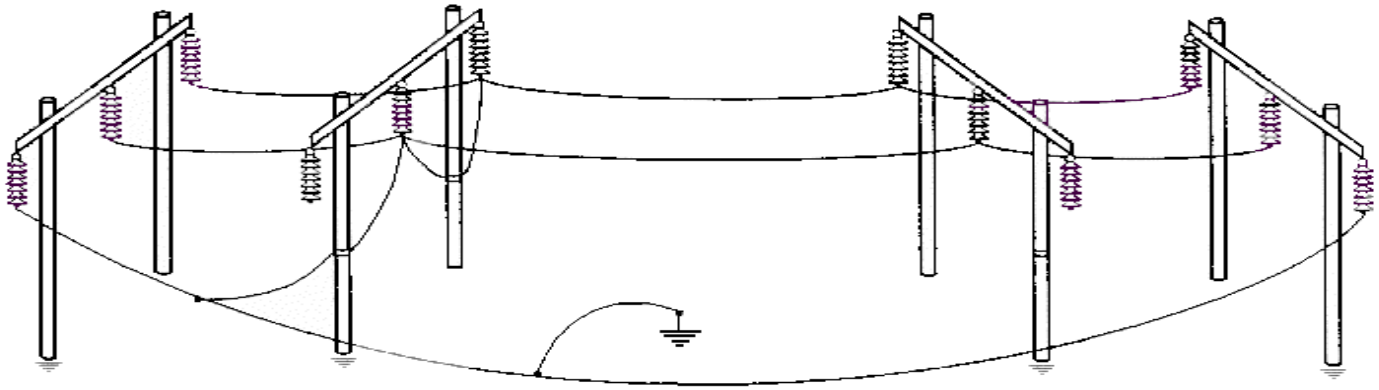
Grounding Rules of Thumb (cont.)

- Properly installed grounds at the worksite DOES NOT MEAN THE **JOB SITE** IS FREE FROM ELECTRICAL HAZARDS. It does remove the electrical hazard from the work **location**, however it creates another electrical hazard (step and touch potential) at the grounded location(s).

Areas of High Frequency of Incidents

- Cutting conductors or removing jumpers changes the circuit. Consider the ***before*** and ***after*** configuration of the circuit prior to performing the splice or removing or connecting the jumper.
- Parallel conditions requires special grounding applications. Why is this considered an issue?

Severing or Splicing



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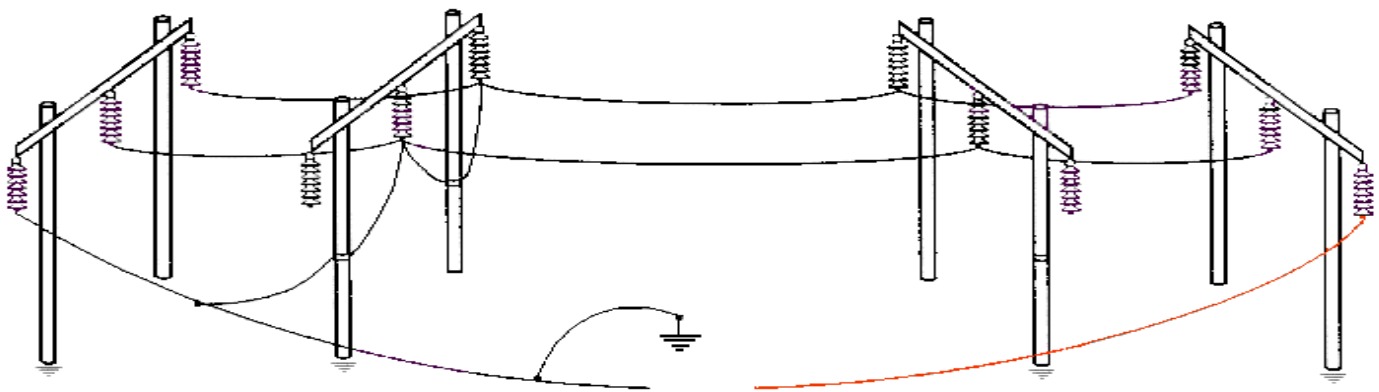
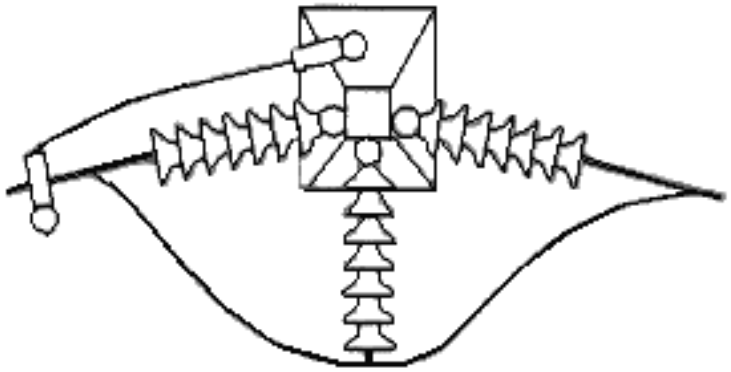


AFTER

Jumpers



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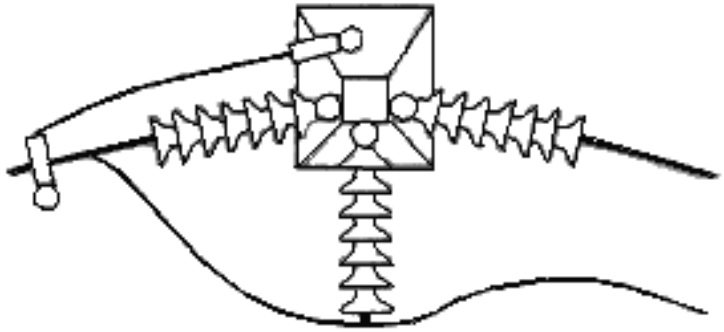


AFTER

Parallel Conditions/Circulating Ground Current

Circulating Ground Current Hazards

- Step potential - Near grounds (structure grounds, grounded equipment and ground rods).
- Touch potential - Between ground and structures and grounded equipment.
- Corrective actions - Keep personnel at least 10 feet away from grounding system (ground rods, structure grounds, down guys, grounded vehicles, etc.).

Removing/Avoiding Circulating Ground Current

- Only one crew on a line at one time.
- Keep disconnects open while worksite grounds are in place.
- When more than one crew is on the line at one time, sectionalize the line with open breaks (for each crew).
- Use live-line hotstick methods in performing maintenance on the deenergized line.

Worksite Grounding Procedures - High Induced Voltage

- Use in-line interrupters.
- Close ground switches while personal grounds are being installed or removed - then re-open after grounds are in place or removed.
- Deenergize parallel line while grounds are being installed or removed - then reenergize after grounds are in place or removed.

Electrical Meter Safety (Harvey Trager)

Electrical Measurement Safety

Understanding hidden hazards and new safety standards

Goals

Ž Awareness of electrical measurement hazards

Ž Understand international safety specifications for DMMs and Scopes

Ž Understand the 4 installation overvoltage categories

Ž Learn how to minimize and avoid electrical measurement hazards

Agenda

- What Electrical Power can do to a DMM
- IEC Safety Standards
- Arc Blast
- Electrical Tester Safety
- Scope Safety

Handheld Test Tool Safety

How not to save time...

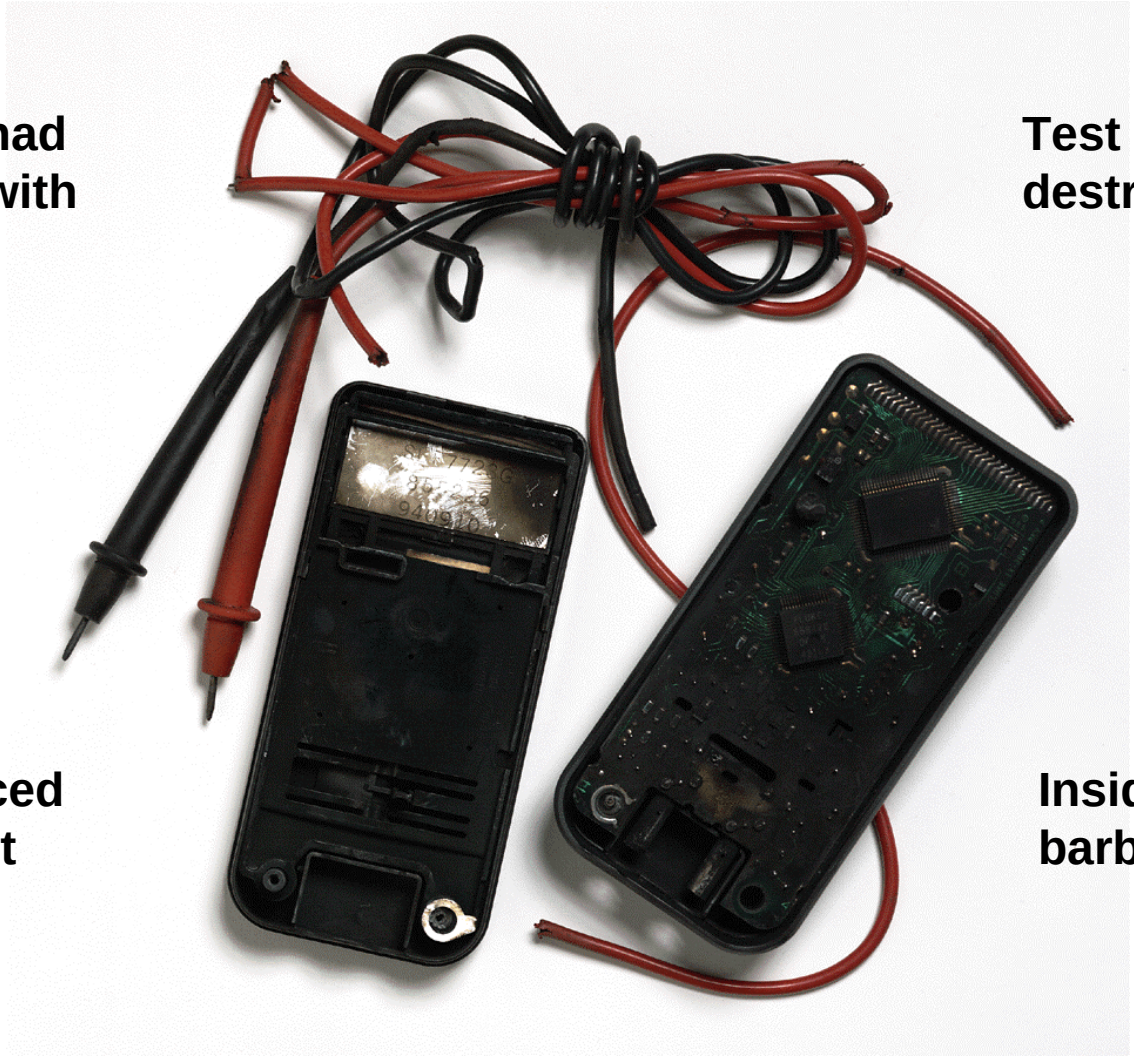
Last known earthly residence of automative fuse used to replace original fuse

Test leads survived intact

Handheld Test Tool Safety

This DMM had a hot date with 13.8 kV.

Test leads destroyed



13.8 kV arced over to test probes.

Insides were barbecued.

Handheld Test Tool Safety

The wrong meter to use on a power circuit.

250V fuse didn't open in time

Poor quality leads and probes led to injury.

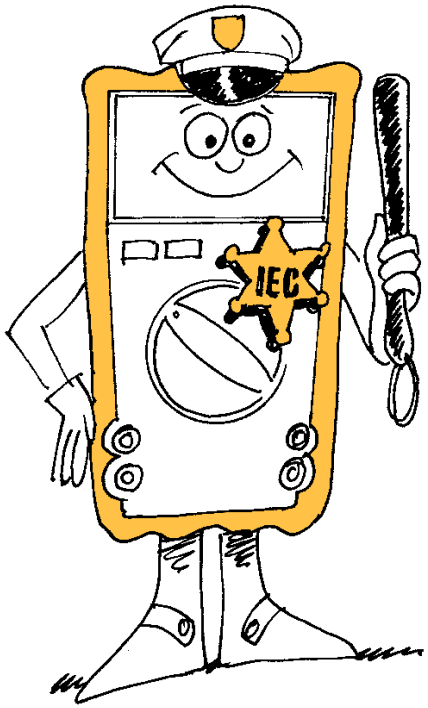
Probe tips burned off

Handheld Test Tool Safety

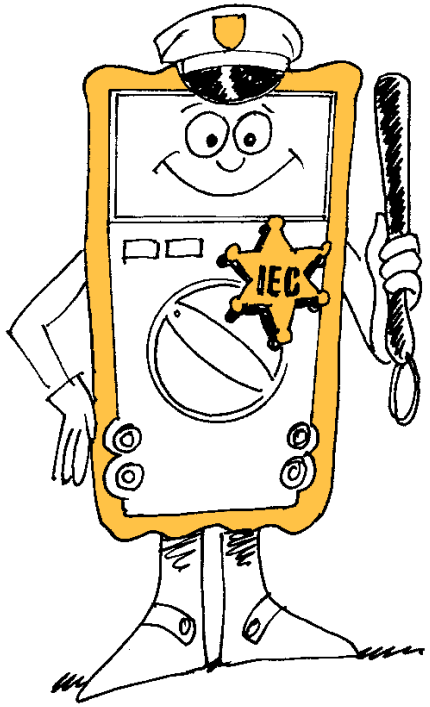
Fingerprints burned into probes

The electrician suffered severe burn injuries on his hand and arm.

New IEC Safety Standards



International Electrotechnical Commission



- **IEC 61010 is the new standard for *low voltage* "test, measurement and control equipment".**
- **IEC 61010 provides much improved protection against "overvoltage impulse transients" - voltage spikes.**
- **IEC 61010 is the basis for:**

  ANSI/ISA-S82.01-94 (US)

  CAN C22.2 No. 1010.1-92 (CAN)

  EN61010-1:1993 (EUR)

IEC 61010 Key Concepts

Protection against Overvoltage Transients

- **CATEGORIES: CAT I to CAT IV**

  The greatest danger from transients is in the high Categories, because they could trigger an *arc blast*.

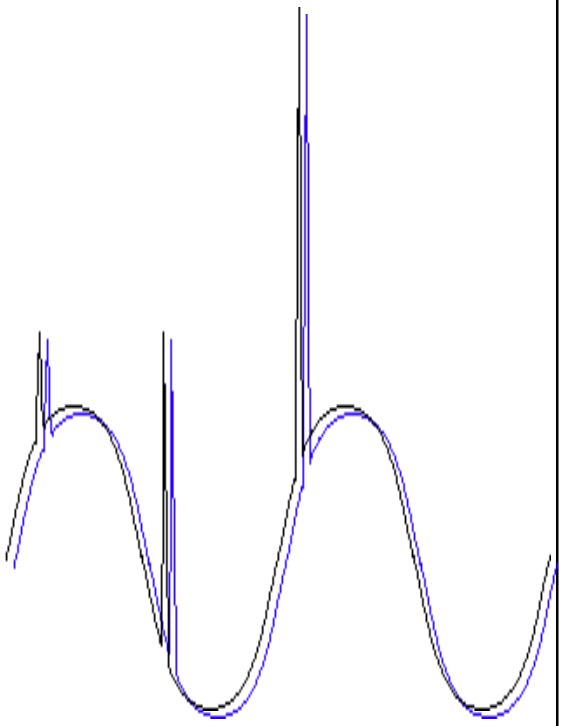
- **IMPULSE TESTING: No failure allowed**

  Meters must be tested by being hit with a specified number of transients, with specified peak voltages.

- **INTERNAL SPACING: increased**

  Clearance (distance through the air) and

  Creepage (surface distance) are increased.



Overvoltage Category

- **The level and energy of voltage impulses is dependent on the *location*.**
  The closer the location is to the power source, the higher the available fault current, the higher the Category

- **IEC 61010 defines four locations or *Categories*:**

  CAT IV **"Origin of installation"**

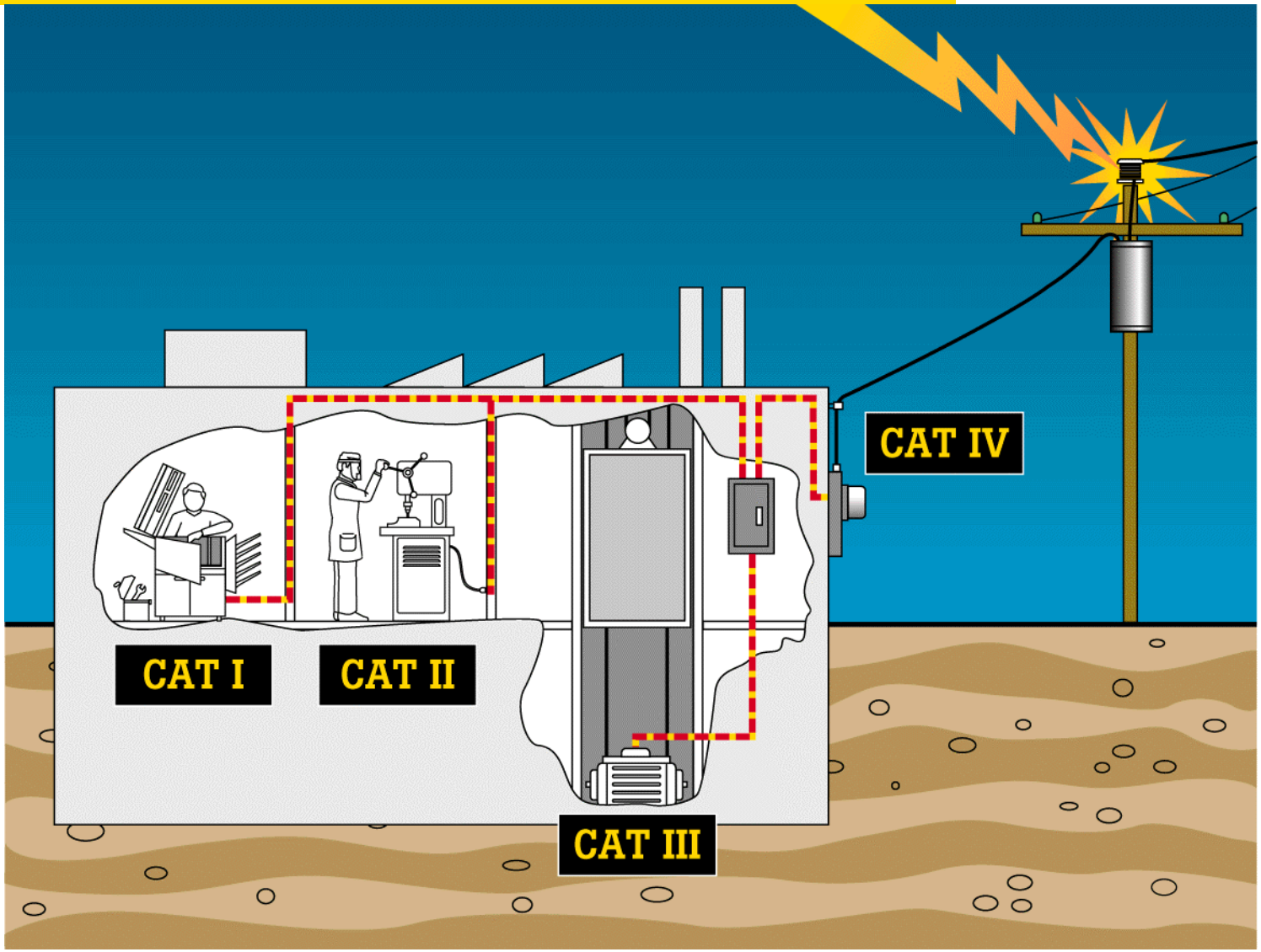
  Utility level and any outside cable run

  CAT III **Distribution wiring, including "mains" bus, feeders and branch circuits; permanently installed loads.**

  CAT II **Receptacle outlet circuit; plug-in loads.**

  CAT I **Protected electronic circuits**

Category Locations



Overvoltage Category

Common sense ways to think of Categories

- **The higher the *short circuit fault current* available, the higher the Category**
  - **High energy transients are much more dangerous, because they can trigger an arc blast**
- **The greater the *source impedance*, the lower the Category**
  - **Transients are dampened by system impedance as they travel from the point where they were generated.**
- **TVSS (Transient Voltage Surge Suppression) devices are sized larger (more joules) at the panel than at the receptacle outlet.**

Working voltage

- "working voltages' within each category

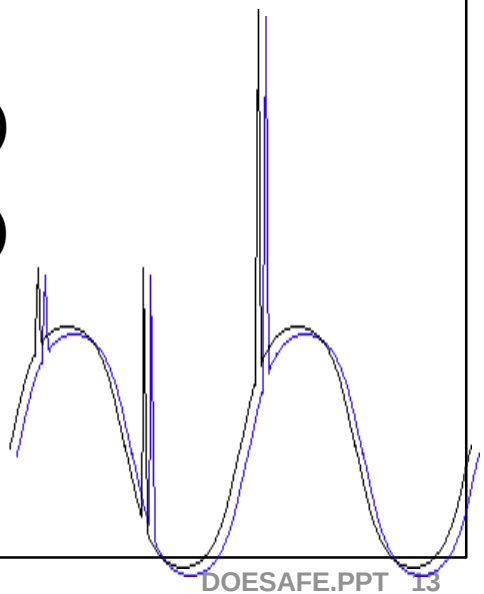
  50, 150, 300, 600, 1000V

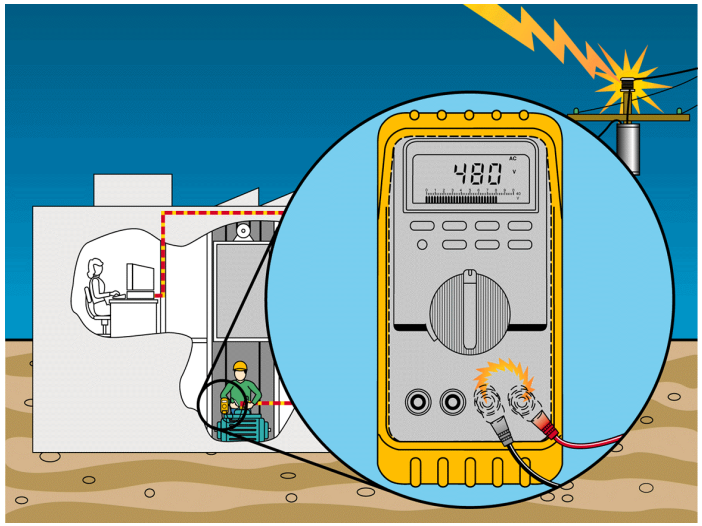
  Higher working voltage has greater transient withstand

- CAT III - 1000V: 8 kV impulse (2 Ω source)

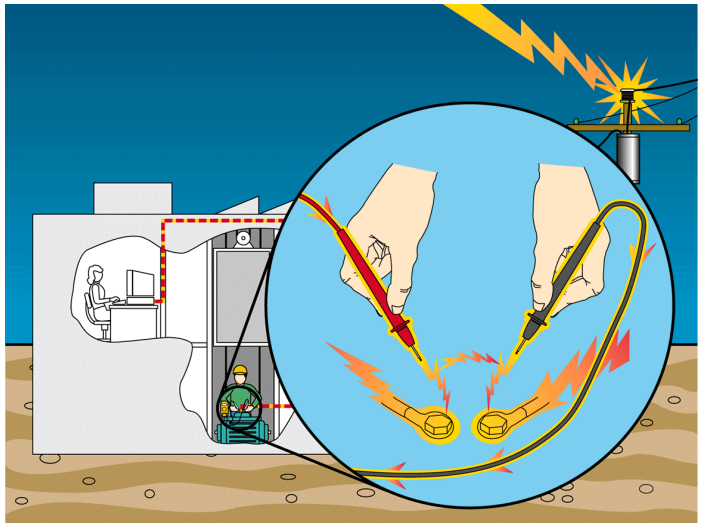
- CAT III - 600V: 6 kV impulse (2 Ω source)

- CAT II - 1000V: 6 kV impulse (12 Ω source)
- CAT II - 600V: 4 kV impulse (12 Ω source)

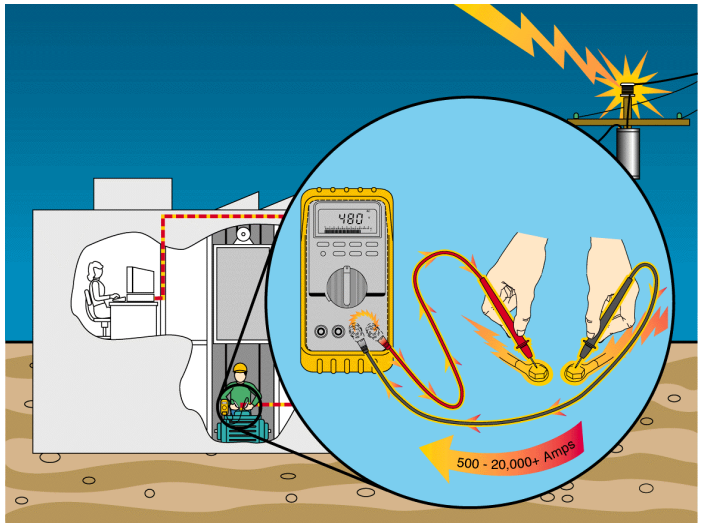




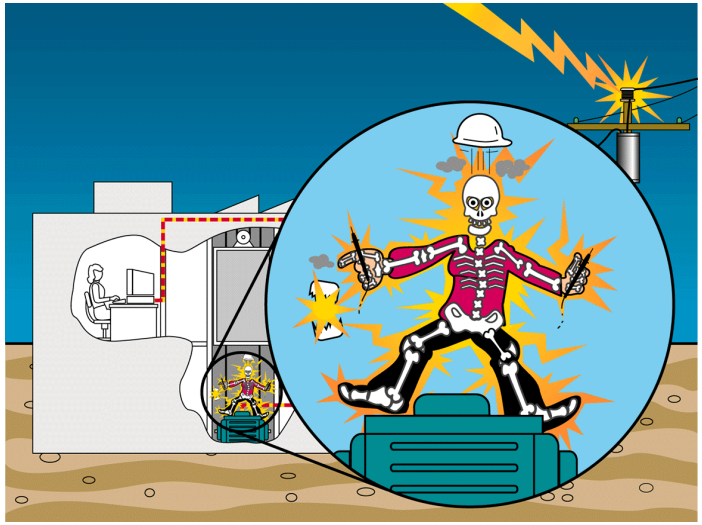
1) Flashover inside meter



3) Arcing at the terminals



2) Fault current in test leads



4) Arc blast

IEC61010 Reinforced Insulation

- **Dielectric withstand**

  Shock hazard protection

  Higher working voltage has greater transient withstand

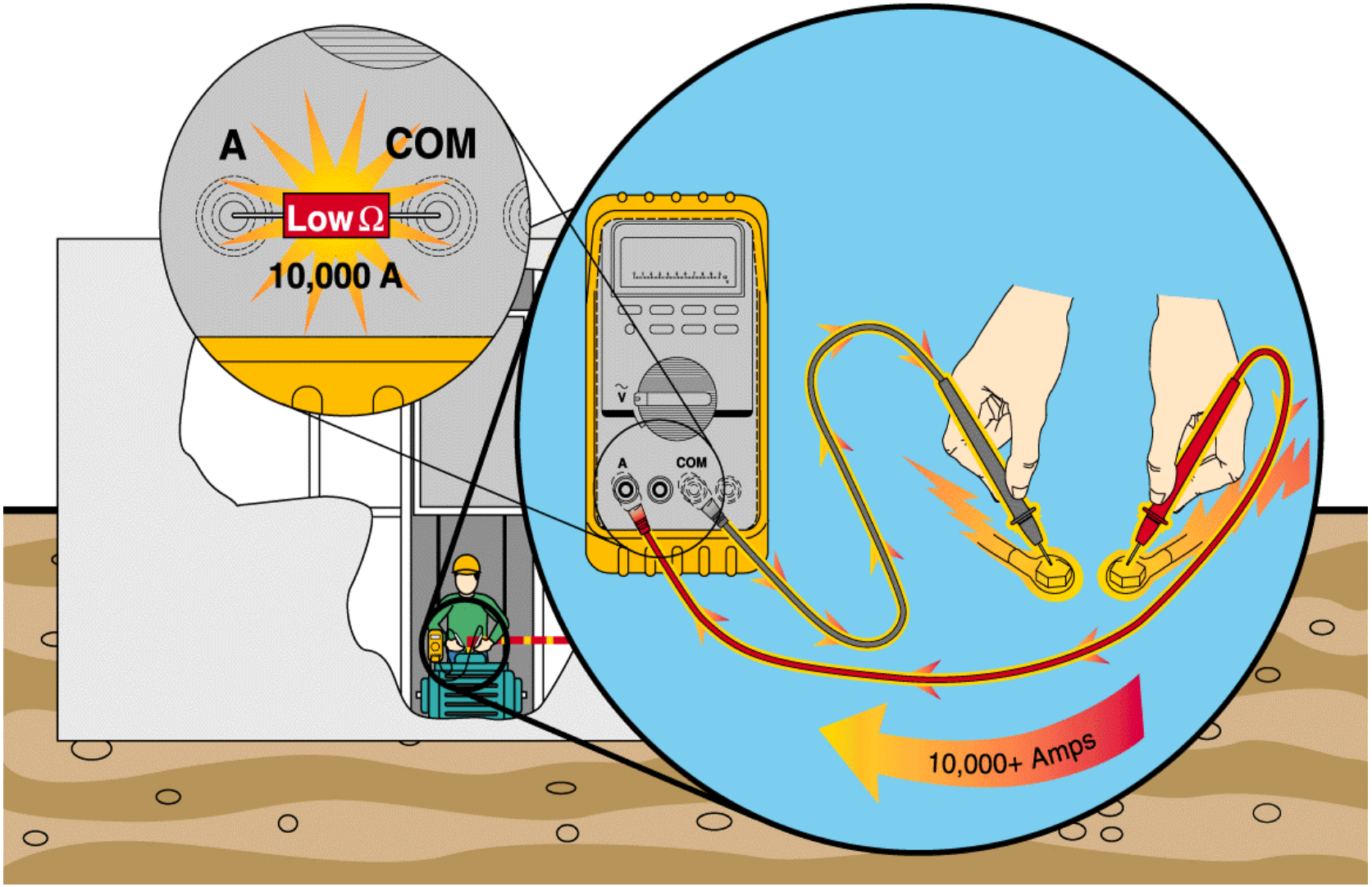
- **CAT III - 1000V:**

  7,400 VAC (rms) / 10,450 VDC for 1 minute

- **CAT III - 600V:**

  5,500 VAC (rms) / 7,850 VDC for 1 minute

Misuse of DMM in Ammeter Mode



Electrical Tester Safety

Protection from Arc Blast

- Over Voltage Category Ratings
  - for Industrial use CAT-III 1000V
- Protected for all tester functions

  Ohms / Continuity

  VDC

  Current
- High impedance (1 Mohm)

Electrical Tester Safety

Test Leads and Probes

- Safety rated (to the same or better than tester)
- Double Insulated
- Non removable test leads

  No banana plugs

  No banana jacks to make contact elsewhere

  Not inter changeable with ‘electronic’ style leads

  … more difficult to misuse

Electrical Tester Safety

Function Selection

- **Auto selection of AC and DC**
  - **one less switch position**
  - **reduced complexity / fewer mistakes**
  - **on DC function some models read zero on VAC**

- **Bright visual and audible warning**
  - **when connected to hazardous voltage**
  - **AC or DC and even Ohms**

Electrical Tester Safety

In-Line Current Measurement

- Can be hazardous if misused
  - leads in Amps jack and measure volts = SHORT
  - some fuses may not interrupt (250V fuses in 1000V meters) causing an arc
  - proper fuse replaced with improper fuse

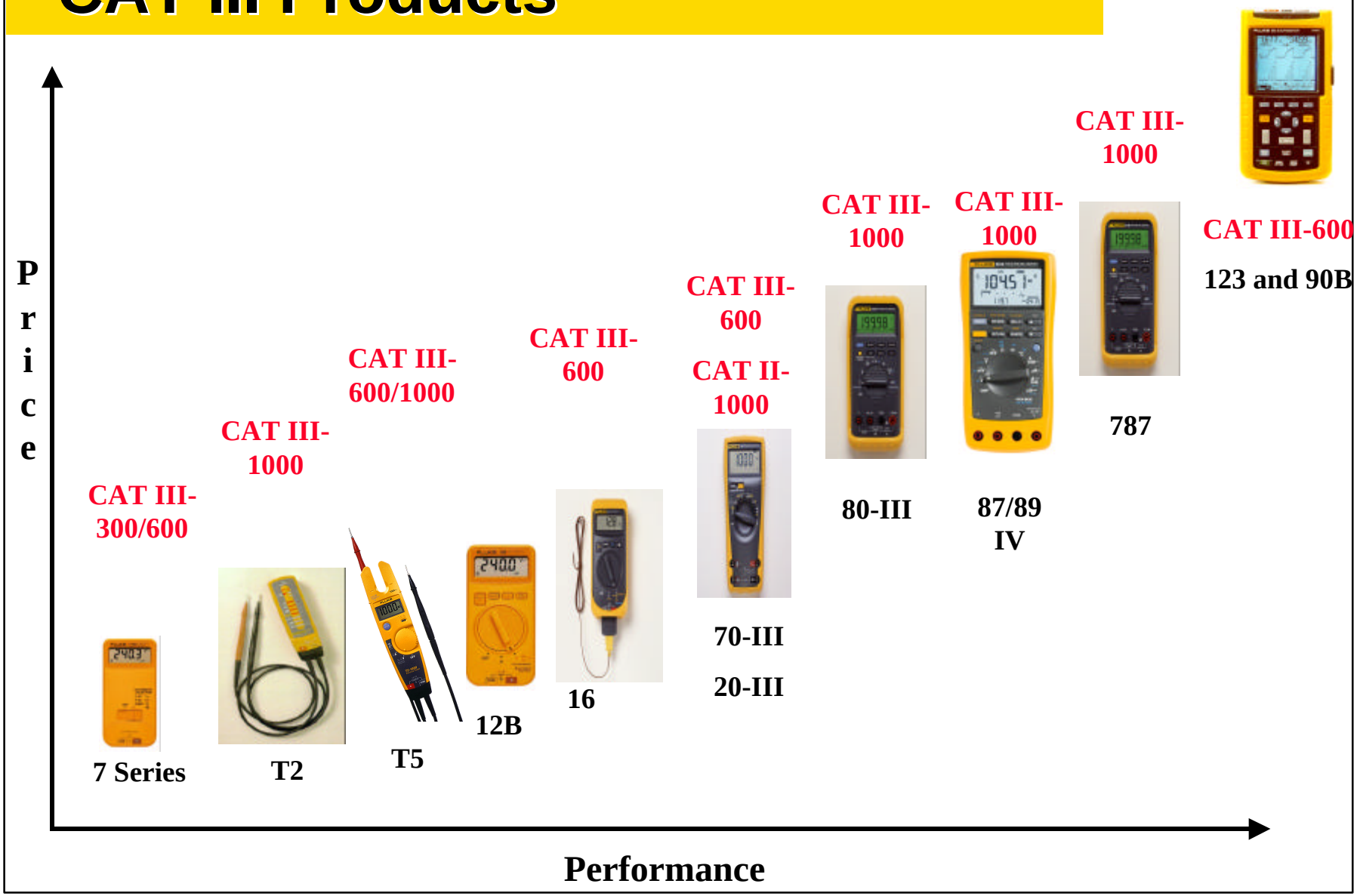
- Remove in-line / Add isolated current
  - no Amps jacks to mis-use
  - no fuses to replace
  - needed function for electrical crafts
  - 'Open Jaw' reduces complexity

Safety Checklist

Insist on these safety features:

- **Fused current inputs (high energy fuses).**
- **Overload protection on the ohms function.**
- **Test leads that have shrouded connectors and finger guards.**
- **Recessed input jacks.**
- **Meet the latest safety standards (CAT III-600V or 1000V) and are *independently certified.***

CAT III Products



What about my old meter?

- **Older meters, when re-evaluated for their CAT rating, almost never qualify as CAT III-600V.**
- **Unless a meter was specifically designed (in the last few years) to meet CAT III-600V or higher, it is probably a CAT II meter.**

***Old* 70**
Series-II
CAT II-600V

***New* 70**
Series-III
CAT III-600V
CAT II-1000V

Common DMM / Tester hazards

- **Arc from transients (lightning, load switching)**

  Protection: Independent certification to meet CAT III-1000V

- **Voltage contact while in continuity or resistance**

  Protection: Overload protection in OHMs up to the meter's Volt rating

- **Measuring voltage with test leads in current jacks**

  Protection: High energy fuses rated to the meter's voltage rating
  Use meters / testers without current jacks

- **Shock from accidental contact with live components.**

  Protection: Test Leads double insulated, recessed / shrouded, finger guards, CAT III - 1000V. *Replace when damaged*

- **Using meter or tester above rated voltage**

  Protection: Good karma

No Substitute for Safe Work Practices

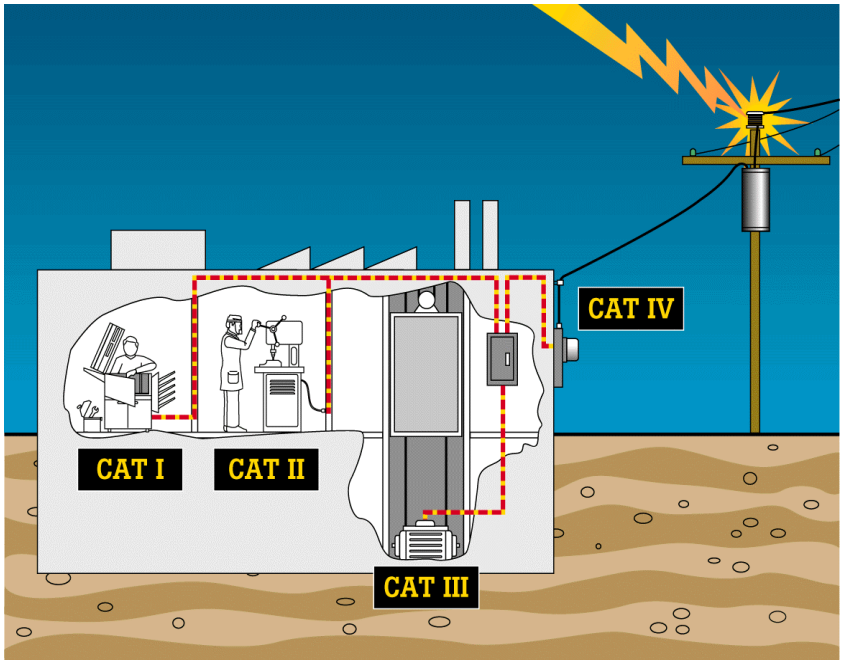
FLUKE ®

Safe practices include..

- Use equipment rated for the task
  - CAT-III 1000V not suitable for medium voltage
- Training
- Protective clothing equipment
- Lockout / Tagout

Oscilloscope Safety

- **Category ratings**
  - **Select a scope <u>and</u> probes <u>and</u> clamps for the worst case category**
- **Voltage ratings**
  - **Working voltage**
  - **Transient voltage**

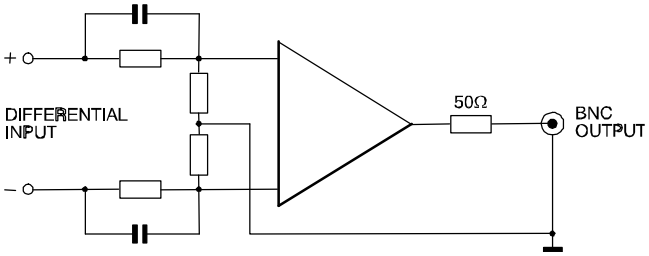


Oscilloscope Safety

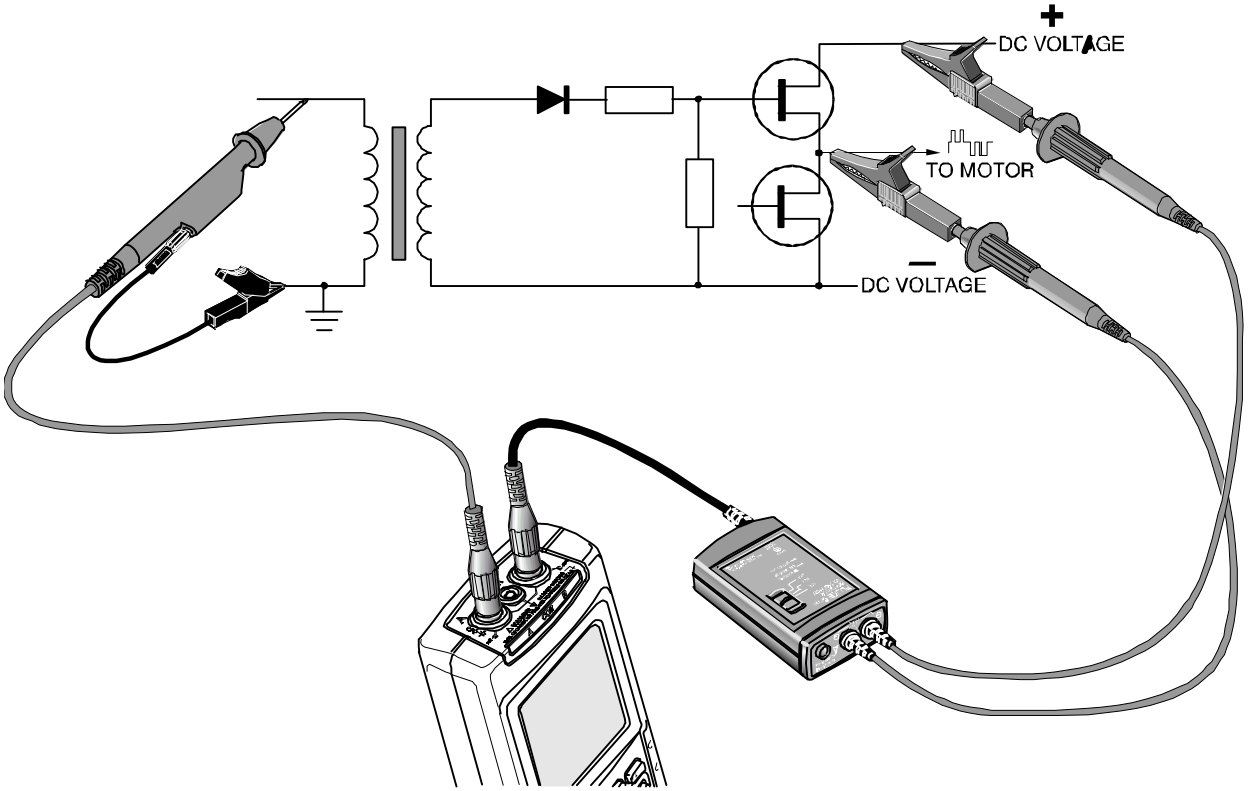
FLUKE ®

Line Powered Bench Scopes

- Use a differential or isolation probe to separate the earth ground connection of the scope from high energy circuits that are also referenced to earth ground.
- Isolate bench scope grounds *only* in conjuction with differential/isolation probes.



Oscilloscope Safety



Typical Use of a Differential Probe

Oscilloscope Safety

FLUKE ®

Battery Powered Scopes -

- Have inherent ground isolation for superior common mode noise rejection
- Some come standard with CAT III 600 volt probes for measurements in high energy circuits

Oscilloscope Safety

FLUKE ®

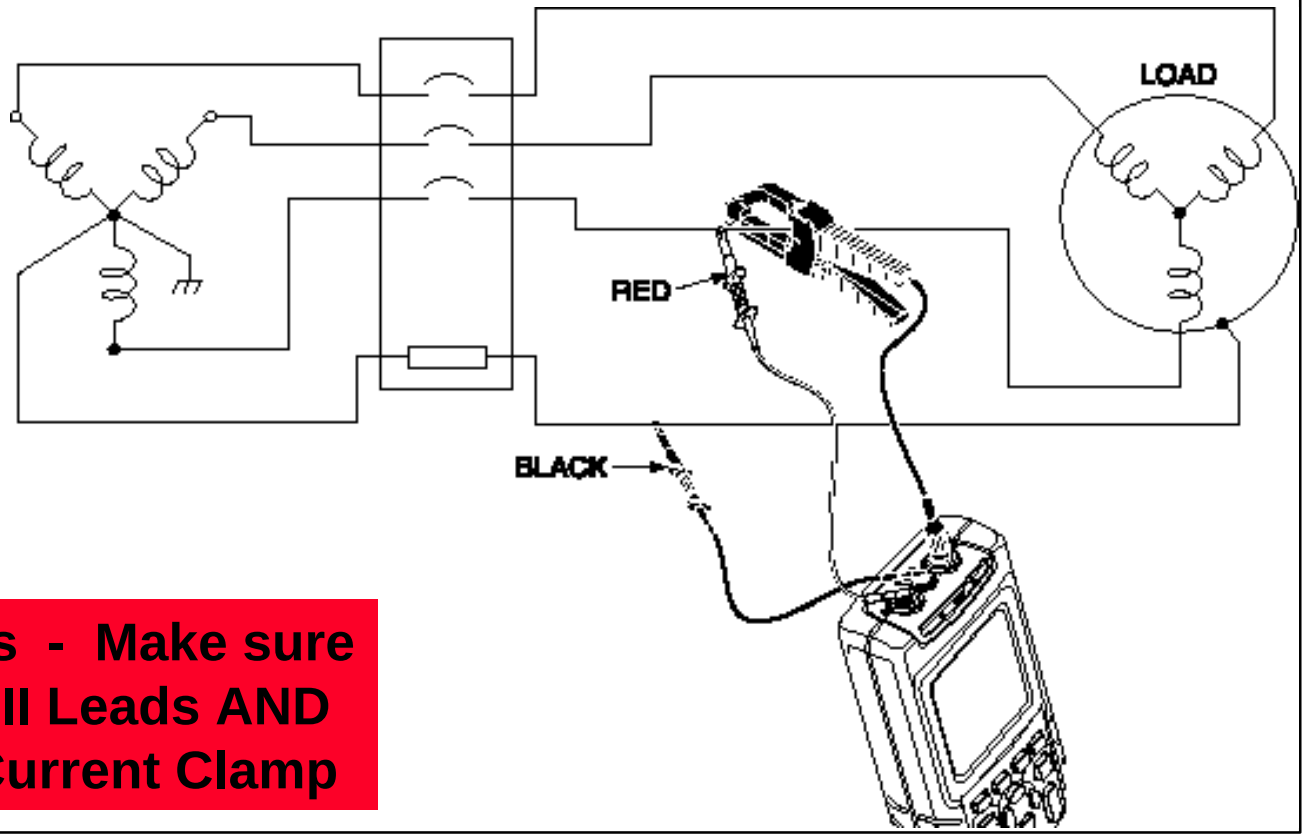
Probes

- Beware of bench scope probes - they are usually CAT I - 500 volts
- Don’t use CAT I or II divider probes on CAT III circuits
- Don’t use probes with exposed metal parts
- Don’t use probes without specified ratings
- Read the manual for safe probe connections - they may vary greatly between instruments

Oscilloscope Safety

Current Clamps

- Clamps have Category and working voltage ratings
- Do not exceed them



CAT III circuits - Make sure you use Cat III Leads AND Scope AND Current Clamp

What's the bottom line?

- **If you use a Scope on power circuits, you need a CAT III-600V Scope and Scope Probes.**
- **CAT II Scopes and Probes are mainly for loads that plug into a receptacle outlet.**

CAT III-600V

Thank You !!

Available support materials

- Safety Video Tape
- Safety Application Note
- Application Notes

(800) 44-FLUKE (800) FLUKEFAX www.fluke.com

harvey.trager@fluke.com / 425.356.6455

International Electrical Standards Update (Allen Bingham)

INTERNATIONAL ELECTROTECHNICAL COMMISSION

TECHNICAL COMMITTEE No 78:
LIVE WORKING

Revised draft agenda for the meeting to be held in Mulhouse (France) on 20 and 21 May 1999

1. **Opening of the meeting**

2. **Approval of the agenda 78/269A/DA**

3. **Confirmation of the minutes** of the meeting held in Birmingham (UK) on 2 nd and 3 rd of October 1997 **78/250/RM, June 1998**

Matters arising from the meeting held in Birmingham

4.1.Liaison with IEC/TC 11 concerning clearances - Report by Mr L. Sparrow;

4.2.Electric and magnetic fields (ACEC Task Force) - Reports by Messers. J. Lalot and G. Erofitsky - ACEC/1 06/INF;

4.3. Liaison with ISO/TC 214 - Report by Mr. A. Pierce;

4.4. Report on the conciliation related to IEC 61243-3 and TC 66 - Chairman of TC 78.

5. **Reports on the activity since the Birmingham meeting**

5.1. Report of the meetings of CAG - Chairman of TC 78 -

78/256/INF, 78/263/INF;

5.2. Information from Central Office - Mr. G. Erofitsky.

5.3. Liaison reports

5.3.1. IEC/TC 1 - Project 50-651: Chapter 651 of the IEV: Live Working Report by Mr. C. Hantouche;

5.3.2. CIGRIt 33-07 - Chairman of TC 78;

5.3.3. CENELEC TC 78 - Report by Mr. A. Pierce.

5.4. Status report relative to New Work Items

5.4.1. 78/253/NP: Revision of IEC 1243-1: Voltage detectors - Part 1 Capacitive type to be used for voltages exceeding 1 kV a.c. 78/266/RVN;

5.4.2. 78/254/NP: Internal insulation of the tools for live working Specification of dielectric type test - 78/267/RVN;

5.4.2. 78/255/NP: Mobile insulating hose used with hydraulic tools for live working - 78/268&268A/RVN.

5.5 Status report relative to projects under maintenance procedure

5.5.1. Project 60743: Terminology for tools and equipment to be used in live working (Revision of IEC60743) - 78/271/Q;

5.5.2. Project 78-4-3 (IEC 61057): Assessment of stability requirements for aerial devices with insulating boom used for live working - 78/272/Q.

5.6. Status report on Stage 0 projects

5.6.1. Project 61474: Portable protective gap for work site;

5.6.2. Project 61483: Guidelines on the use of earthing and short-circuiting device;

5.6.3. Project 78-5 (IEC 61482-2): Clothing for thermal protection of workers. Thermal hazards of an electric arc - Part 2: Performance requirement;

5.6.4. Project 61840: Gloves and Mitts of insulating material for electrical purposes without protective covers.

6. **Progress reports from Working Groups 78/276ANF**

6.1. Progress report of WG 1: Terminology and symbol;

6.2. Progress report of WG 11: Technical support;

6.3. Progress report of WG 12: Tools and equipment;

6.4. Progress report of WG 13: Protective equipment;

6.5. Progress report of WG 14: Diagnostic equipment;

7. **Projects completed since the Birmingham meeting**

7.1. Project 61229: Amendment - Rigid protective covers for live working on a.c. installations - quality assurance plan and acceptance test;

7.2. Project 61243-3: Voltage detectors - Part 3: Low voltage detectors for use on LV systems - (Two-Pole voltage type);

7.3 Project 61472: Live working - Minimum approach distance: Method of calculation

7.4. Project 61911: Live Working - Installation of distribution line conductors - Stringing equipment and accessory items.

8. **Status on documents circulated since the last meeting**

8.1. Project 60895: Conductive clothing for live working at a nominal voltage up to 800 kV a.c. or ± 400 kV d.c. - 78/249A/CD, 78/270/CC;

8.2. Project 60903 Ed.2 : Live working - Specification for gloves and mitts of insulating material for live working - 78/282/CD;

8.3. Project 61243-2: Addendum to IEC 1243-2 : Voltage detectors - Part 2: Resistive type to be used for voltages of 1 kV to 36 kV a.c. - 78/259/CDV, 78/281/RVC;

8.4. Project 61477: Guidelines for use of tools and equipment for live working - 78/265/CD;

8.5. Project 61478: Live working - Ladders of insulating material - 78/277/CD;

8.6. Project 61479 - Live working - Conductor covers (line hoses) of insulating material for electrical purposes - 78/273/CDV;

8.7. Project 61481: Portable phase comparators for use on voltages of 1 kV to 36 kV a.c. - 78/260/CDV;

8.8. Project IEC 61482-1: Clothing for thermal protection of workers. Thermal hazards of an electric arc - Part 1: Test methods - 78/283/CD;

8.9. Project 61813: Guidelines on the care and maintenance of aerial devices with insulating booms used for live working - 78/242/CD, 78/262/CC.

9. **Program of work and relevant decisions**

9.1. Review of TC 78 Strategic Policy Statement (SPS) -78/280/DC;

9.2. Replacement of CFC in TC 78 standards - 78/274/DC;

9.3. Decision related to symbol 5216 PR (double triangle);

9.4. Membership of TC Working Groups - 78/275/WG.

10. **Other business**

10. 1. ICOLIM 2000, Madrid (Spain) May 2000;

10.2. ESMO 2000 Montreal, (Canada), October 2000.

11. **Date and place of the next meeting**

12. **Close of the meeting**

e-mail: Burlteccon@AOL.com

TENTATIVE AGENDA FOR WORKING GROUP #13
MULHOUSE, FRANCE – MAY 17-18, 1999
CONVENOR – ARTHUR L. LEWIS

1. Review of 60903 – This is an update of IEC 903, originally issued in 1988. At our last meeting in Lisbon (September 19, 1998) we agreed that it was desirable to have as few standards as possible covering insulating gloves. Accordingly, we decided to incorporate IEC 61942 into 60903 as a category "M" glove. The revision was recently sent to the Central Office for circulation as a CD. If you do not receive it prior to the meeting, we will try to send copies to working group members prior to the meeting.

2. Review of 60895 – This standard covers conductive clothing for use in bare hand work on energized construction. It is obvious that a considerable amount of work remains to be done to determine what should be the resistance values desired. A study is currently being implemented and cooperation will be necessary in the providing of clothing for study. There is currently too much variation in results due to measurement technique and manufacture. We hope to have a draft circulated prior to the meeting and, if not, we will provide copies for group members either prior to or at the meeting.

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4. Review of status of 61840 – This standard was being prepared to cover gloves and mitts without protective covers to be used at voltages up to 4 kV. The Project Leader of this standard has been Ian Thorp. We had anticipated that a draft of this project could be circulated at several times over the past few months but due to delays, Chairman Gela has notified the Central Office to set the work back to Stage 0. Hopefully we can discuss the work at our meeting.

   If any member wishes to add a topic to the agenda please let me know prior to the meeting so that we can properly schedule our time.

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Face and Eye Protection from Electrical Arcs (Jack Hirschmann, Jr.)

In A Flash

"Is Your Electrical Flash Protection Adequate?"

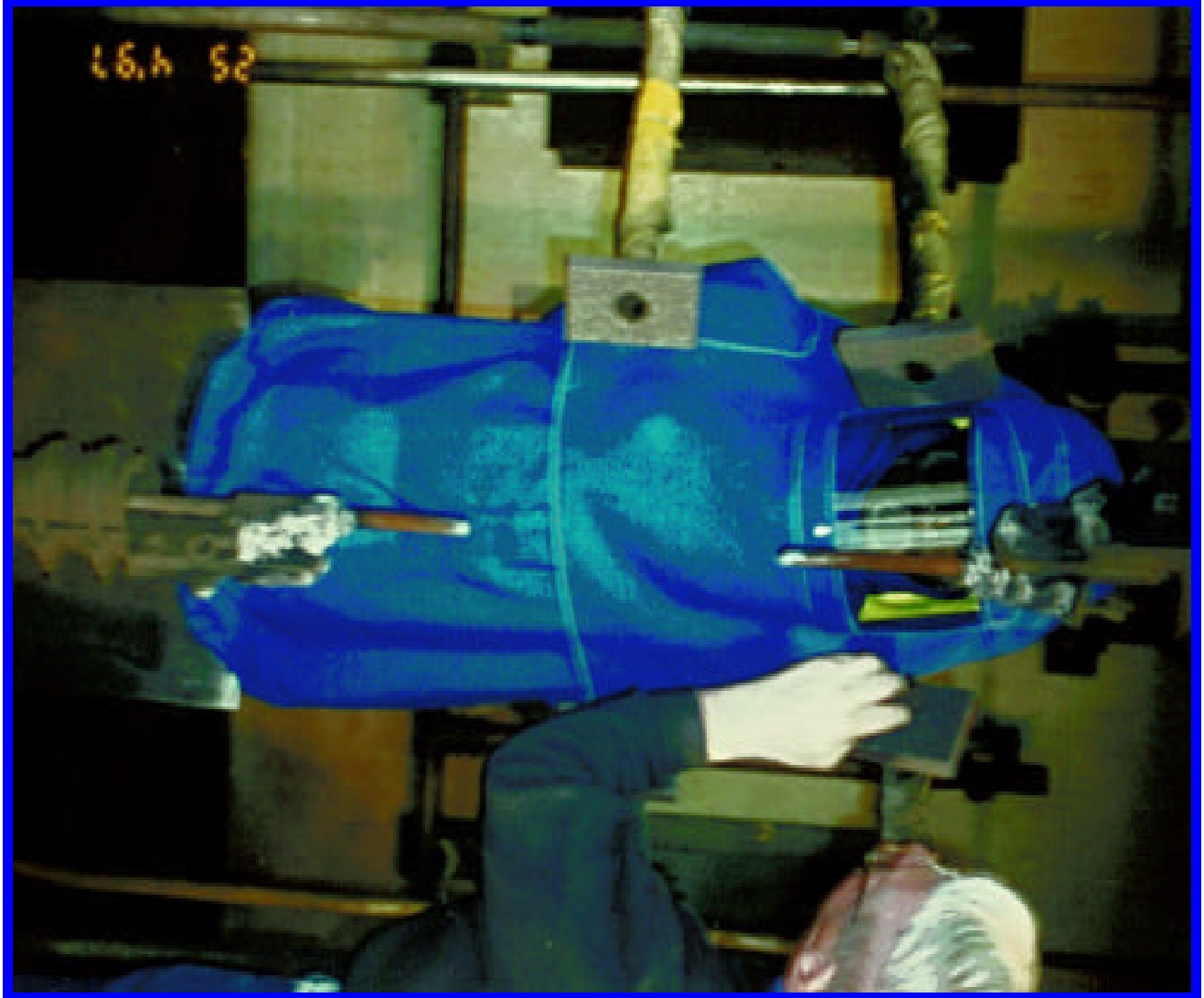
by Jack B. Hirschmann, Jr.

President of Oberon Company

Face and body protection must be incorporated together

B98

24 4'97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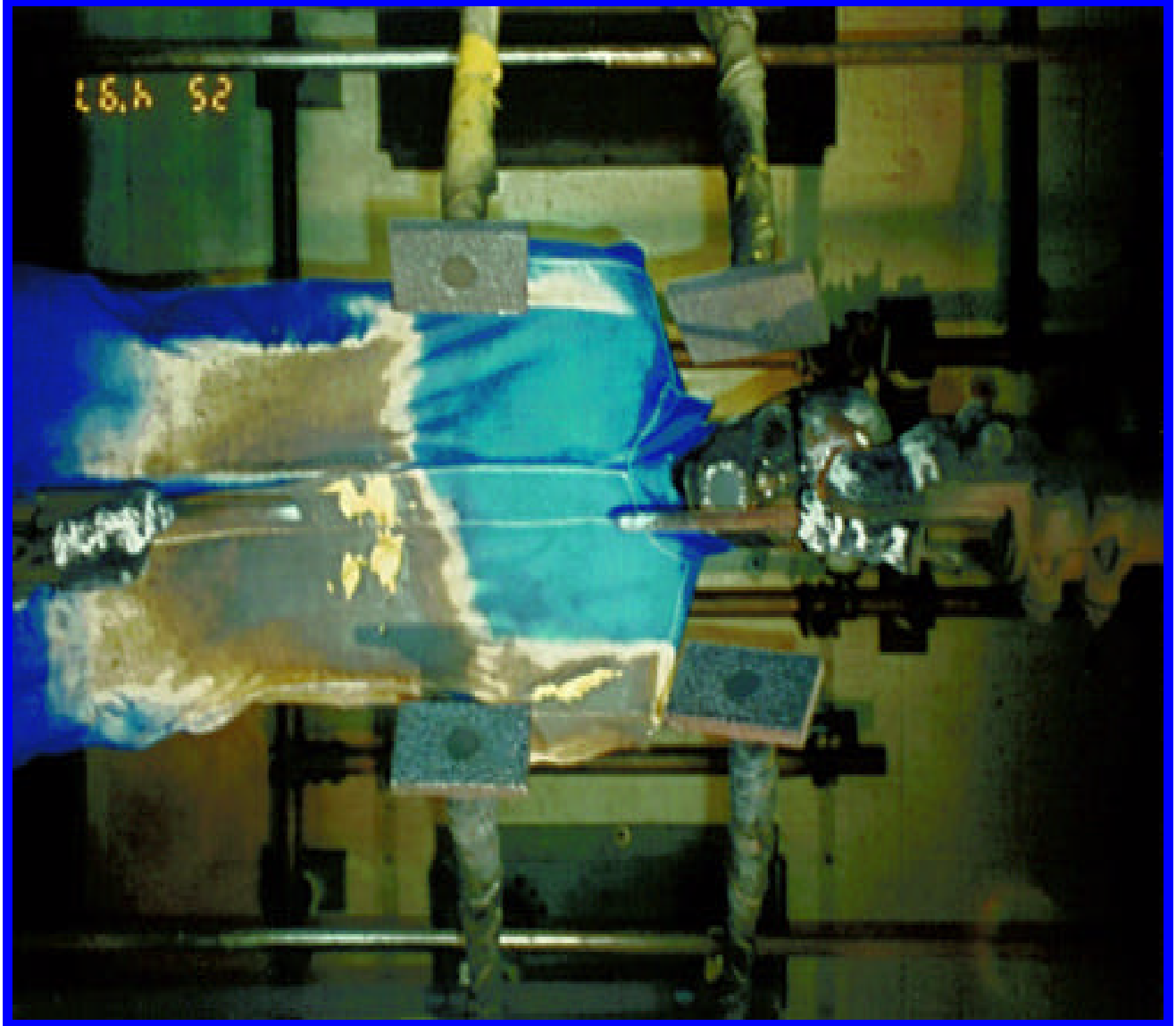

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Stoll Values - Oberon Company Test Results

SHIELDS	**ATP Values**
Clear UV absorbing Polycarbonate faceshield	1.2 cal/cm2
Gold Reflective UV Absorbing Polycarbonate faceshield	7.33 cal/cm2
Shade 5 propionate faceshield	3.7 cal/cm2*

* This item is only preliminary, the full requirement of samples were not run.

FABRIC	**ATP Values**
Single layer FR Cotton	
3 X 1 twill weave 7.5 oz.	6 cal/cm2
3 X 1 twill weave 9.3 oz.	7.9 cal/cm2
Single layer Polybenzimidazole	
4.6 weave	6.0 cal/cm2
6.0 weave	6.8 cal/cm2
8.6 weave	9.2 cal/cm2
Single layer Aramid	
4.5 oz. weave	4.6cal/cm2
6.0 oz. weave	6.4 cal/cm2
7.5 oz. weave	7.0 cal/cm2
Combination 6 oz. Aramid over 10 FR Cotton	31 cal/cm2
7 oz. Polybenzimidazole Para Aramid Aluminized weave	20.4 cal/cm2
6 oz. Aluminized Polybenzimidazole Blend Knit over 6 oz. Fr Cotton Flannel	55.4 Cal/cm2

At Oberon Company using the following conditions:

480 Volt System at the panel:

	Condition 1	Condition 2	Condition 3	Condition 4
Fault Current (Amperes)	12887	1300	15661	1094
Duration (Cycles)	8	300	8	300
Distance to Arc (inches)	8	8	8	8
Arc Length (inches)	4	4	4	4
Heat Output (Cal/cm2)	17.4	17.4	12.5	13.4
Heat Output (Cal/cm2)	34.8	34.8	25	26.8
Voltage	**12kv**	**12kv**	**21kv**	**21kv**

During the test, we discovered that not only did the reflective layer on the faceshield improve protection, but a reflective layer on the fabrics also proved to increase protection. Other findings:

- The state of art of faceshields needs to improve.

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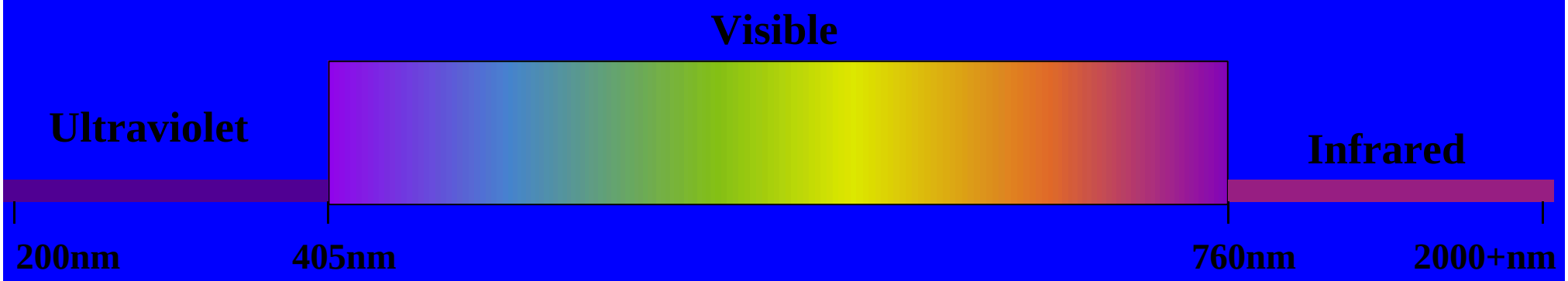
- The distance from the arc to the face may be further than the body.
- Users must consider multiple and aluminized fabrics.
- The inverse square rule may help, but don’t count on it.
- Always do a hazard site assessment, calculate the ATP value required and choose adequate face and body protection.

Spectrum of Visible, Ultraviolet and Infrared light



Transmittance Requirements for Clear Lenses and General-Purpose Filter

Shade Number	Luminous Transmission			Max. Effective Far-Ultraviolet Avg. Transmission	Max. Infrared Average Transmission
	Maximum %	Nominal %	Minimum %		
Clear	100	----	85	---	---
1.5	67	61.5	55	0.1	25
1.7	55	50.1	43	0.1	20
2.0	43	37.3	29	0.1	15
2.5	29	22.8	18.0	0.1	12
3.0	18.0	13.9	8.50	0.07	9.0
4	8.5	5.18	3.16	0.04	5.0
5	3.16	1.93	1.18	0.02	2.5
6	1.18	072	.44	0.01	1.5
7	0.44	0.27	0.164	0.007	1.3
8	0.164	0.100	0.061	0.004	1.0
9	0.061	0.037	0.023	0.002	0.8
10	0.023	0.0139	0.0085	0.001	0.6
11	0.0085	0.0052	0.0032	0.0007	0.5
12	0.0032	0.0019	0.0012	0.0004	0.5
13	0.0012	0.00072	0.00044	0.0002	0.4
14	0.00044	0.00027	0.00016	0.0001	0.3

Stoll Visible Light

Shields	Visible transmission	Stoll values
Clear UV	80 %	1.2
Gold	25 %	7.33
Shade 5	3 %	3.7

Identifying a Potential Arc Hazard Exposure to the Worker

- Electrical system voltage

Identifying a Potential Arc Hazard Exposure to the Worker

- · Electrical system voltage
- · Fault current available

Identifying a Potential Arc Hazard Exposure to the Worker

- · Electrical system voltage
- · Fault current available
- · Arc time duration

Identifying a Potential Arc Hazard Exposure to the Worker

- · Electrical system voltage
- · Fault current available
- · Arc time duration
- · Estimated arc gap based on equipment geometry

Identifying a Potential Arc Hazard Exposure to the Worker

- · Electrical system voltage
- · Fault current available
- · Arc time duration
- · Estimated arc gap based on equipment geometry
- · Minimum distance from the arc center line to the worker

Identifying a Potential Arc Hazard Exposure to the Worker

- · Electrical system voltage
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Identifying a Potential Arc Hazard Exposure to the Worker

- · Electrical system voltage
- · Fault current available
- · Arc time duration
- · Estimated arc gap based on equipment geometry
- · Minimum distance from the arc center line to the worker
- · Number of phases, single phase or 3-phase
- · Configuration of the arc (e.g. open arc or “arc in a box”).

NFPA 70E/OSHA Electrical Clothing Requirements (Allen Bingham)

Burn Accidents in Power Line Work

David M. Wallis

OSHA, Office of Electrical, Electronic, and Mechanical Engineering Safety Standards

Introduction

- Why is there so much interest in clothing for power line workers?
  - Number of injuries
  - Severity of injuries

✶ Reduction in Number of Injuries

- Minimize exposure
- Better work rules
- Better enforcement
  - Employers
  - OSHA
- (Not clothing!)

✶ Reduction in Severity of Injuries

- Reduce the power of the arc
- Reduce the time of the arc
- Increase the distance from the arc
- Wear personal protective equipment
  - Electrical protective equipment
  - Clothing

What Kind of Burn Injuries Have Occurred?

- Electric utilities
- Electrical power line contractors

Source of Data

- OSHA 17O forms
  - Federal OSHA data
  - Some state data
  - Only since April 1994
  - Only reviewed data

✶ OSHA 170 Forms

- All fatal accidents
- Five or more hospitalized injuries
- Newsworthy
- Other?

Electric Utility Burn Accidents
April 1984-December 1996

	Accidents	Injuries	Fatalities
All burn accidents	114	—	—
Electrical burn accidents	90	143	25

✶ Type of Work

	Accidents	Injuries	Fatalities
Generation	18	34	8
Substation	26	42	7
Transmission	3	9	0
Distribution	43	58	10

✶ Voltage

	Accidents	Injuries	Fatalities
120/240 V			
277/480 V	7	9	2
1.0 - 15.0 kV	36	51	8

✶ Voltage (continued)

	Accidents	Injuries	Fatalities
15.1 - 46.0 kV	7	8	
46.1 - 121 kV	7	18	1
138 kV +	1	2	

Severity of Injury

- Of the accidents where the extent of the burn injury was reported:
  - 75 percent had third degree burns
  - 70.8 percent had second degree burns
  - 37.5 percent had first degree burns

Electric Utility Burn Accidents
November 1994-December 1996

	Accidents	Injuries	Fatalities
All burn accidents	24	—	—
Electrical burn accidents	15	22	1

✶ Type of Work

	Accidents	Injuries	Fatalities
Generation	3	4	0
Substation	3	4	0
Transmission	2	7	0
Distribution	7	7	1

✶ Voltage

	Accidents	Injuries	Fatalities
120/240 V			
277/480 V	3	4	
1.0 - 15.0 kV	6	7	

✶ Voltage (continued)

	Accidents	Injuries	Fatalities
15.1 - 46.0 kV	1	1	
46.1 - 121 kV	3	8	
138 kV +			

Contractor Burn Accidents
April 1984-February 1994

	Accidents	Injuries	Fatalities
Electrical burn accidents	33	39	3
Substation	5	7	1
Transmission	1	1	0
Distribution	27	31	2

✶ Voltage

	Accidents	Injuries	Fatalities
1.0 - 15.0 kV	12	12	
15.1 - 46.0 kV	4	4	
138 kV +	2	2	

Severity of Injury

- Of the accidents where the extent of the burn injury was reported:
  - 100 percent had third degree burns
  - 50 percent had second degree burns
  - 12.5 percent had first degree burns

Conclusion

- There are a significant number of burn injuries
- The injuries are severe
  - Likely to cause death or
  - Serious injury

Conclusion (continued)

- Many of the injuries can be prevented
- The severity of the injuries can be reduced

OSHA 1926 Sub Part V

Timeline for Power Transmission and Distribution Standard Construction

June to August 1999	Stakeholder meetings to review current draft
July 15, 1999	Contractor to begin work on PRIA
October 15, 1999	Draft rule incorporating stakeholder comments (includes preamble)
May 2000	Contractor to complete work on PRIA
July 2000	Complete draft ready for OMB review
November 2000	Publication of proposal in Federal Register

NOTICE

This document is a pre-release version of Appendix C to the Program Directive on §1910.269. It currently has no official status within OSHA. It is still under development and does not represent official Occupational Safety and Health Administration policy.

Appendix C--Clothing

I. The ignition threshold of 100 percent natural cotton.

For an employer to use 100 percent natural cotton to comply with §1910.269(l)(6)(iii), the employer must estimate the maximum available heat energy to which each employee would be exposed. (There are computer programs that will calculate the heat energy from an electric arc based on the available fault current, arc duration, arc length, system voltage, and distance from the center line of the arc to the employee.)

In reviewing relevant electrical burn accidents, OSHA has found that the electric arc is nearly always closer to the employee than the minimum approach distance. In fact, an employee's violation of the minimum approach distance has been the primary cause of electric arc accidents involving burn injury. Additionally, mechanical failures can cause electric arcs. Even if the employee is outside the minimum approach distance of an energized part, an electric arc caused by a mechanical failure is as likely to be nearer to the employee as it is to be farther away. This would be the case, for example, if the energized part moved toward the employee during the failure or if the grounded part to which the electric arc traveled is between the energized part and the employee. (See Figure 1.) OSHA believes that a distance less than the minimum approach distance must be used to estimate the worst case exposure if the electric arc is caused by mechanical failure or unanticipated violations of the minimum approach distance.

To be considered reasonable, an employer's estimate of the maximum available heat energy to which an employee would be exposed must be based on the following assumptions:

1. The electric energy consumed by the arc would generate the maximum available arc power, and

2. For hot-stick work performed from below the conductors, for rubber glove work methods, and for other work methods that place the employee close to exposed energized parts, the employer must assume that an arc can occur at no more than 30.5 cm (12 inches) from the employee, unless the employer can demonstrate that safeguards are in place to assure that an arc cannot occur this close to the employee. For hot-stick work that places the employee to the side or above the exposed energized parts, the employer may determine that the arc will occur at a greater distance from the employee. However, for any work method, the employer must consider the different types of mechanical and electrical failures and human errors in determining the distance (which in the worst case will be less than the actual approach distance) that may occur.

An employer may use other assumptions if he or she can demonstrate that they are reasonable for the specific workplace application. However, the employer may not assume that the distance from the electric arc to the employee is greater than that given here unless other precautions, such as protective barriers, are used.

Table 1 lists the minimum heat energy under electric arc conditions that can reasonably be expected to ignite different weights and colors of cotton fabrics. The values listed, expressed in calories per square centimeter, represent a 10 percent probability of ignition with a 95 percent confidence level. If the maximum available heat energy estimated by the employer does not exceed the values listed in Table 1 for a particular weight and color of cotton fabric, then an outer layer of that material would not be expected to ignite and would be considered as being permitted under §1910.269(l)(6)(iii). Conversely, if the estimated heat energy exceeds the values listed in Table 1 for a particular weight and color of cotton fabric, that material may not be worn as an outer layer of garment.

For white cotton fabrics of a different weight from those listed, choose the next lower weight of white cotton fabric listed in Table 1. For cotton fabrics of a different color and weight combination than those listed, choose an equal or lesser weight of blue cotton fabric. If a white garment has a logo, a decorative insignia, or other design included on it, then the entire garment will be considered as being of a color other than white. (The darker portion of the garment can ignite earlier than the rest of the garment, which would cause the entire garment to burn.)

Employers may choose to test samples of genuine garments rather than rely on the values given in Table 1. The appropriate electric arc ignition test method is given in ASTM PS57. Using this test method, employers may substitute actual test data analysis results representing a 10 percent probability of ignition with a 95 percent confidence level.

Table 1—Ignition Threshold for Cotton Fabrics

Fabric Description				Ignition Threshold (cal/cm²)
Weight (oz/yd²)	Color	Weave	Material Type	
5.2	Blue	Twill	Shirt	4.6
6.2	White	Fleece	Shirt	6.4
6.9	Blue	Twill	Shirt	5.3
8.0	Black	Twill	Shirt or Pants	6.1
8.3	White	Sateen	Shirt or Pants	11.6
11.9	Tan	Duck	Shirt or Pants	11.3
12.8	Blue	Denim	Jeans	15.5
13.3	Blue	Denim	Jeans	15.9

Source: "Testing Update on Protective Clothing & Equipment for Electric Arc Exposure," IEEE Paper No. PCIC-97-35

II. Other considerations.

Clothing loses weight as it wears. This can lower the ignition threshold, especially if the garment has threadbare areas or is torn.

Adding layers of clothing beneath an outer layer of flammable fabric has no significant effect on the heat energy needed to ignite the outer fabric layer. Therefore, the outer layer of clothing must be treated as if it were a single layer to determine the proper ignition threshold.

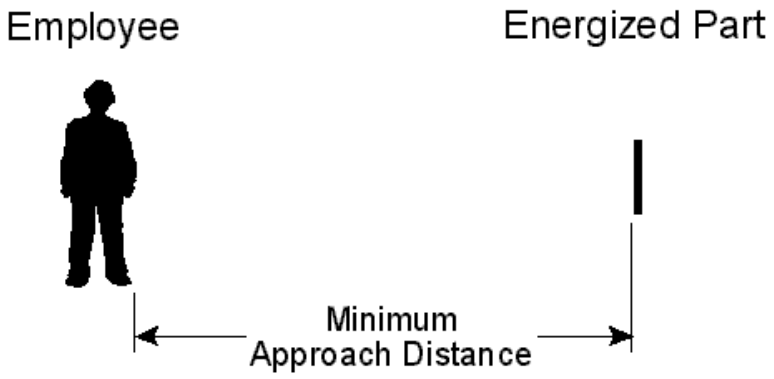
Flammable clothing worn in conjunction with flame-resistant and flame-retardant-treated clothing may not pose an ignition hazard. Flammable clothing may not be worn as an outer layer if it could be exposed to heat energy above the ignition threshold. Outer flame-resistant layers may not have openings that expose flammable inner layers that could be ignited.

When an outer flame-resistant or flame-retardant-treated layer would be unable to resist breakopen,[(1)] the next (inner) layer should be flame-resistant or flame-retardant treated.

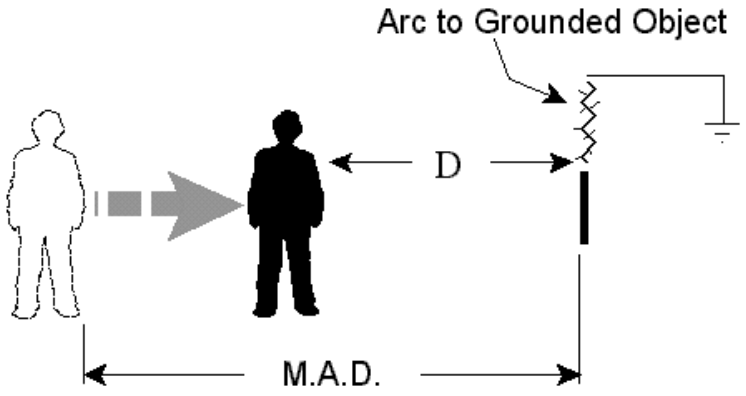
Meltable fibers must be avoided. When these fibers melt, they can adhere to the skin, transferring heat more rapidly, exacerbating any burns, and complicating treatment. This can be true even if the meltable fabric is not directly next to the skin.

Grounding conductors can become a source of electric arcing if they cannot carry fault current without failure. These possible sources of electric arcs[(2)] must be considered in estimating the distance from the electric arc to the employee.

Figure 1—Distance from Electric Arc to Employee



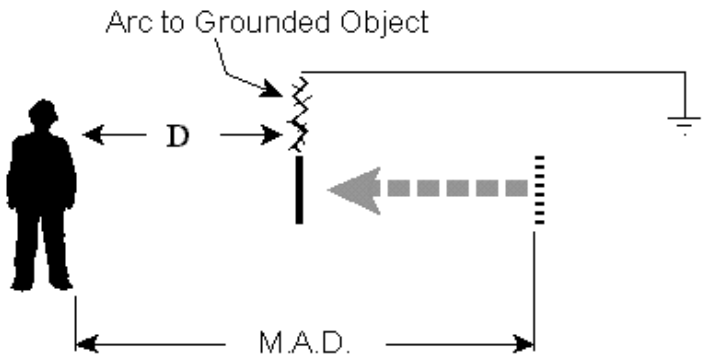
A — No Arc



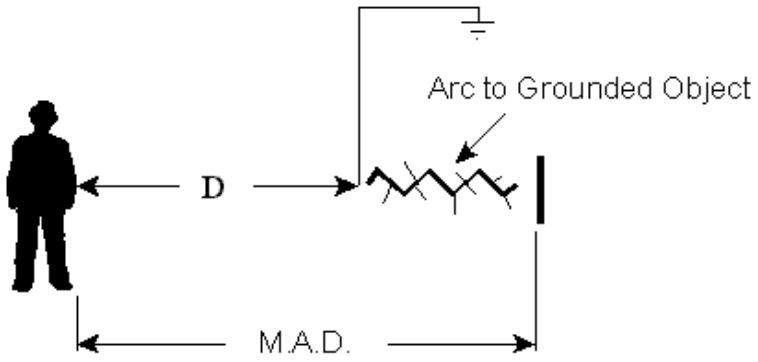
B — Employee Breaches M.A.D.

D = Employee to Arc Distance

Figure 1—Distance from Electric Arc to Employee—Continued



C — Mechanical Failure, Live Part Breaches M.A.D.



D — Mechanical Failure, Grounded Part Breaches M.A.D.

D = Employee to Arc Distance

1. Breakopen is the creation of holes, tears, or cracks in the exposed fabric such that incident energy is no longer effectively blocked.

2. Static wires and pole grounds are examples of grounding conductors that might not be capable of carrying fault current without failure. Grounds that can carry the maximum available fault current are not a concern and need not be considered a possible electric arc source.

Arc Resistant Rainwear (Bill Snyder)

JOMAC®

ARC RESISTANT RAINWEAR

DOE Electrical Safety Conference

Orlando, FL

Presented by: Bill Snyder

HISTORY

- MARCH 1998 ASTM F-18 COMMITTEE APPROVED THE STANDARD AND TEST METHOD FOR RAINWEAR EXPOSURE TO ELECTRIC ARCS.
- STANDARD SPECIFIES THE MINIMUM LEVEL AT WHICH RAINWEAR BREAKS OPEN WHEN EXPOSED TO MOMENTARY ELECTRIC ARCS OR OPEN FLAMES

WHAT IS AN ELECTRIC ARC?

- A PASSAGE OF SUBSTANTIAL ELECTRICAL CURRENT THROUGH IONIZED AIR
- THE ARC TYPICALLY LAST LESS THAN ONE SECOND
- HAS EXTREMELY HIGH RADIANT ENERGY
- IS EXPLOSIVE IN NATURE
- CAN MELT OR IGNITE EVERY DAY CLOTHING

WHY SHOULD YOU CONSIDER ARC-RESISTANT RAINWEAR?

- MUCH OF THE RAINWEAR SOLD IN THE US AND CANADA WITH AN ‘FR’ LABEL ONLY PASSES A FEDERAL TEST METHOD FTMS 191A-5903 WHICH EASILY PASSES RAINWEAR WITH MELTING CHARACTERISTICS
- MOST OF THIS TYPE OF ‘FR’ RAINWEAR SHOWS MELTING CHARACTERISTICS

JOMAC®

ARC RESISTANT RAINWEAR

FTMS 191A-5903

- FLAME RESISTANT, VERTICAL MOUNTED SPECIMENS SHALL NOT MELT OR DRIP WHEN SUBJECTED TO THE FLAME OR CONTINUE TO BURN MORE THAN TWO SECONDS AFTER REMOVAL OF THE IGNITION SOURCE
- CHAR LENGTH SHALL BE LESS THAN 6”

JOMAC®

ARC RESISTANT RAINWEAR

WHAT HAPPENS WHEN THIS RAINWEAR IS EXPOSED TO AN ELECTRIC ARC?

- MELTS, DRIPS AND SPLATTERS
- BREAKS OPEN EXPOSING CLOTHING UNDER IT TO THE ELECTRIC ARC. IF THAT CLOTHING IS NOT FLAME RESISTANT, IGNITION CAN RESULT.

CONSEQUENCES OF ELECTRIC ARCS

- INJURY
  - SECOND AND THIRD DEGREE BURNS
  - POTENTIALLY FATAL BURNS
- COST
  - MEDICAL CARE
  - WORKER'S COMPENSATION
  - LOST PRODUCTIVITY
- EQUIPMENT DAMAGE

WHO IS EXPOSED TO THE RISK OF ELECTRIC ARCS?

- SWITCHING OPERATORS
- LINE WORKERS
- ELECTRICIANS
- POWER GENERATION WORKERS
- UNDERGROUND CABLE WORKERS
- SUBSTATION OPERATORS

WHAT AFFECTS THE EXTENT AND SERIOUSNESS OF INJURY?

- INTENSITY OF AN ELECTRIC ARC
- DURATION OF AN ELECTRIC ARC
- DISTANCE OF THE WORKER FROM THE ARC
- TYPE AND FIT OF CLOTHING WORN
- PERCENTAGE OF BODY BURN
- AGE
- MEDICAL CONDITION

SELECTING A RAINSUIT TO MEET STANDARD

- GARMENT MUST MEET PERFORMANCE CRITERIA OF STANDARD
- ATPV: (ARC THERMAL PERFORMANCE VALUE) THE INCIDENT ENERGY ON A FABRIC OR MATERIAL THAT RESULTS IN SUFFICIENT HEAT TRANSFER THROUGH THE FABRIC OR MATERIAL TO CAUSE THE ONSET OF A SECOND DEGREE BURN

SELECTING A RAINSUIT TO MEET STANDARD (CONT)

- ARC PRO SOFTWARE PROGRAM CAN BE USED TO DETERMINE ATPV LEVELS
- STRENGTH AND WEAR RESISTANCE OF MATERIAL AND SEAMS
- SIZING
- LABELING
- FLAME RETARDANCY

JOMAC®

ARC RESISTANT RAINWEAR

- **CAN MANUFACTURERS DESIGN GARMENTS FOR YOUR NEEDS?**
  - REFLECTIVE TAPE
  - LOGO
  - POCKETS
  - CAPE VENTED BACK
  - GENEROUS SIZING
  - COLORS
- **FEATURES AND BENEFITS OF MATERIAL**
  - LEVEL OF PROTECTION
  - COMFORT
  - PRICE
  - WATERPROOF
- **DO WORKERS AND COMPANY LIKE IT?**

JOMAC®

ARC RESISTANT RAINWEAR

WHAT TYPE OF GARMENTS ARE AVAILABLE?

- TRI-LAMINATE UTILITY SUIT
  - *Jomac style #806*
- NEOPRENE ON NOMEX IIIA
  - *Jomac style #807*
- PVC ON E-89 NOMEX/KEVLAR
  - *Jomac style #808*

JOMAC®

ARC RESISTANT RAINWEAR

TRI-LAMINATE UTILITY SUIT

➔CONSTRUCTION FEATURES ONE LAYER OF FLAME RETARDANT POLYURETHANE BETWEEN TWO LAYERS OF NOMEX III

➔9 OUNCE SQUARE YARD

➔BREATHABLE

➔LIQUID PROOF

➔ATPV VALUE OF 14.98 cal/cm^2

➔NON-CONDUCTIVE

➔SEWN WITH KEVLAR THREAD FOR ADDED DURABILITY

➔ALL SEAMS DOUBLE LOCK STITCHED AND TAPED

➔ALL SEAMS AND HARDWARE GUARANTEED

➔MADE IN USA.

JOMAC®

ARC RESISTANT RAINWEAR

NEOPRENE ON NOMEX IIIA

- ➔ NEOPRENE ON NOMEX IIIA
- ➔ SOFT AND PLIABLE
- ➔ 10 OZ. SQUARE YARD
- ➔ NON CONDUCTIVE
- ➔ SEWN WITH KEVLAR THREAD FOR ADDED DURABILITY
- ➔ RAGLAN SLEEVE
- ➔ ALL SEAMS DOUBLE NEEDLE STITCHED AND TAPED
- ➔ ATPV OF 14.85 cal/cm^2
- ➔ ALL SEAMS AND HARDWARE GUARANTEED
- ➔ MADE IN USA

JOMAC®

ARC RESISTANT RAINWEAR

PVC ON E-89 NOMEX/KEVLAR

- ➔ 8 OZ. SQUARE YARD
- ➔ LIGHT WEIGHT

2

- ➔

  ALL SEAMS AND HARDWARE GUARANTEED
- ➔

  SEWN WITH KEVLAR FOR ADDED DURABILITY
- ➔

JOMAC®

ARC RESISTANT RAINWEAR

WHAT IS ACCEPTABLE UNDER THE STANDARD?

- PVC OR NEOPRENE COATING ON NOMEX
- NOMEX-KEVLAR COTTON LINING
- NOMEX TRI LAMINATE

WHAT SHOULD BE AVOIDED?

- RAINWEAR WITH MELTING SUBSTRATES
  - NYLON
  - POLYESTER

SUMMARY

- UNDERSTAND INDUSTRY STANDARDS
- UNDERSTAND THE NEEDS OF YOUR COMPANY
- CHOOSE THE BEST RAINSUIT TO SATISFY YOUR NEEDS
- KNOW WHAT PRODUCTS THE INDUSTRY HAS TO OFFER

JOMAC®

ARC RESISTANT RAINWEAR

- BILL SNYDER - PRODUCT MANAGER
- PHONE: 800-566-2258
- FAX: 215-343-0912
- E-MAIL: JOMAC@JOMAC.COM
- INTERNET: WWW.JOMAC.COM

JOMAC®

ARC RESISTANT RAINWEAR

QUESTIONS

COMMENTS

DISCUSSION

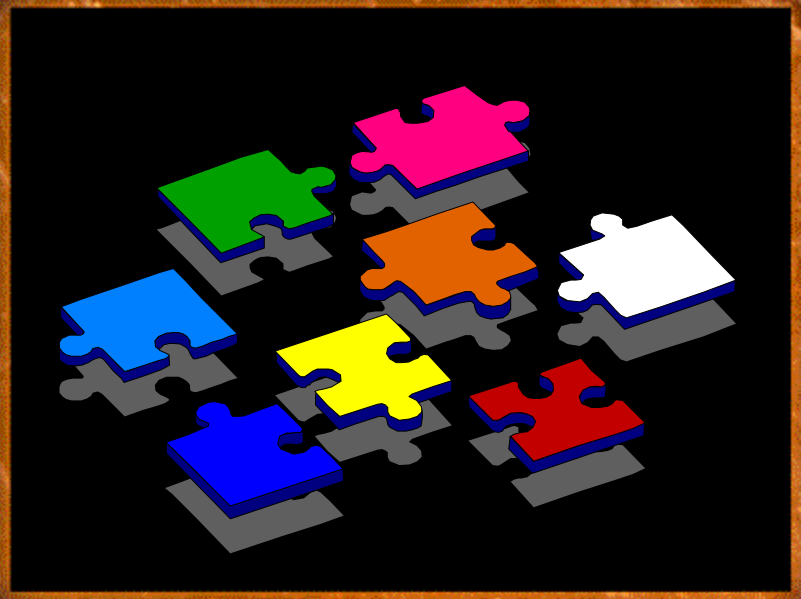
Jomac Products Inc. • 863 Easton Road • Warrington, PA 18976
Phone (215) 343-0800 • 800-566-2289
Fax (215) 343-0912 • Order Fax: 800-995-6622
Internet: www.jomac.com • e-mail: bsnyder@jomac.com

Underground Detection Update (Jerry Phillips)

Metrotech helps you
get the
job done
METROTECH

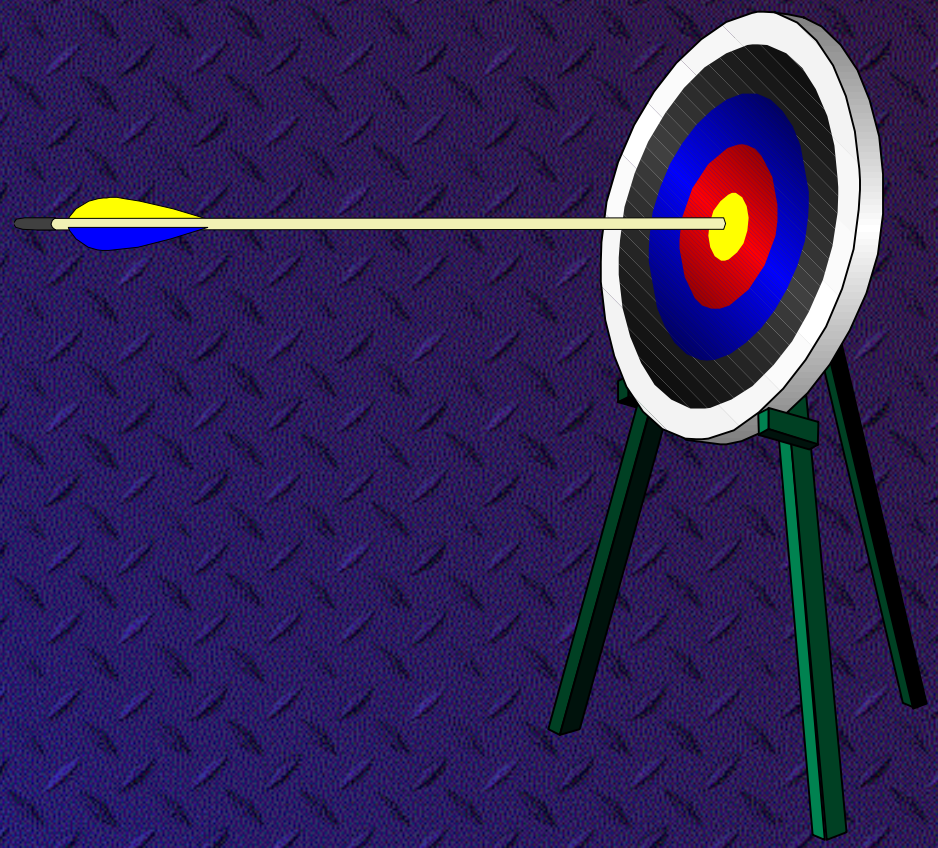
Confident Locating

Putting the puzzle together



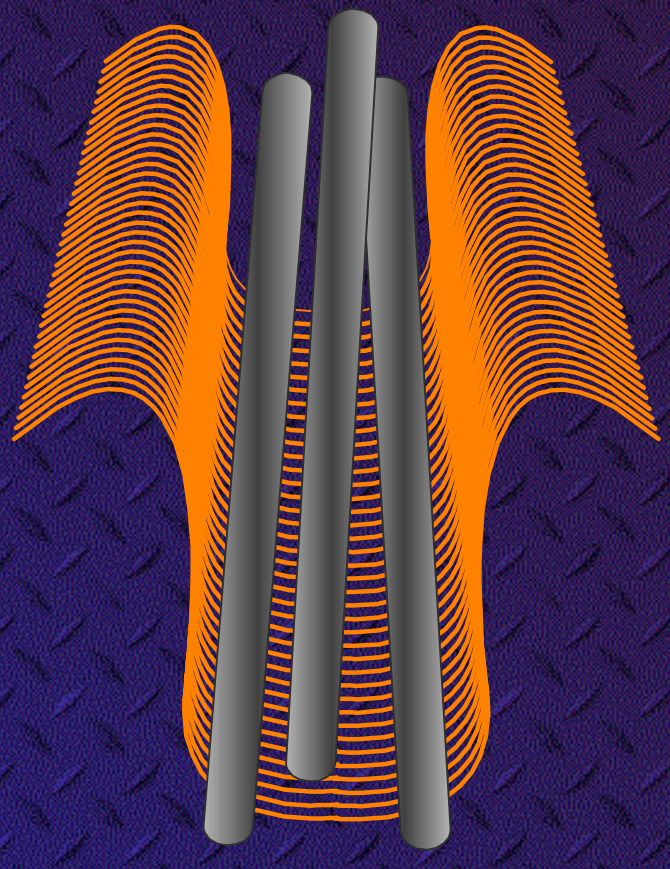
METROTECH

What is the Only Way to be 100% certain of a utility's location?



METROTECH

To See the Utility Exposed or to Dig It Up!



METROTECH

Digging may not be practical or desirable. We rely on pipe and cable locators to determine the utility's location with a high (but never 100%) level of confidence.

METROTECH

Solving the Puzzle

Locating is like playing "Jeopardy" or solving a jigsaw puzzle:

- You don't know what image the puzzle pieces will eventually form.
- You are expected to identify the picture as quickly as possible.

Puzzle Pieces Are Elements of Information

Such as:

- Method of connection
- Frequency
- Grounding
- Signal Strength

Purpose of this Presentation

To provide you with the necessary tools for quick
and confident locating judgement.

"Play the Game"

You Will Learn:

- How your locator works.
- How to evaluate your locating site.
- How to interpret the information the locator gives you.

METROTECH

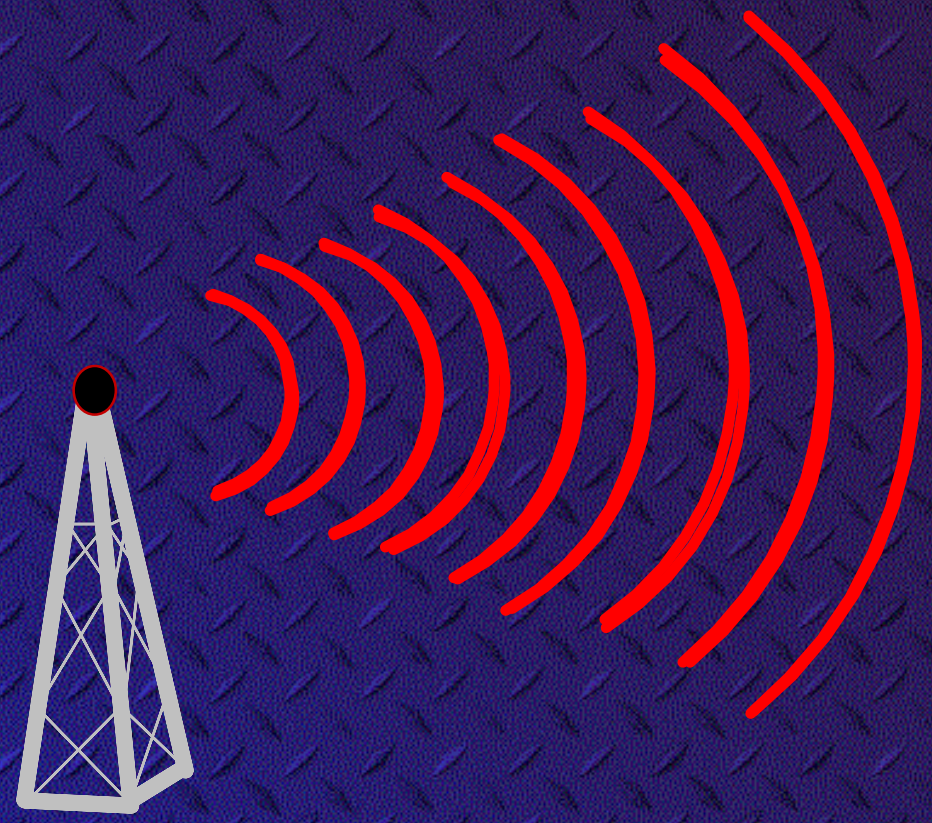
SECTION 1

Basic Locating Theory

(Inside the "Magic")

METROTECH

How Locating Works



Visualize the Transmitter as a "Radio Station" transmitting one or more specific frequencies.

METROTECH

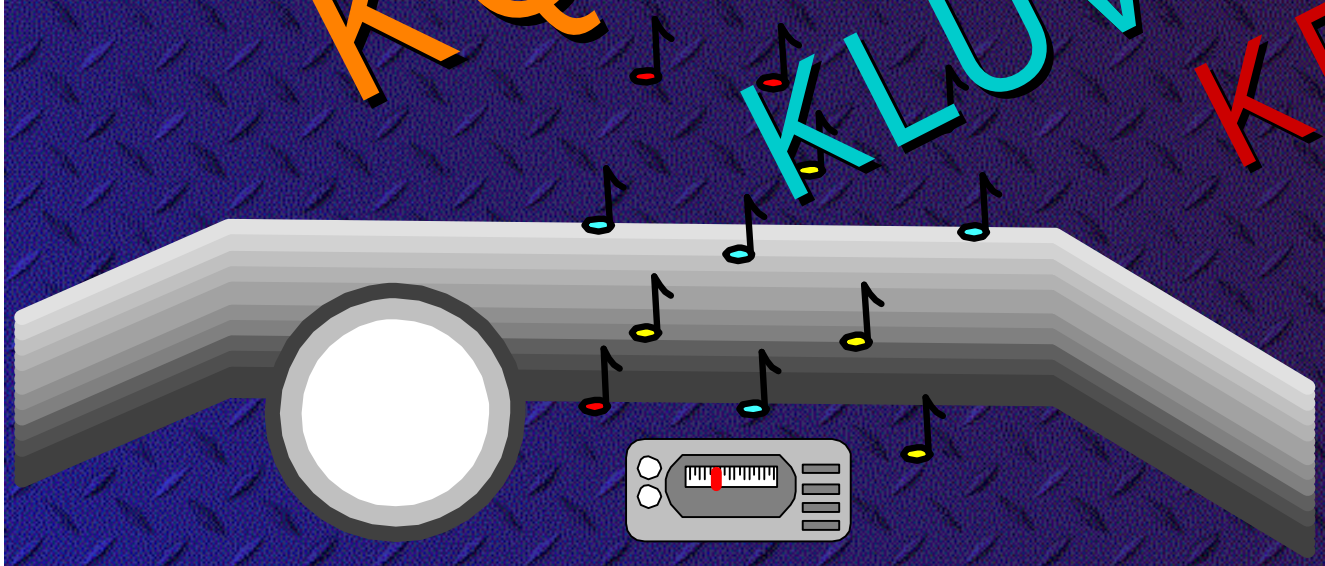
Imagine your Receiver as a Car Radio receiving signals transmitted from your selected station's frequency.

3 Radio Stations

KQED

KLUV

KROC



=3 signals

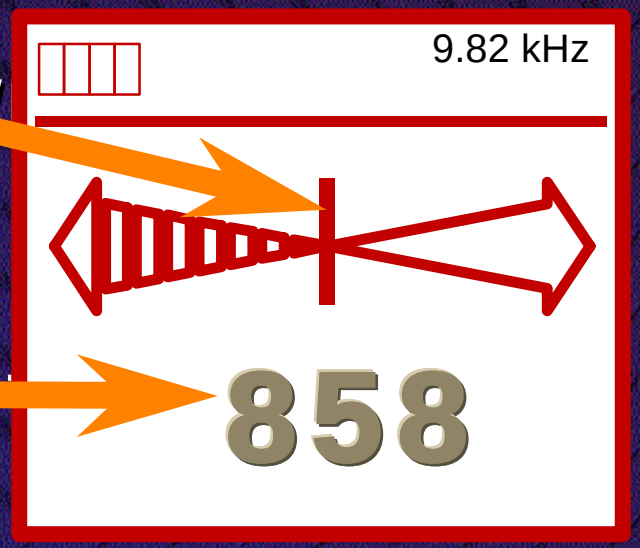
METROTECH

Locator Receiver

A Receiver receives the signal applied to a target conductor by the Transmitter. Information is computed, then displayed by the Receiver.

Locator Receiver

Centerline (L/



Signal Streng

Tone

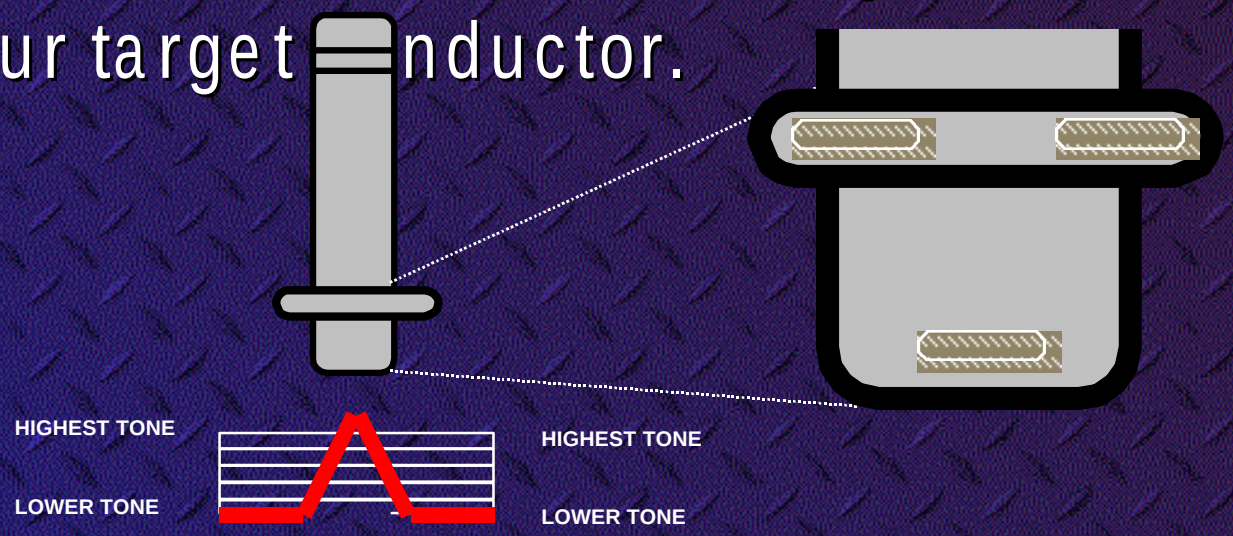
Audible Tone

Good signal strength indications are: crisp L/R, high signal strength and clear tone.

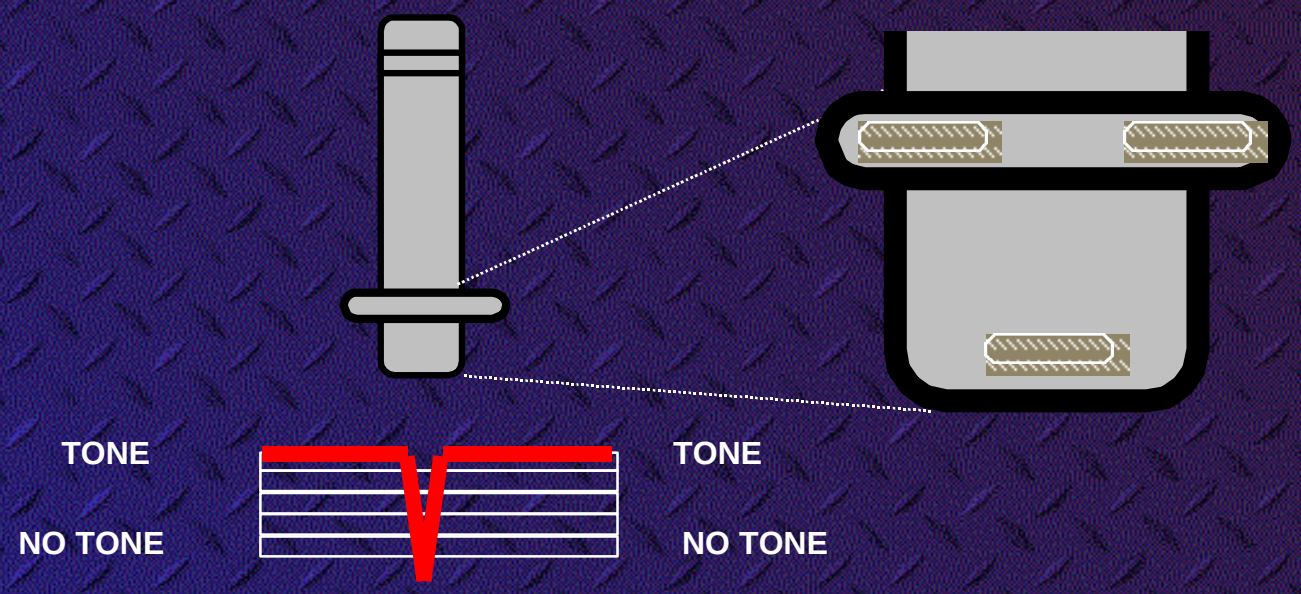
METROTECH

Most Locator Receivers work in two modes: "Peak" and "Null"

"PEAK" gives a maximum indication over your target conductor - loudest tone and highest signal strength. Use this method to find the general location of your target conductor.

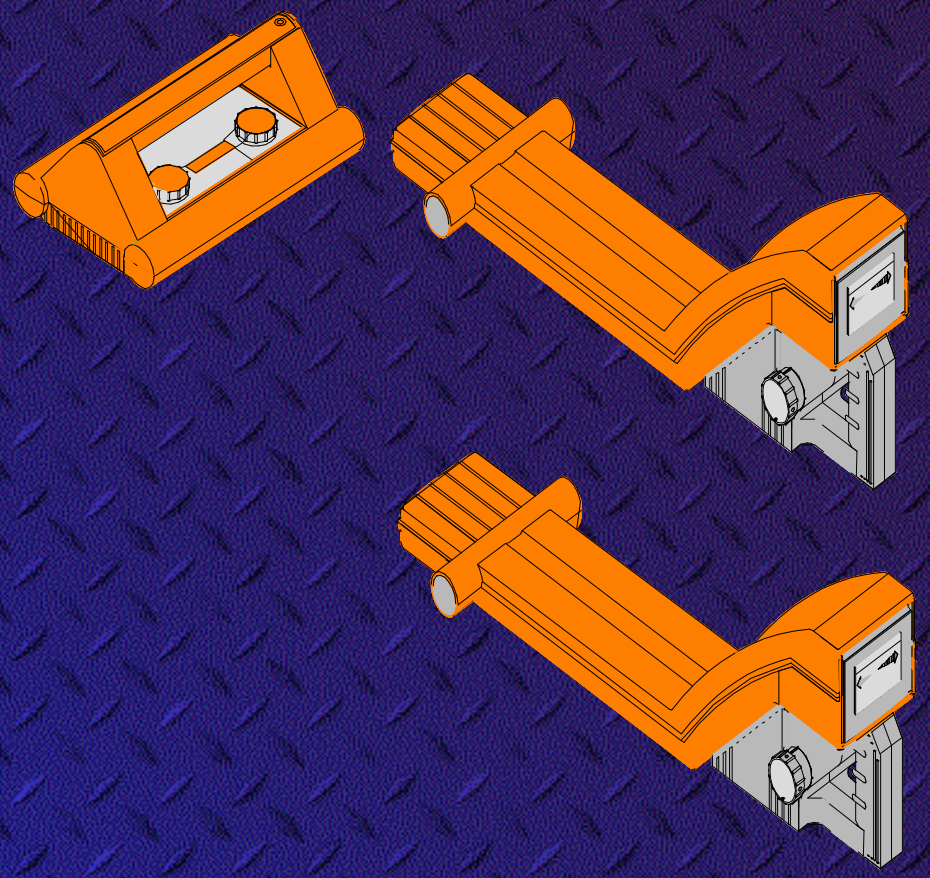


"NULL" gives a minimum indication - NO tone and highest signal strength at the exact centerline of your target conductor. Use Null for precise pinpointing of your conductor.



METROTECH

Two Types of Locating



Active Locating

Transmitter & Receiver

Passive Locating

Receiver Only (Verification Only)

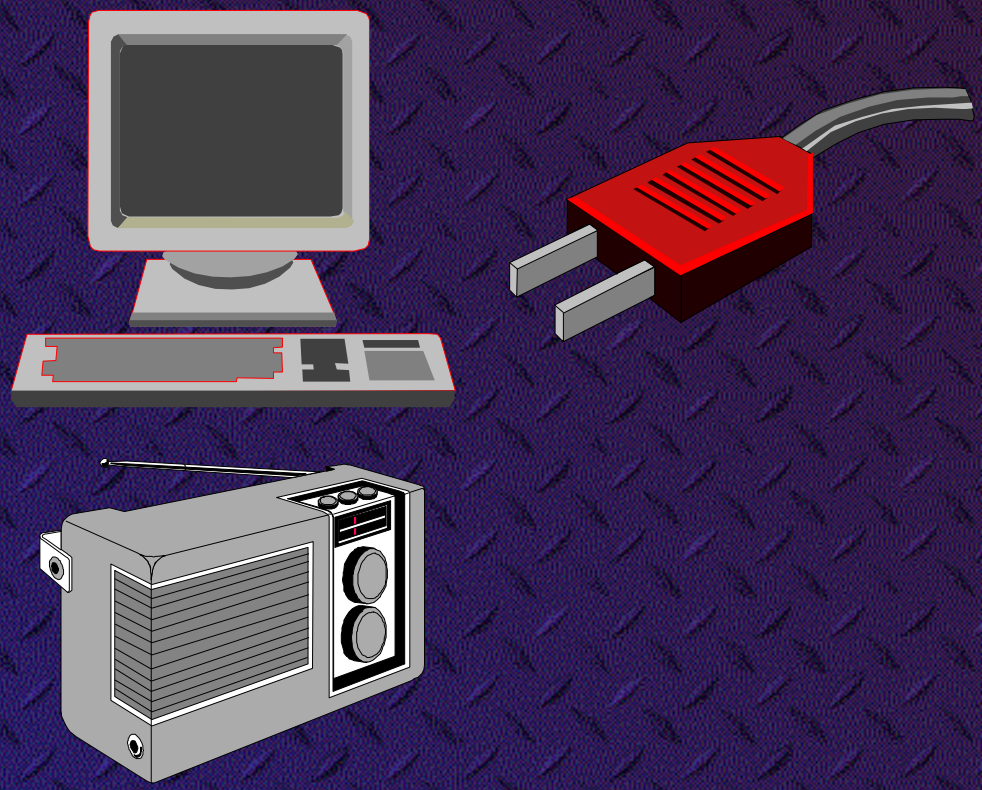
METROTECH

Passive Locating

Using frequencies transmitted by common sources.

50/60HZ
Only if power drawing appliances are "ON" (31kHz CRT, TV's, video monitors)

Electronic Noise
Many sources
14kHz - 22kHz
(Radio transmitters of all variety)



METROTECH

Drawbacks of Passive Locating

- Lack of any signal on a buried conductor when the power source is off.
- No control over frequency or intensity of the signal.
- Non-specific frequency (RF).
- Signal path may be unrelated to the signal source (60Hz on water pipes).
- May be inaccurate or misleading.
- CAUTION: A conductor may be present without receiving a signal.

Active Locating
Direct Connect = Best Results

- Strongest Signal Strength
- Most Accurate Locate Method

METROTECH

Active Locating-Signal Transmission

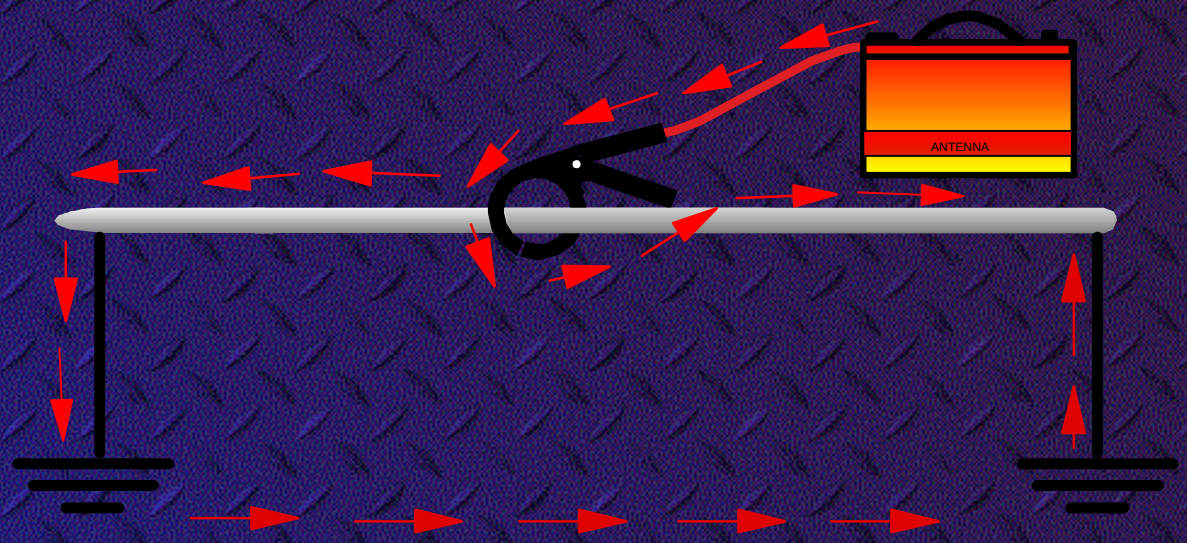
3 methods of applying a signal to your target cond

1. DIRECT CONNECT (CLIPS)

METROTECH

Active Locating-Signal Transmission

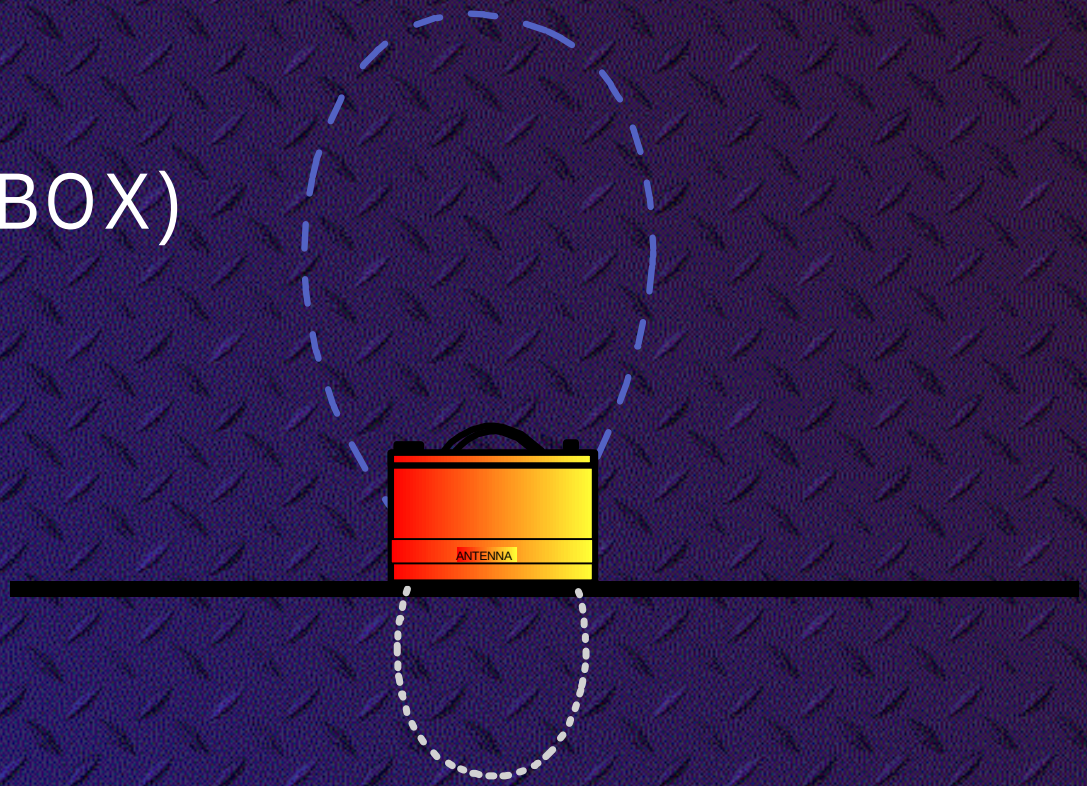
2. INDUCTIVE COUPLING (CLAMP)



METROTECH

Active Locating-Signal Transmission

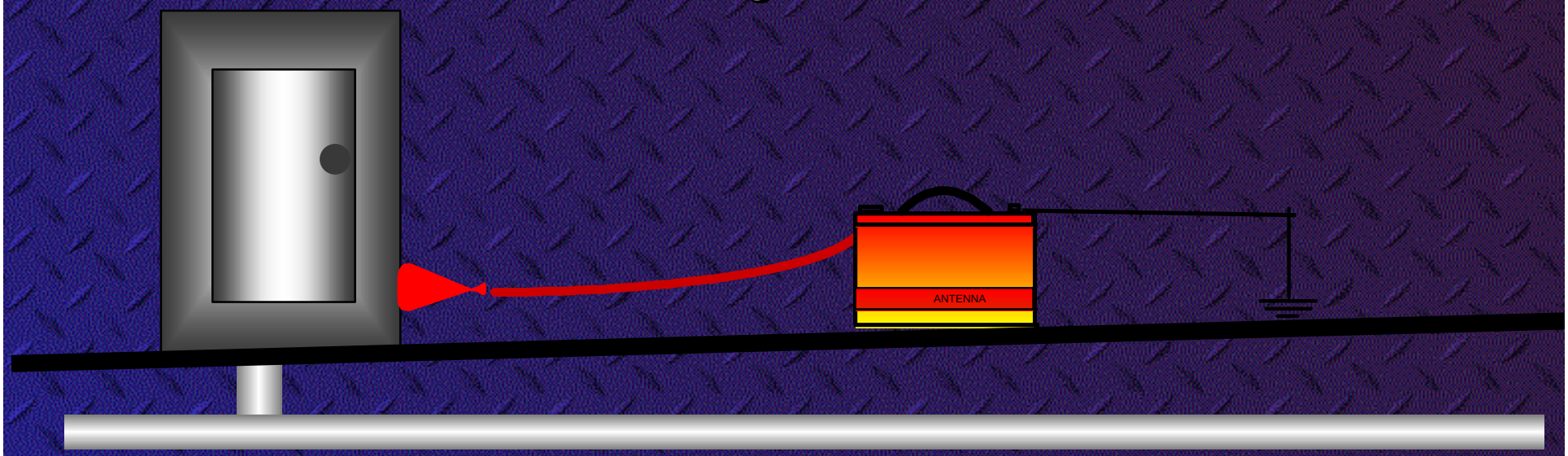
3. INDUCTIVE (BOX)



METROTECH

Direct Connect (Clip)

Most efficient way of transmitting signal onto the target conductor



Transmitter is direct connected to the conductor

METROTECH

Possible Direct Connection Points

Water - Hydrant, Meter,

Curb Sto
Valves, I

Gas - Meter, Valve,

Trace W

Test Leads

METROTECH

Possible Direct Connection Points

Power Transformer - Neutral phase, Case, Pole Ground,
House Box, (if disconnected) Ground, Meter Conductor

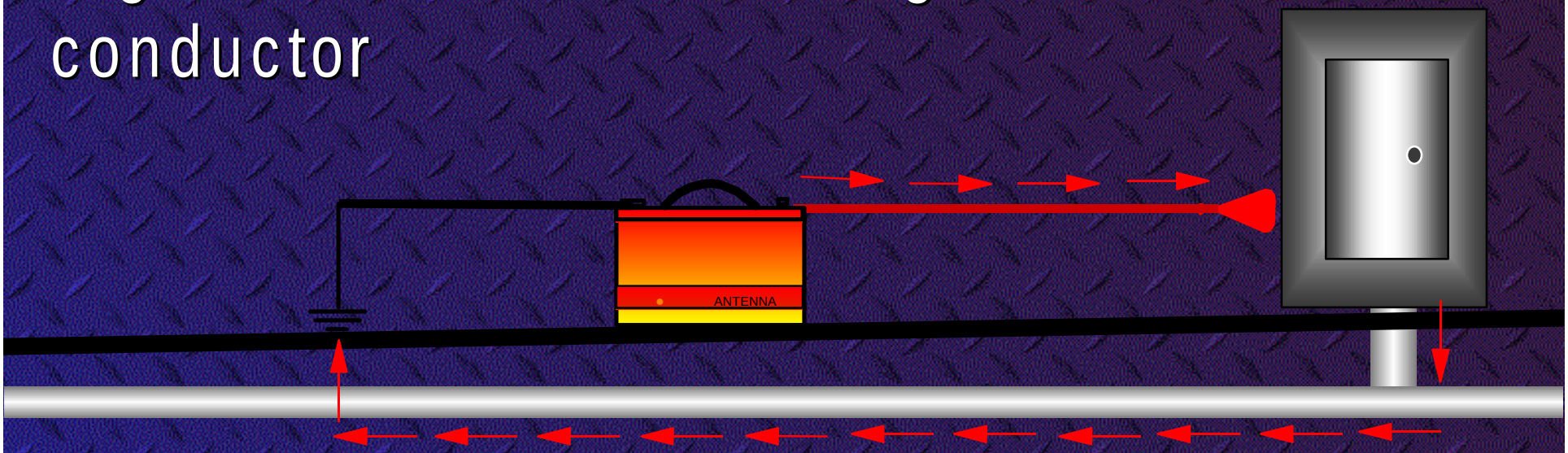
Telephone Pair - Sheath, Vacant Cable (on tip side)

CATV Pedestal Case - Sheath, (if properly bonded and grounded)

METROTECH

Direct Connect Using the Clip

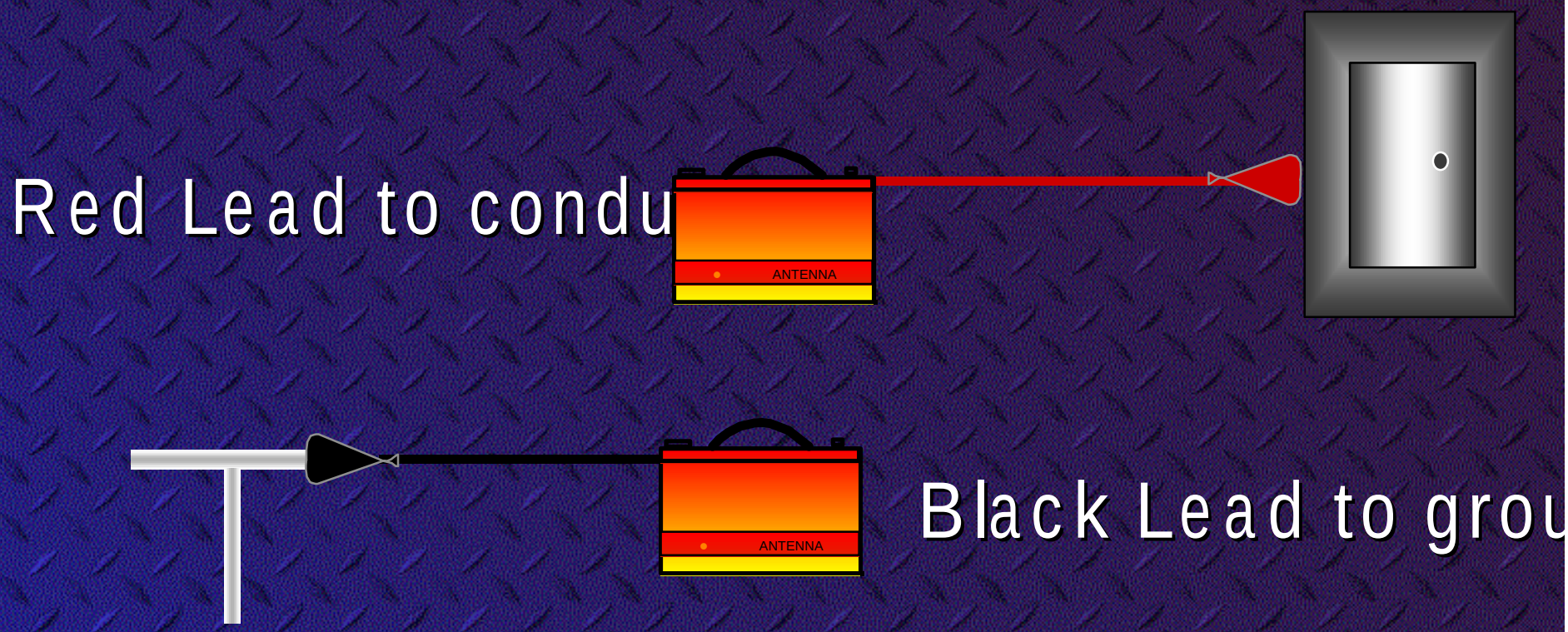
Signal is transmitted through the cable to the conductor



Air- Coupling is not a factor when direct connected.

METROTECH

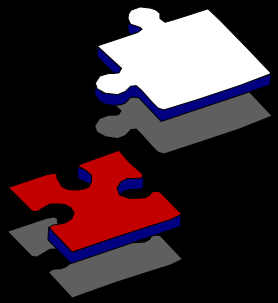
Attaching the Direct Connect Clip and Ground Lead



METROTECH

SECTION 2

Importance of Grounding



METROTECH

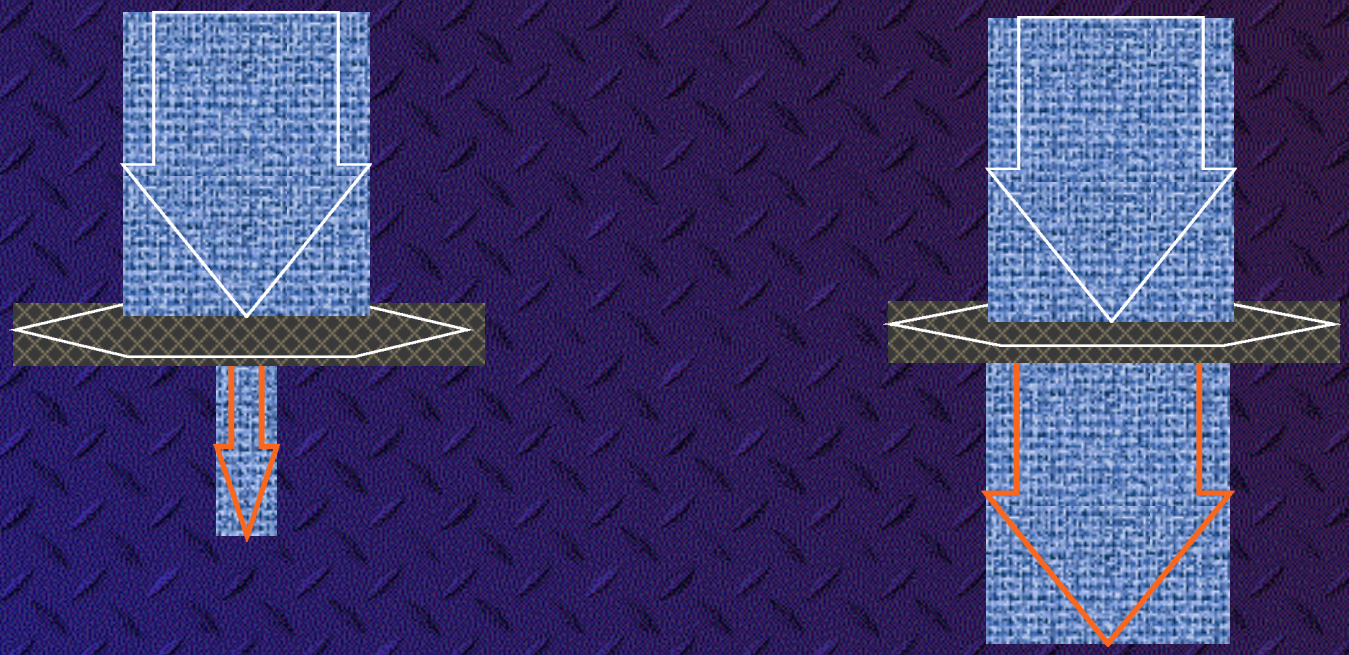
Importance of Grounding

Grounding is the Most Important Factor in the Direct Connect Method

- The signal (current) must "flow" in a loop to be detected by the Receiver.
- A metal earth/ground provides a focal point for the signal to travel back to the signal source - closing the circuit (loop).
- The larger the metallic surface, the stronger the signal loop.

METROTECH

Principle of Grounding

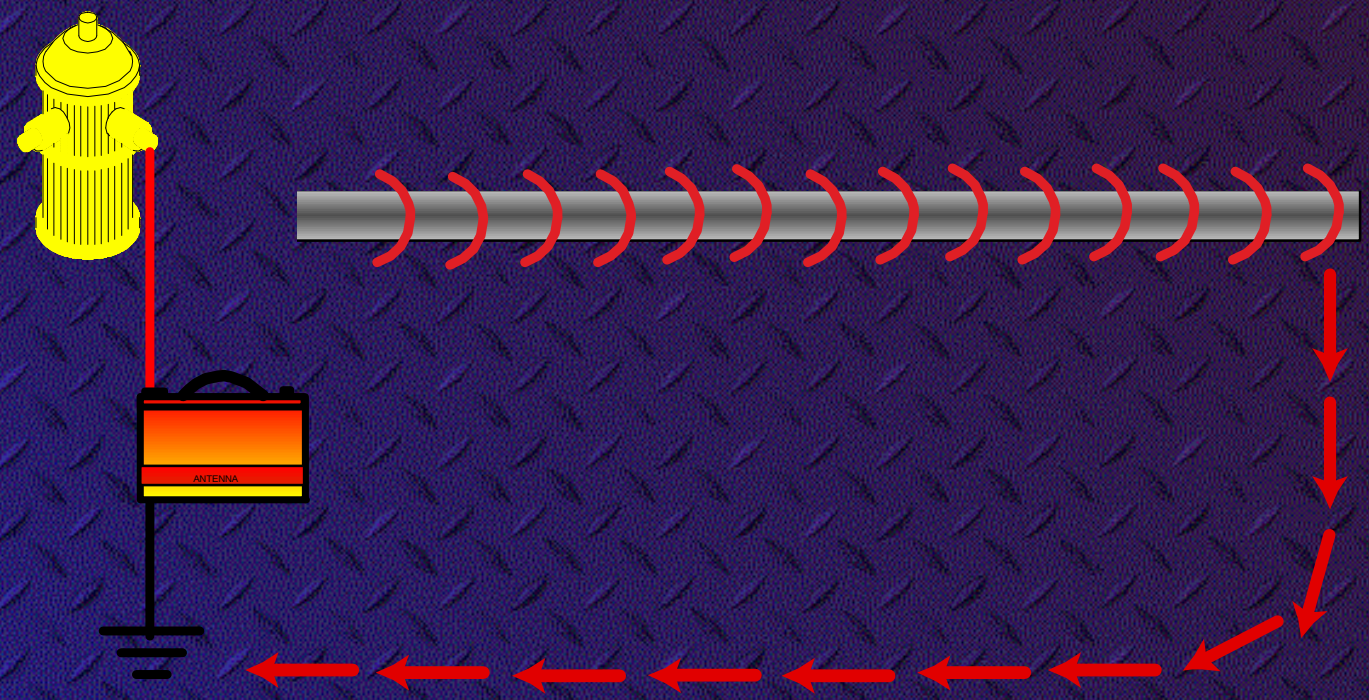


If the current was water, the earth/ground would be a

drain - the better the drain, the better the water flow.

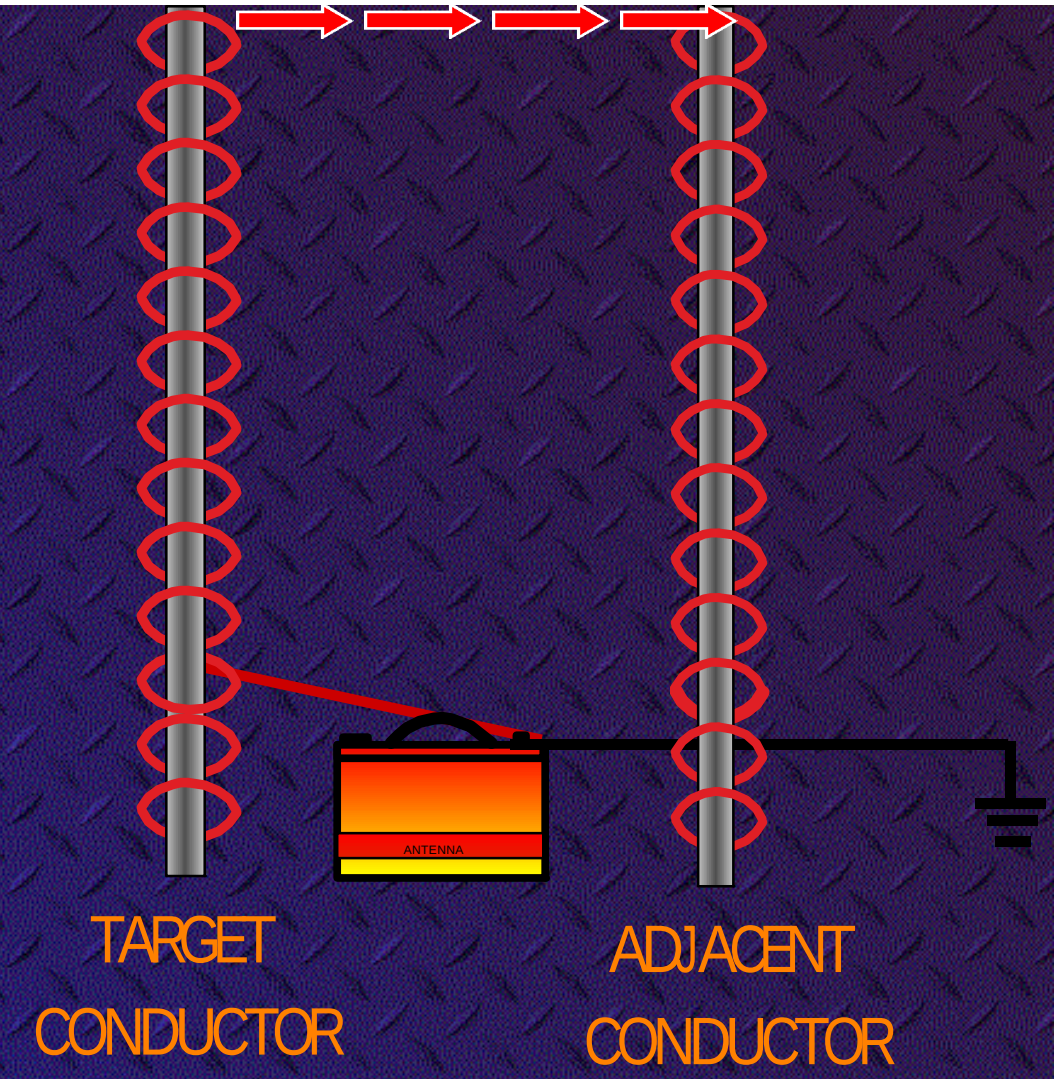
METROTECH

Ground Rod Placement



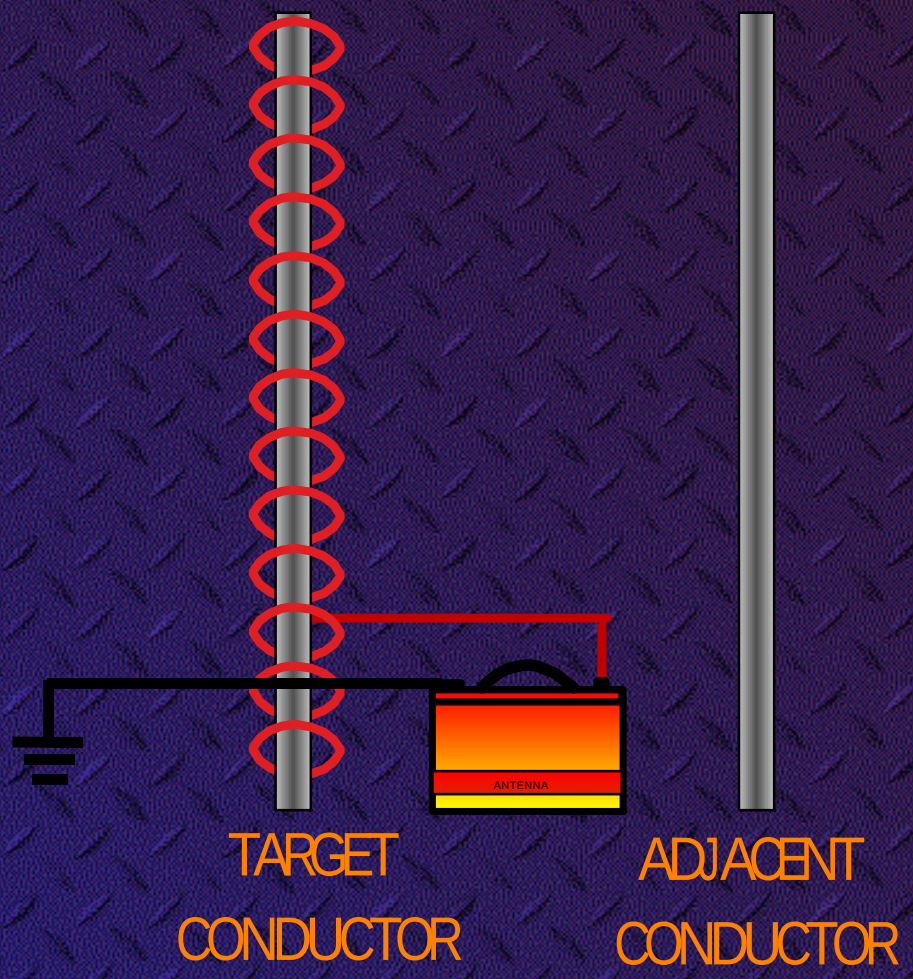
Attach Black Lead to Ground Rod at right angle to

METROTECH



Crossing over an adjacent conductor places unwanted signal on that conductor.

METROTECH



Place ground lead away from other conductors.

METROTECH

Avoid "Destructive Interference"

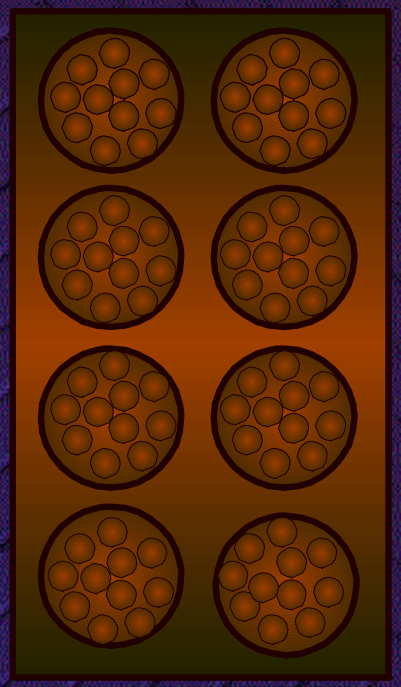
Connect Ground at right angle.

This rare situation most commonly

occurs when two (or more) conductors

are physically connected,

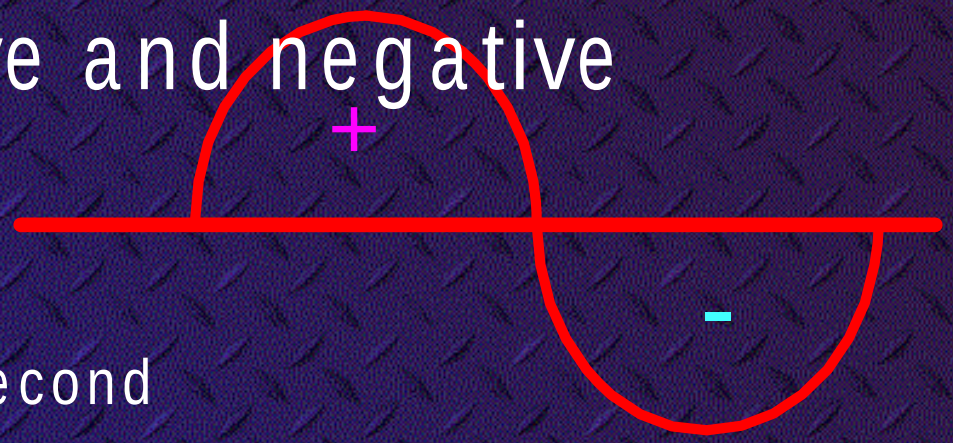
e.g. common trenching



METROTECH

A Few Important Terms Describing Alternating Current:

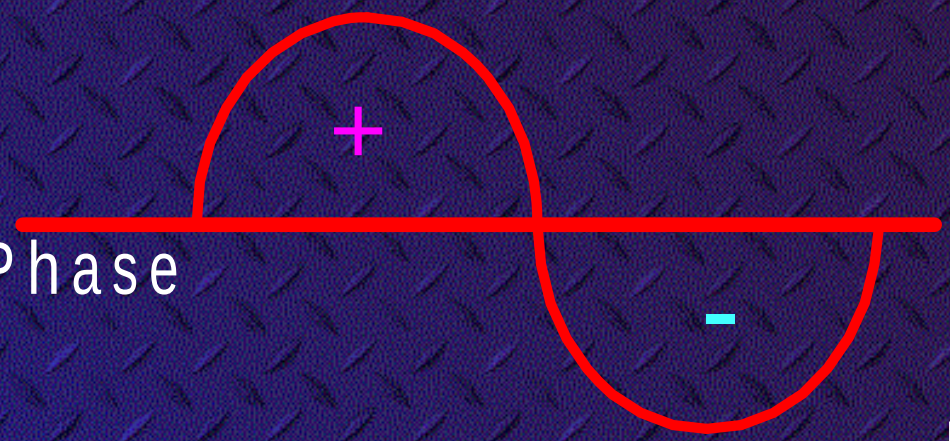
<u>Cycle</u> One round of "up and down" or positive and negative potential.



One cycle per second

"Alternating Current" Terms

<u>Phase</u> Signal goes both "up" and "down".



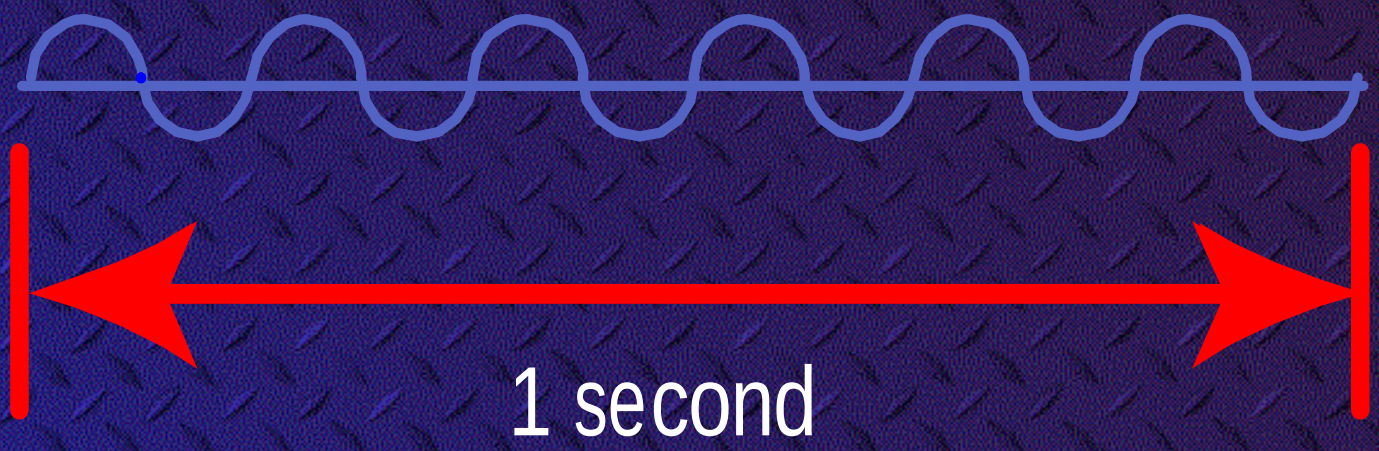
Positive Phase

Negative Phase

METROTECH

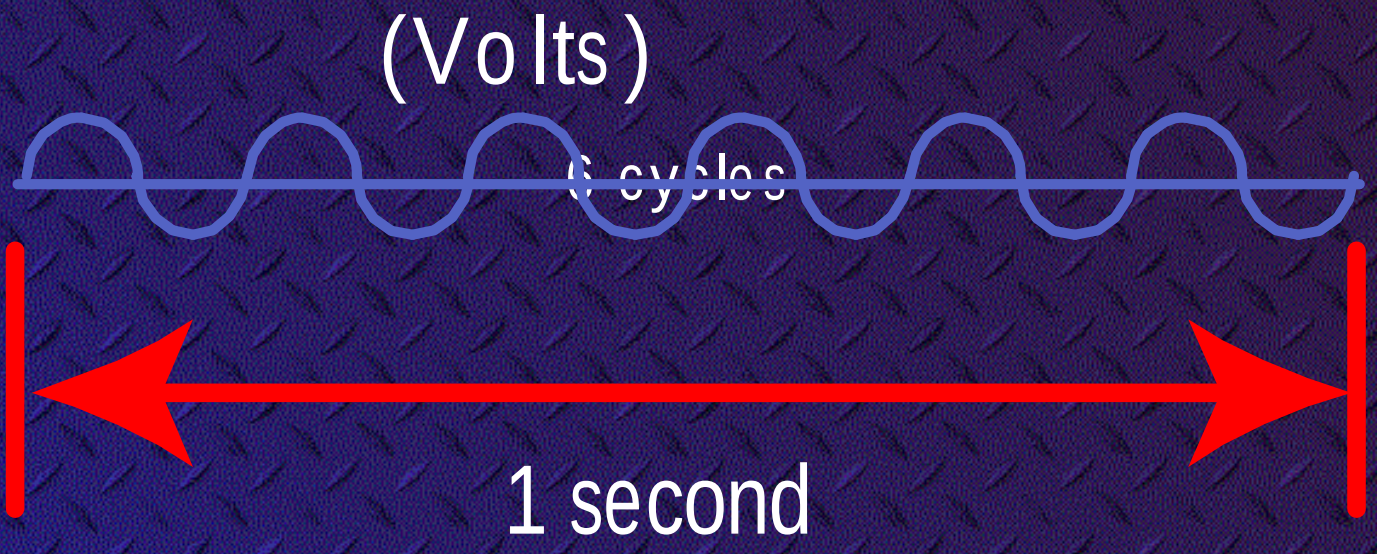
"Alternating Current" Terms

<u>Frequency</u> The number of cycles that occur within one second.



"Alternating Current" Terms

<u>Amplitude</u> The height (or depth) of a phase.

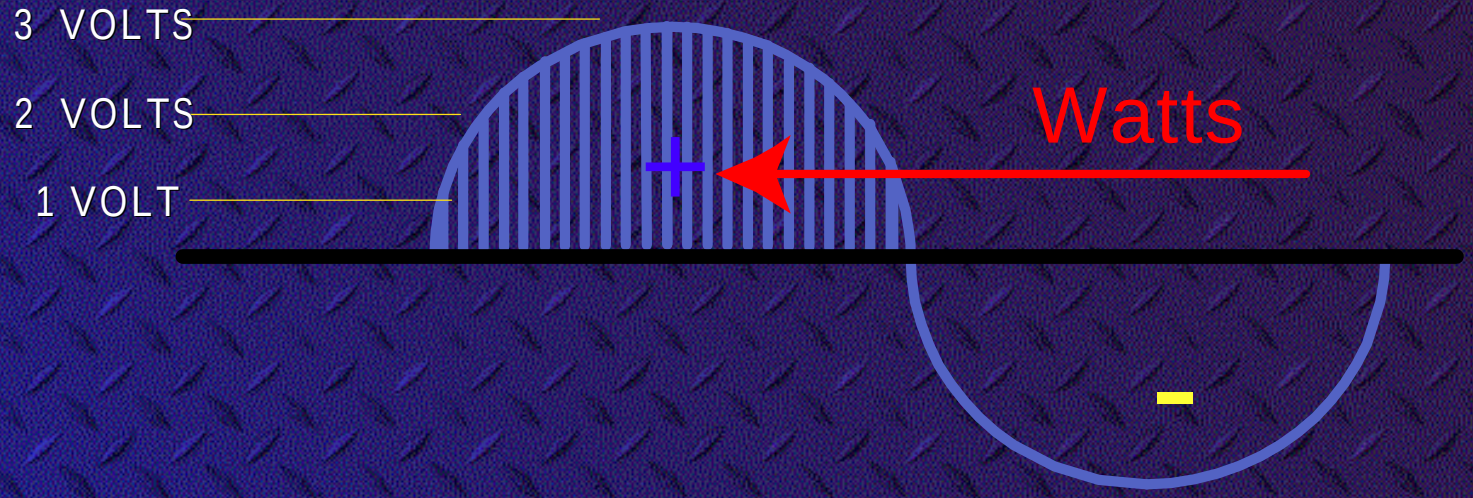


6 cycles per second = 6 Hz

METROTECH

"Alternating Current" Terms

<u>Power</u> The area under the curve. (Watts)



"Alternating Current" Terms

<u>Cycle</u>

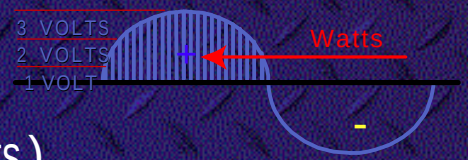
One "up and down" or positive and negative potential.

<u>Phase</u>

Signal is going both "up" and "down".

<u>Frequency</u>

Number of cycles occuring within one second.

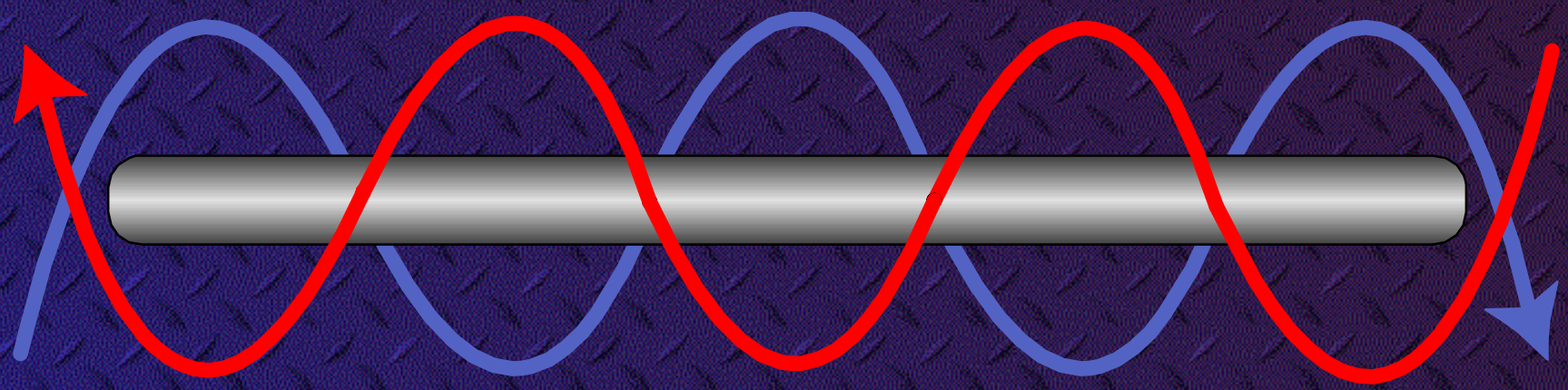
<u>Amplitude</u> (Volts) 

Height (or depth) of a phase.

<u>Power</u> (Watts) Area under the curve.

METROTECH

“Destructive Interference”



When a transmitted signal on the target conductor meets a returning signal in the opposite phase, the signals cancel or distort each other.

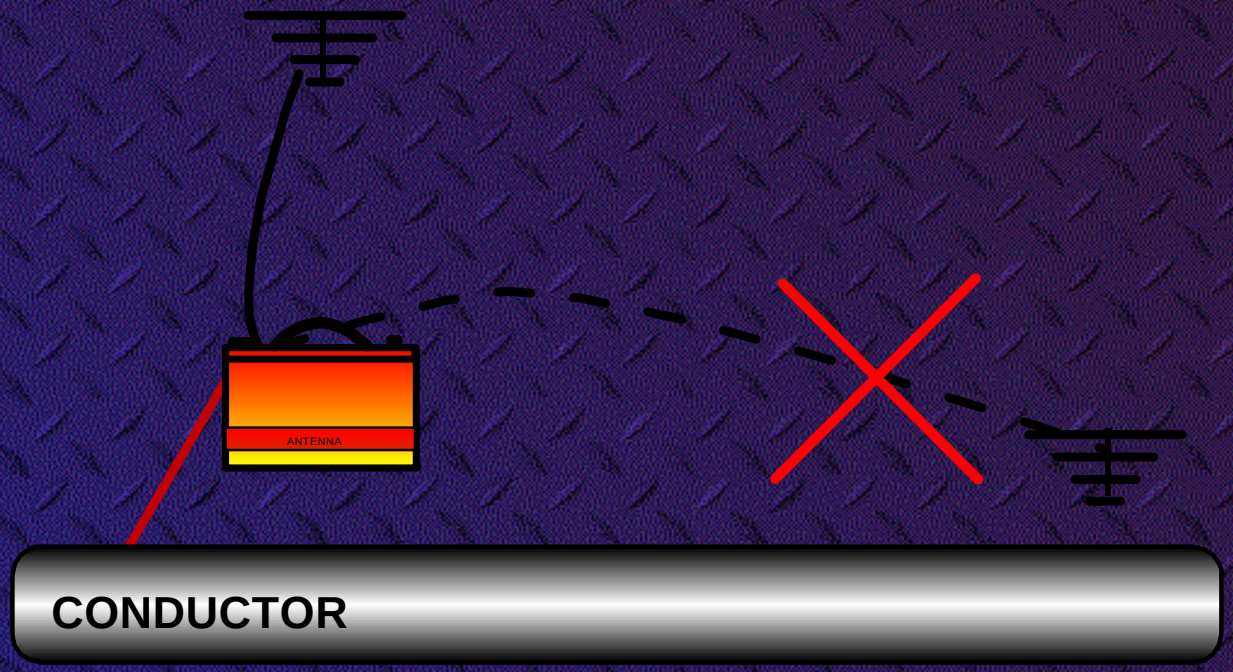
METROTECH

Symptoms of "Destructive Interference" or Poor/No Ground

- Fluctuating signal strength (by a constant 50+ points up and down).
- Inconsistent Centerline or Peak.
- Inconsistent or Non-repeatable Depth Readings.

METROTECH

Avoid
"Destructive Interference"



Determine probable path of your conductor and move your ground rod accordingly.

METROTECH

Destructive Interference

Locating is Possible

Recognize the Problem

- Fluctuating Signal Strength
- Inconsistent Centerline or Peak
- Non-Repeatable Depth

Determine the Source

- Common Bonding
- Ground Rod Placement

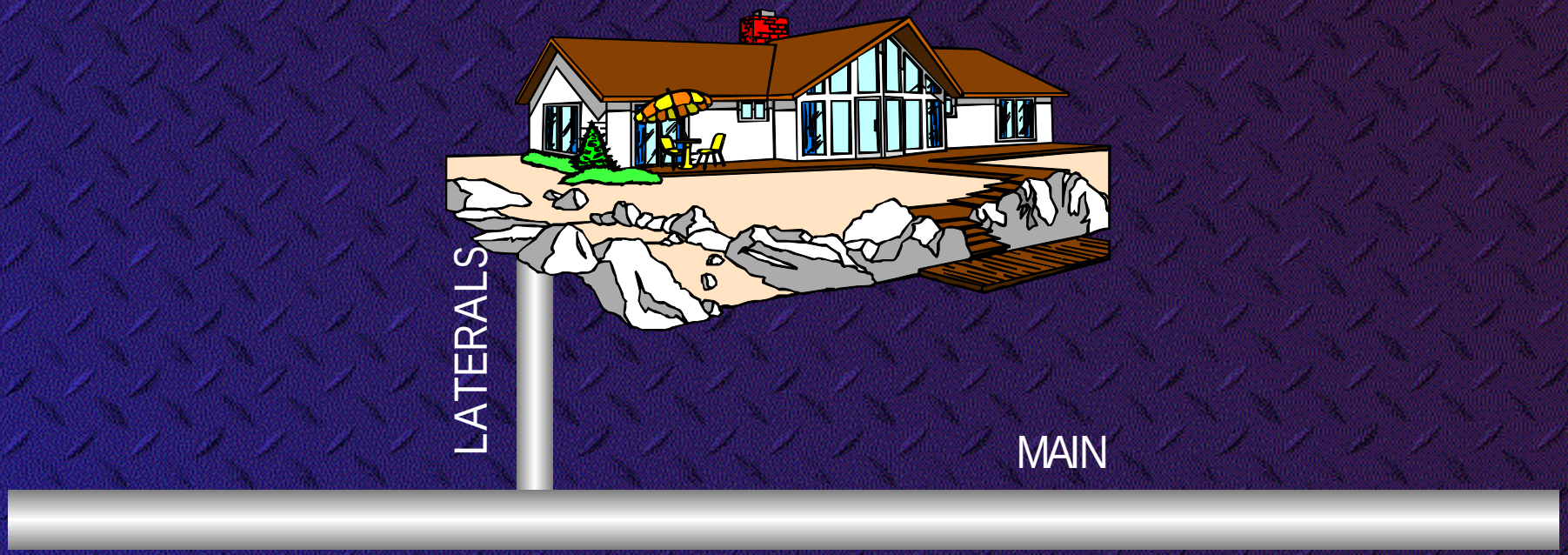
METROTECH

I know I am supposed to attach the ground at right angles to the conducto

How do I know which way the conductor is running?

METROTECH

“ Read the Street”



"Large delivery" (water main) is typically parallel to the street. Small delivery (laterals, house connections) is perpendicular to the street.

METROTECH

Industry Terms for Delivery Systems

Water - Main and Lateral (Service)

Gas - Main and Lateral (Service)

Power - Primary and Secondary

Telephone - Underground and Aerial Cables (F1 and F2) and Service

METROTECH

More Clues to the Probable Path of Your Conductor

Note Positions of:

Water - valves, curb stops, meters, hose bibs

Gas - meters, electrical test points

Power - transformer boxes, switch gear, risers

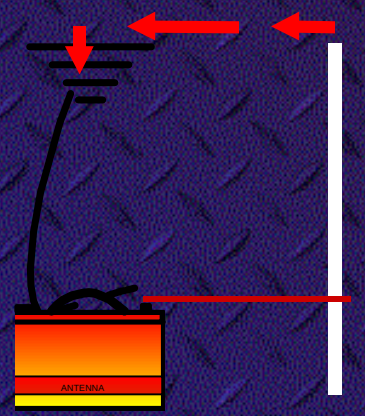
Telephone - pedestal boxes, risers, manholes, terminals, protector

CATV - pedestals, risers,

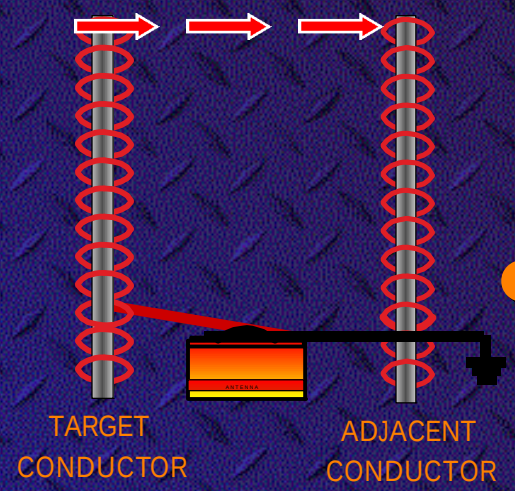
METROTECH

Avoid Destructive Interference

When placing the ground rod:



- Do not lay ground attachment (black) parallel or adjacent to the target conductor.

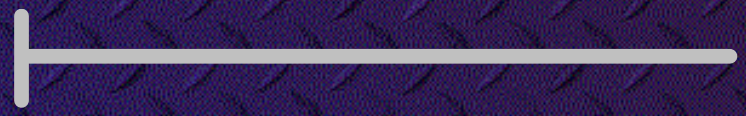


- Do not cross over adjacent conductor.

Methods to Improve Your Ground

Create larger surface area to attract signal -

- Longer ground rod - be careful not to penetrate another line

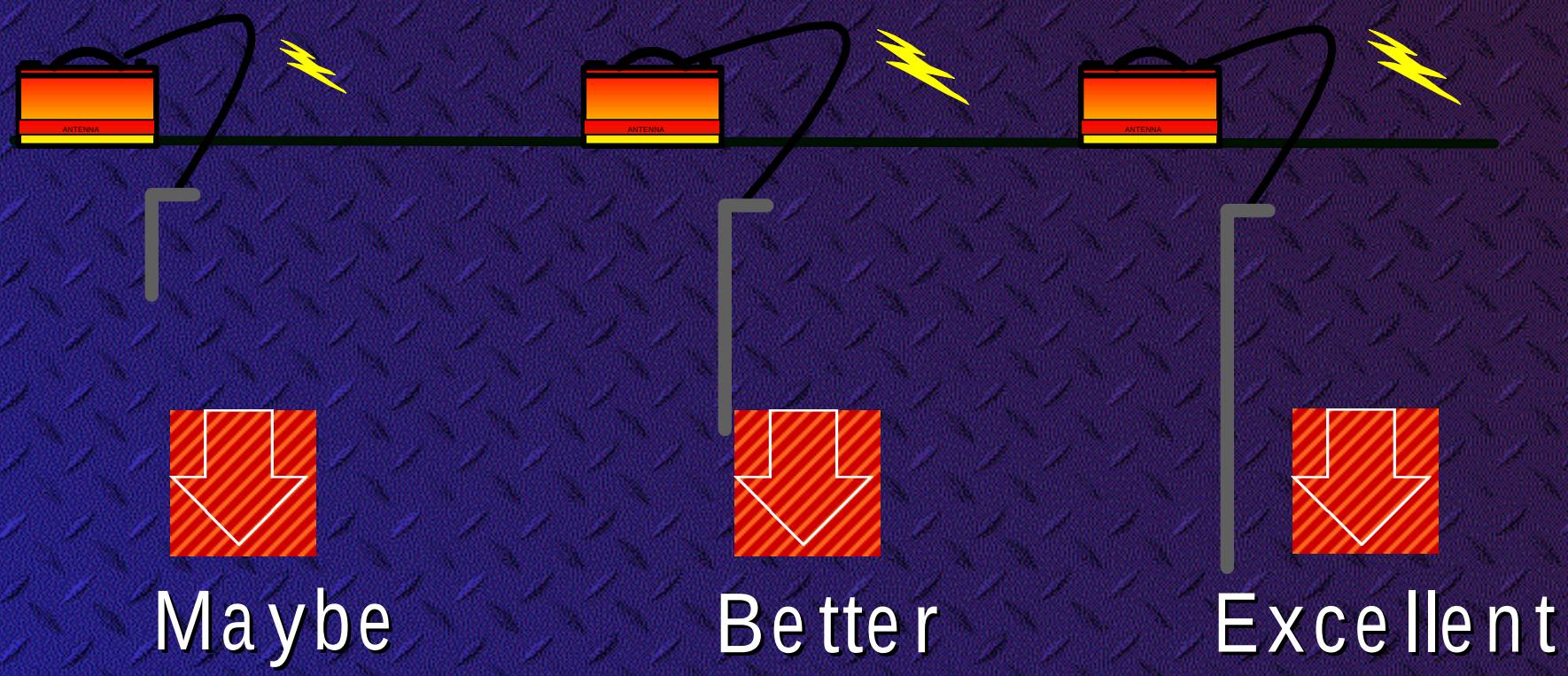


- Multiple rods connected

- Use an available ground that is deeply buried

- Water/moisture improves conduction

Larger Surface Area Attracts More Signal (Current)



METROTECH

Convenient Available Grounds That Provide More Surface Area

Stop Sign/Street Sign

Metal fence post

Do not use if parallel to your conductor's path

METROTECH

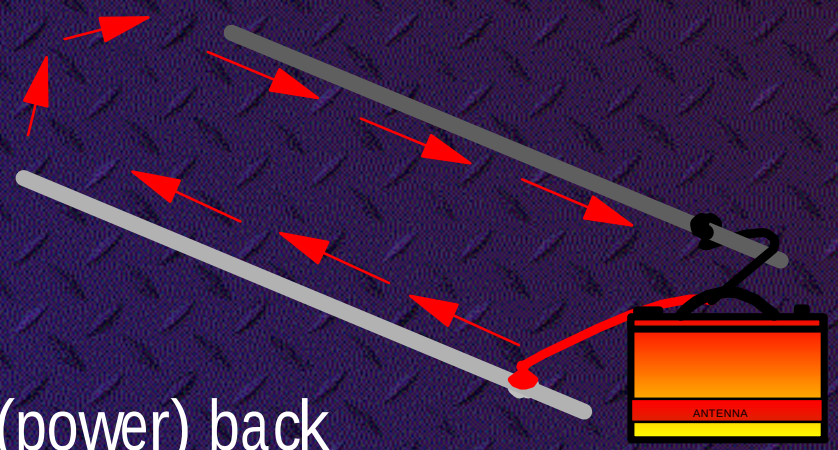
Alternative Ground

If you are cautious - it is possible to use a parallel utility as your return signal path.

When you do this, verify that you start out and end up at a termination point that is specific to the utility that you are tracing.

Parallel Utility Ground - Return Locate

Convenient for user who is locating multiple utilities (such as a contract locator).



If grounded to adjacent utility -
Locate one (water) out and the other (power) back
You don't need to move your Transmitter.

Important to verify terminations

METROTECH

In Conclusion –

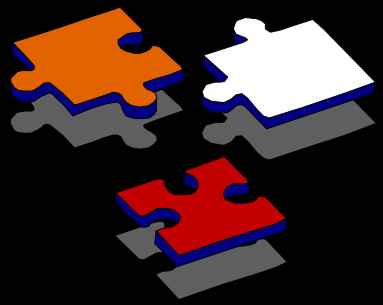
Direct Connect Provides a Superior Locate Because It:

- Isolates conductor from adjacent conductors.
- Get more signal distance - don't need to move Transmitter.
- Provides the strongest signal to the best Receiver, resulting in the best Receiver accuracy.

METROTECH

Section 3

Determining Depth



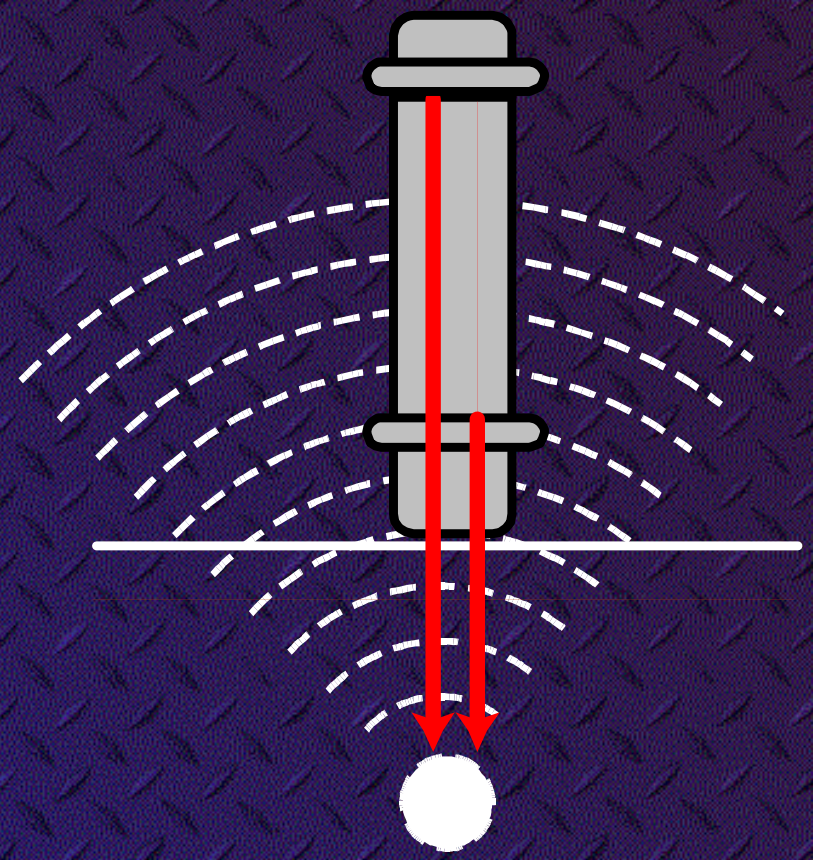
METROTECH

Push-Button Depth

How the Receiver Measures the Depth of Your Conductor

Two coils in Receiver are picking up signal from your conductor.

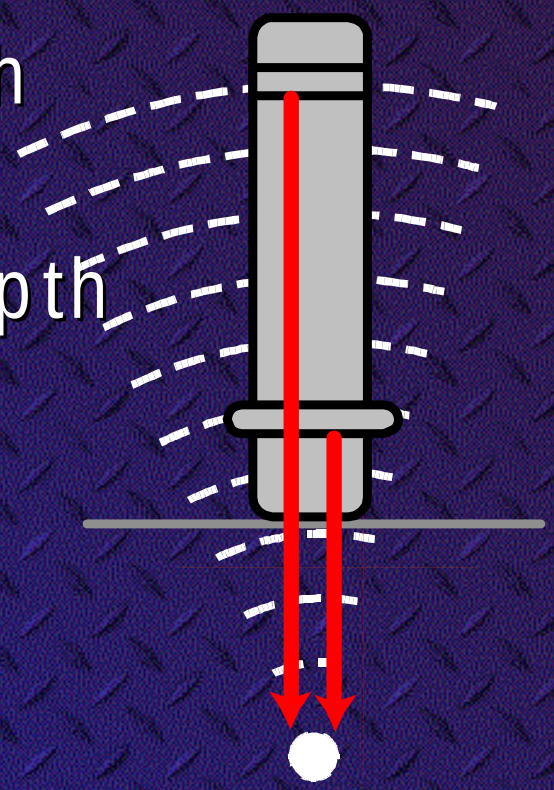
Microprocessor measures signal differential between coils and determines depth based on fixed distance between coils.



METROTECH

Strong Signal Receiver Can Calculate Accurate Depth

Signal Strength strong enough to calculate depth



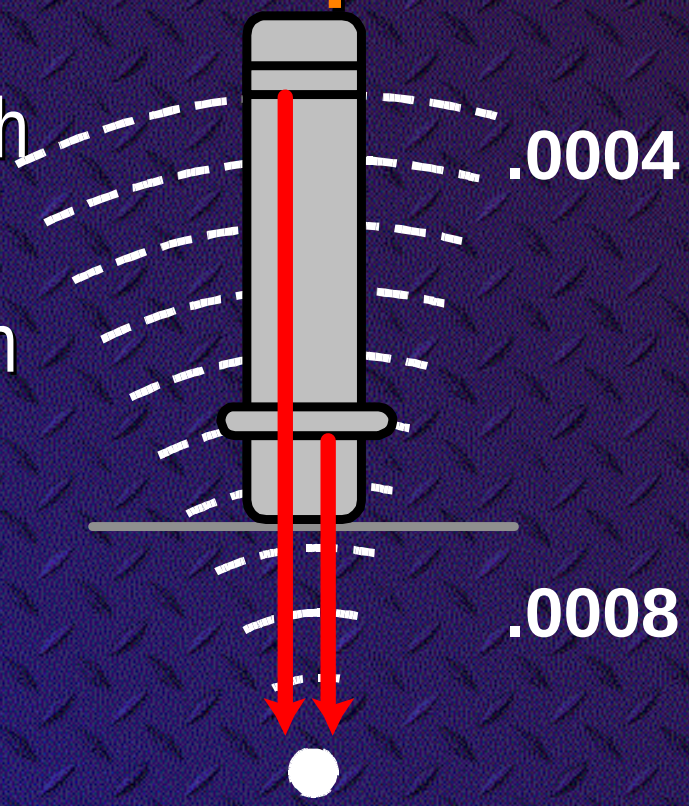
4.0 weaker signal farther from source

8.0 stronger signal closer to source

METROTECH

Weak Signal - Receiver Cannot Accurately Calculate Depth

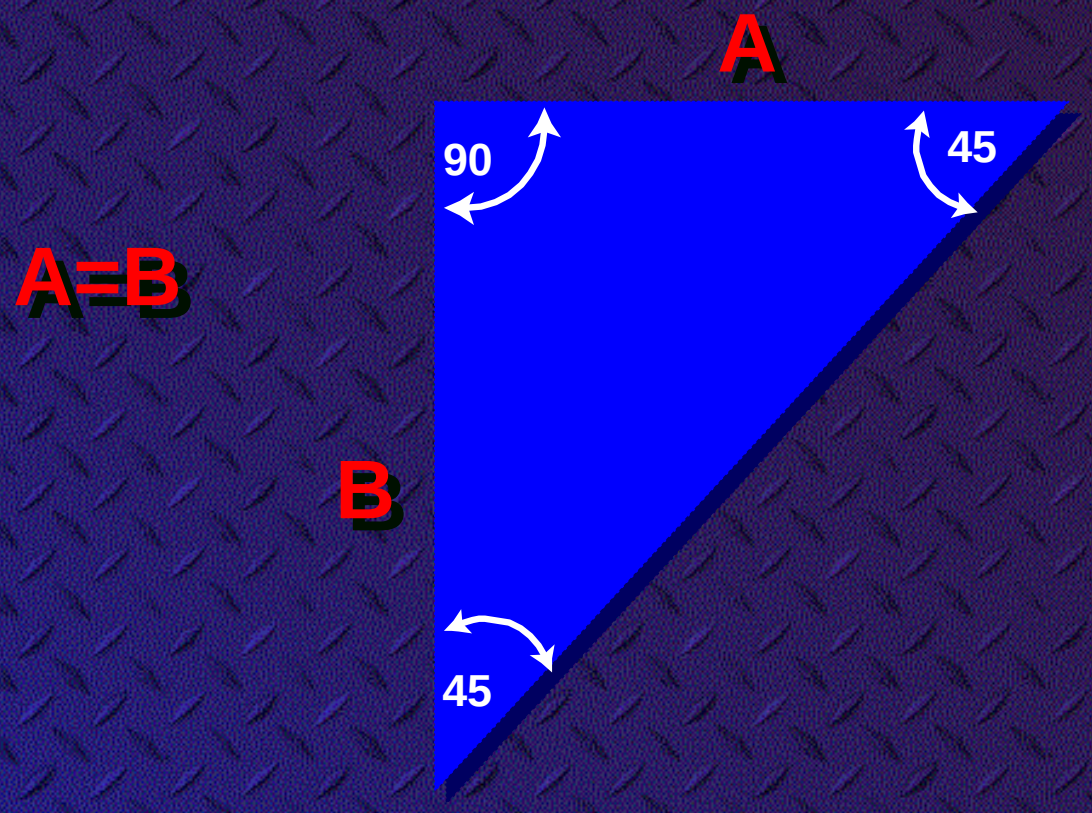
Signal Strength is too weak to calculate depth



The signal difference between the two coils is too small for the processor to calculate. This results in inaccurate depth readings.

METROTECH

When Signal is Weak
Alternative - Triangulation



METROTECH

Use Triangulation for Depth Measurement

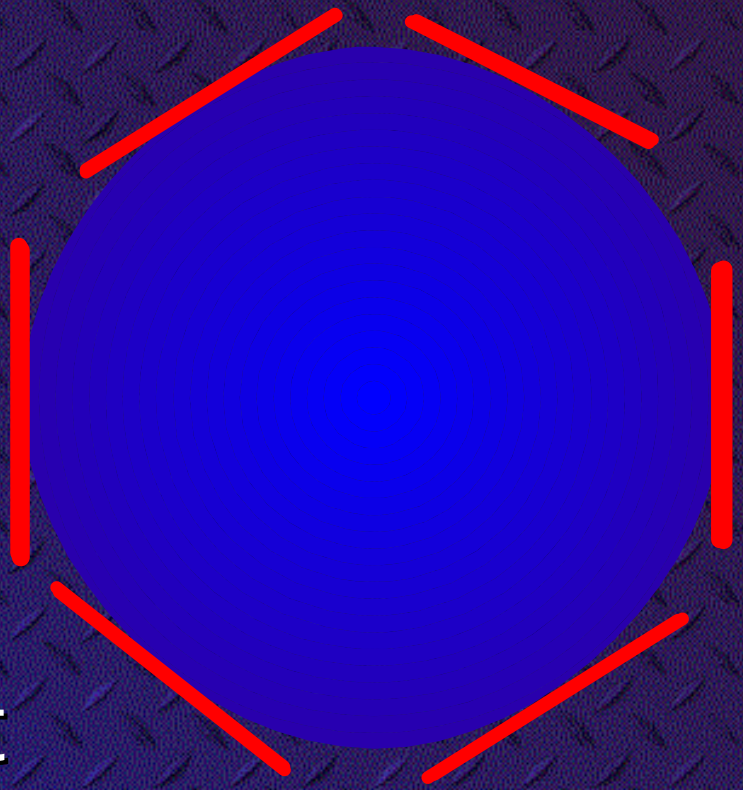
- When you have a weak signal due to distance, attenuation, or other locating methods. (Inductive Coupling, Inductive)
- When interference prevents accurate depth measurement.
- Verifies Signal Distortion

METROTECH

Triangulation Can Also Be Used to Verify Depth Measurement

METROTECH

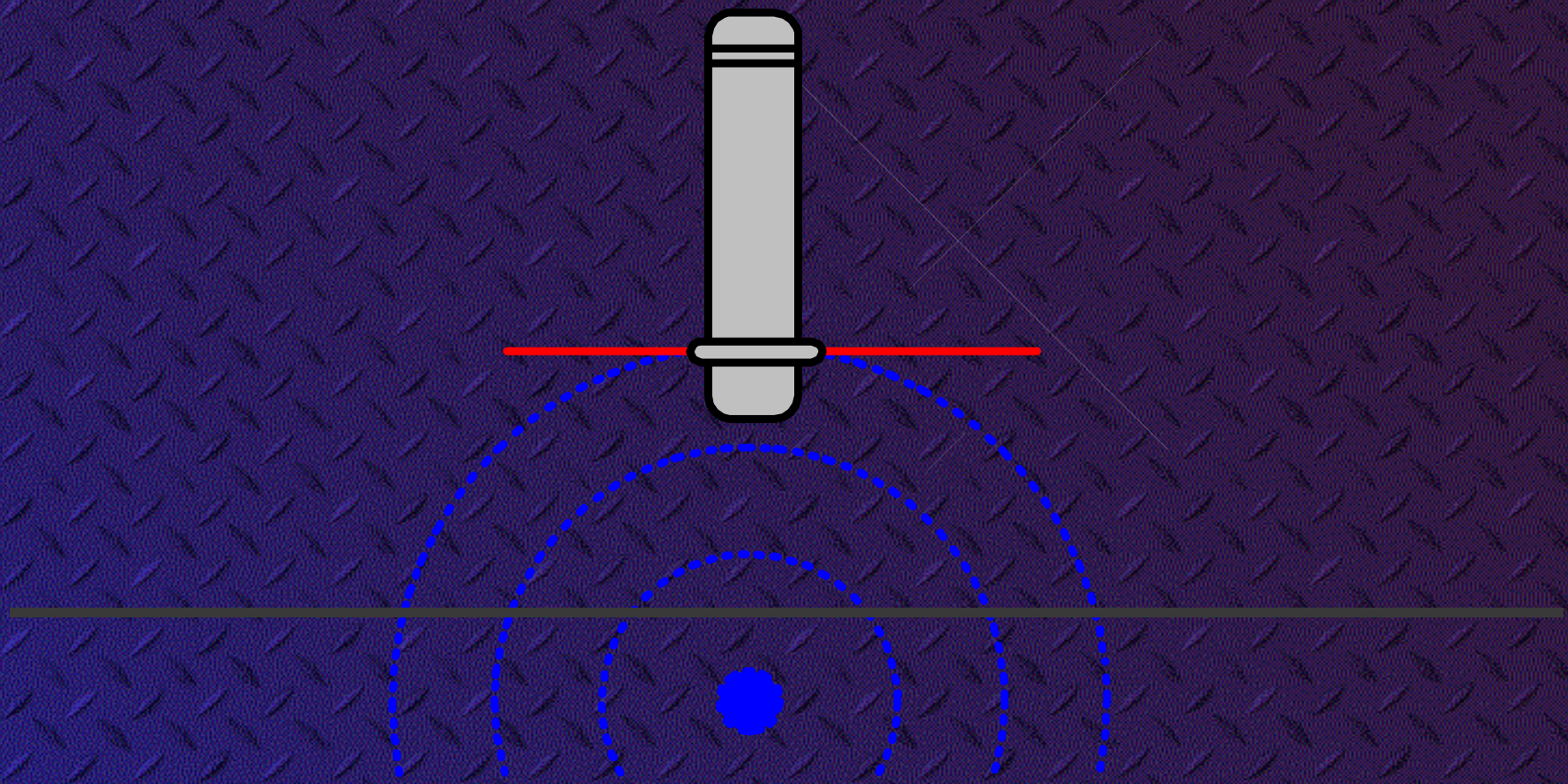
Triangulation Method Based on Three Geometric Principles



1 Tangent

A tangent can be formed at any point on a circle.

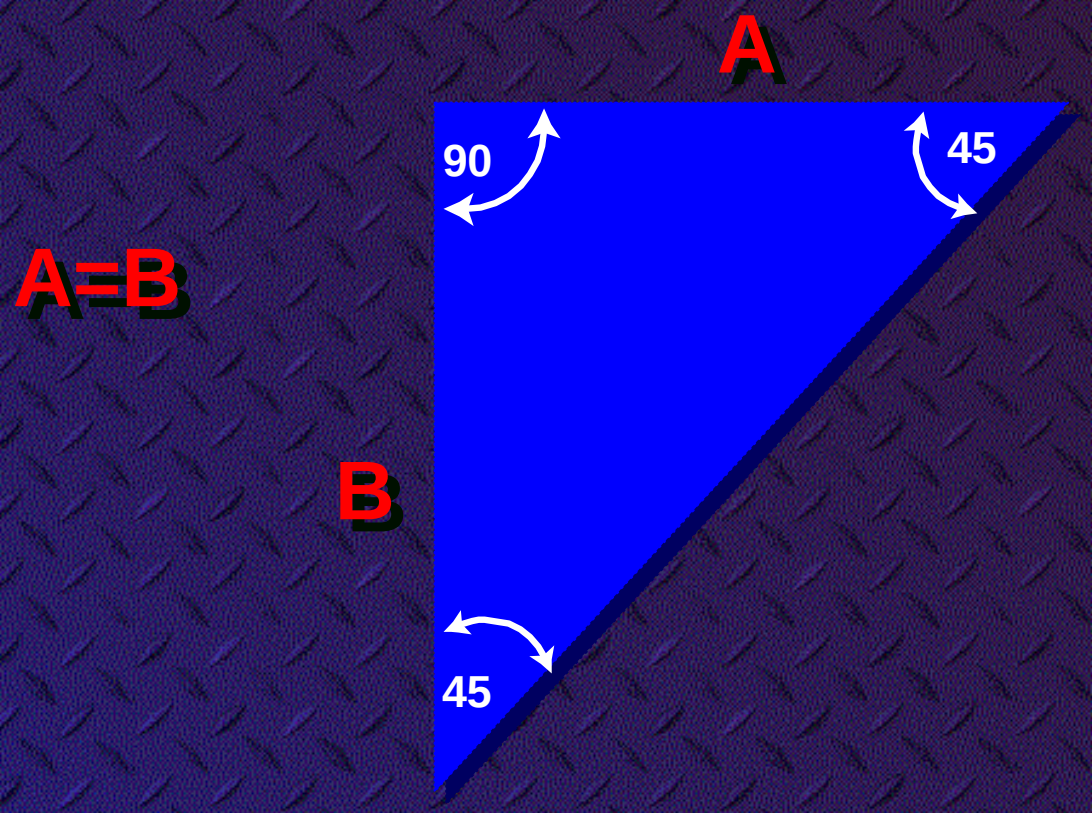
METROTECH



2 Receiver Peaks When Tangent to Signal Circle

A peak Receiver coil senses its peak when it is tangent to an ideal circle of signal.

METROTECH



3 Receiver Peaks When Tangent to Signal Circle

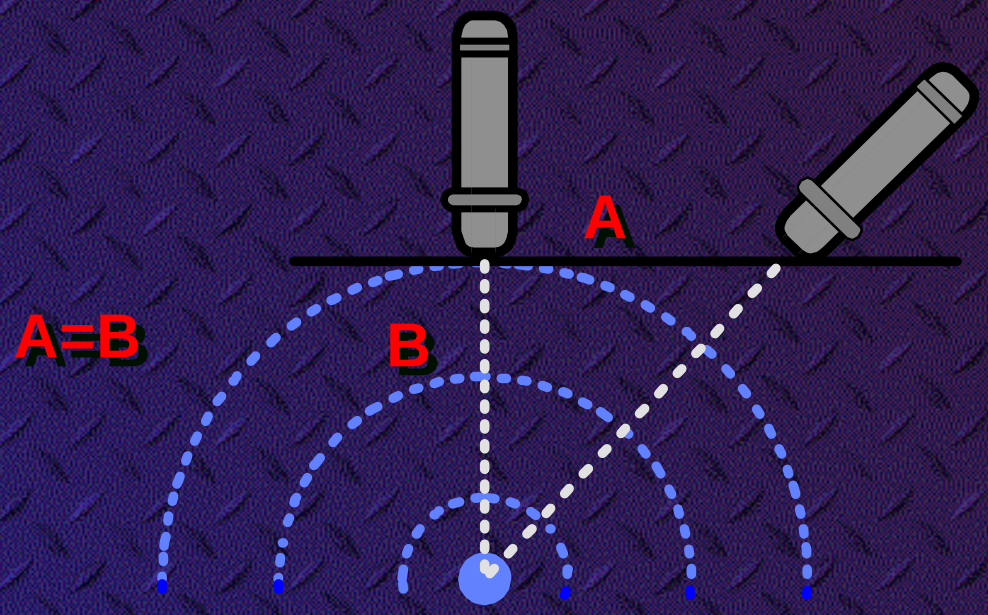
A peak Receiver coil senses its peak when it is tangent to an ideal circle of signal.

METROTECH

How Does All This Relate To Locating?

METROTECH

Combine the Three Principles



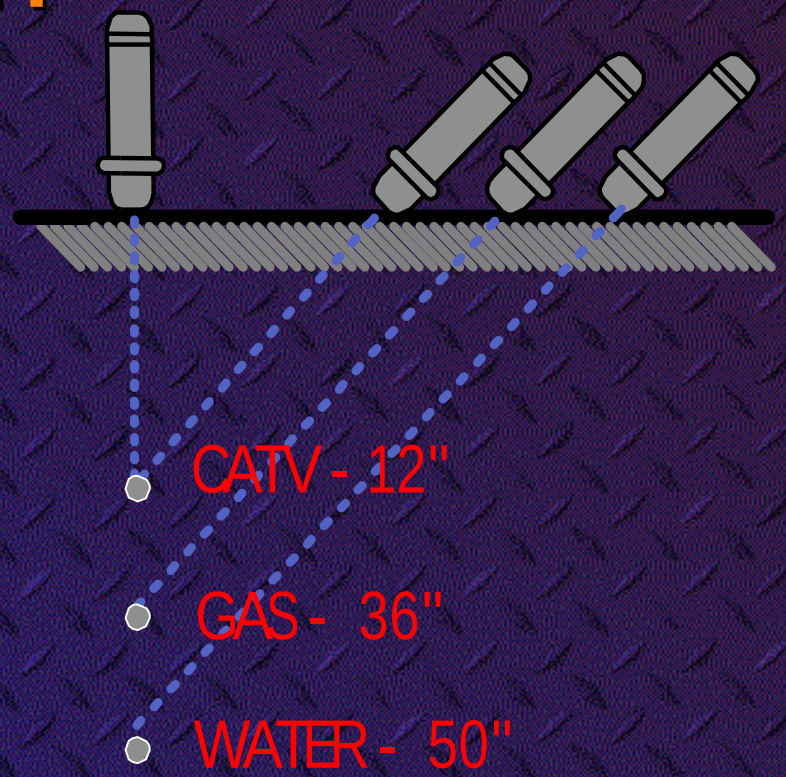
- Superimpose a Right Isosceles Triangle over the signal circle.
- Find "Second" centerline when Receiver at a 45 degree angle.
- Move to the side of your first centerline.
- Your depth equals the distance A.

METROTECH

How to Use the Triangulation Method for Determining Depths in Common Trench

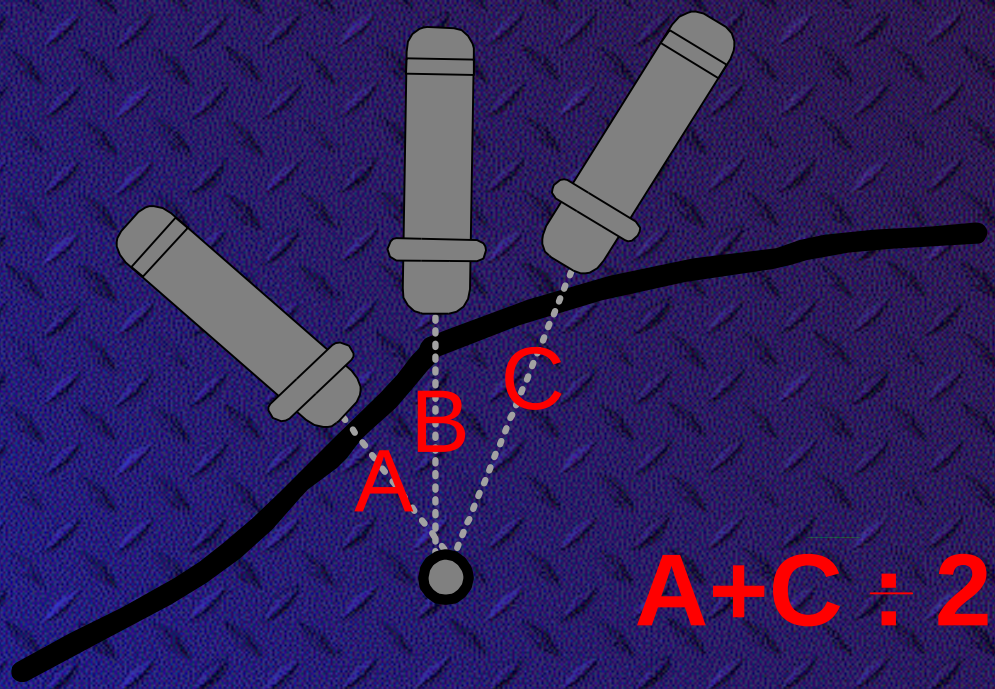
Use this same principle to determine depths of multiple conductors in a common trench.

Verify the type of utility by tracing to the point of termination. If you can "Direct Connect" to each utility, you can determine the depth of each one.



METROTECH

Triangulate for Depth on Both Sides of Your Centerline, Compensating for Uneven Ground and Signal Distortion



Uneven Ground

Average the two sides to compensate for the slope.

A+C ÷ 2 = B

METROTECH

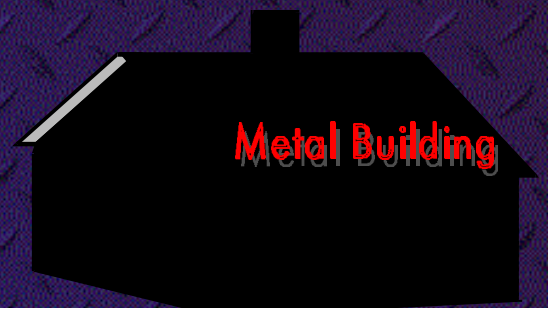
"Signal Distortion"

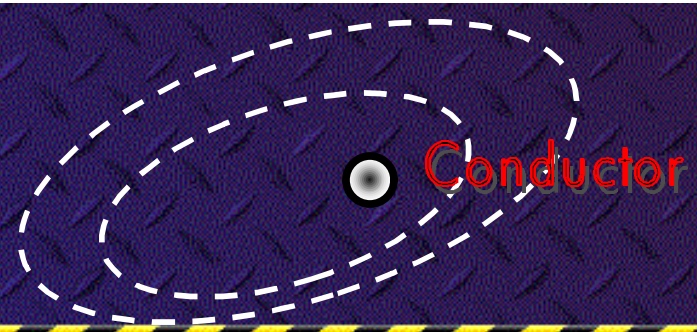
- Buried Metal Objects

  Large Storage Tanks

- Metal Buildings

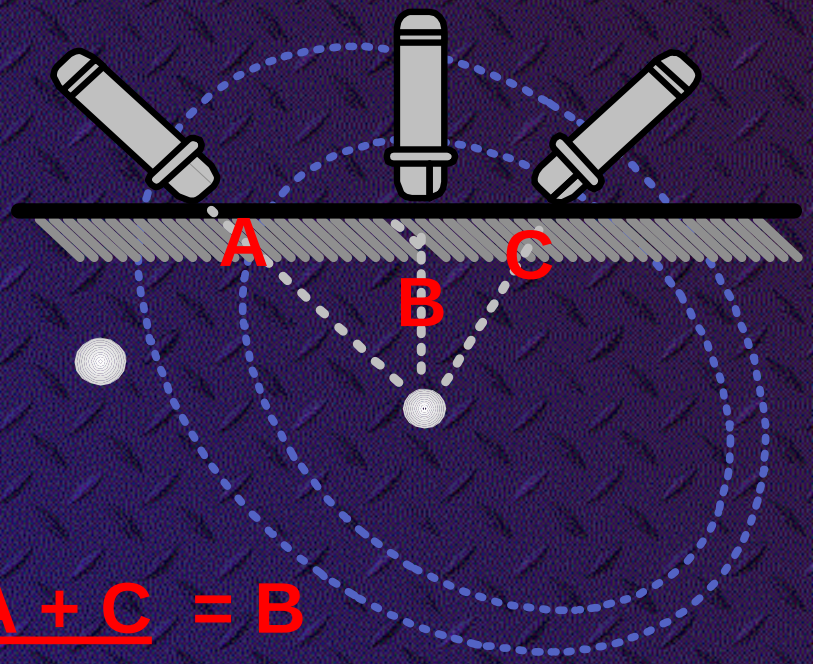
  Grain Storage





The Same Theory Applies to "Signal Distortion" Situations

If the two triangulated distances (A&C) are different, but the ground is level, this indicates "signal distortion". This is normally caused by bleedover from an adjacent conductor. Depth can be determined by averaging distances A and C.



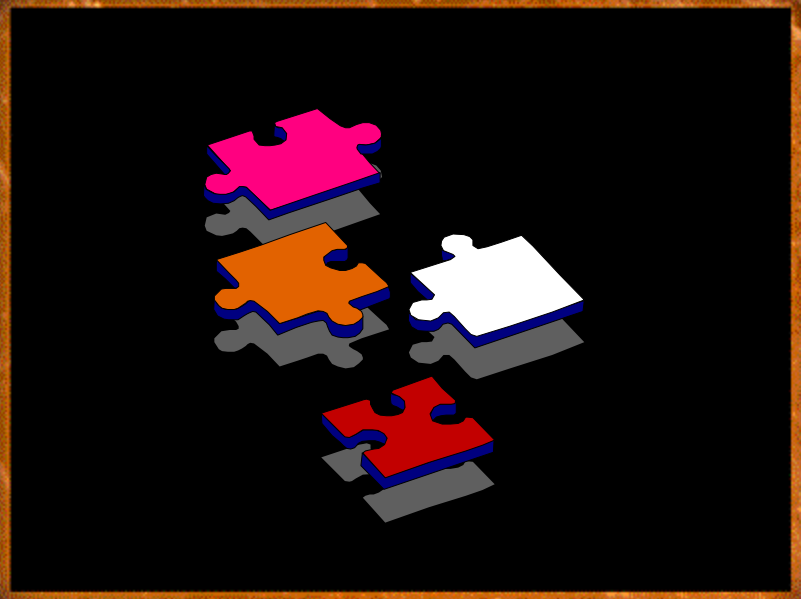
$$\text{DEPTH: } \frac{A + C}{2} = B$$

Verify Your Push Button Depth Measurement With Triangulation

METROTECH

Section 4

Inductive Coupling (Clamp)



METROTECH

When to Use Inductive Coupling (Clamp)

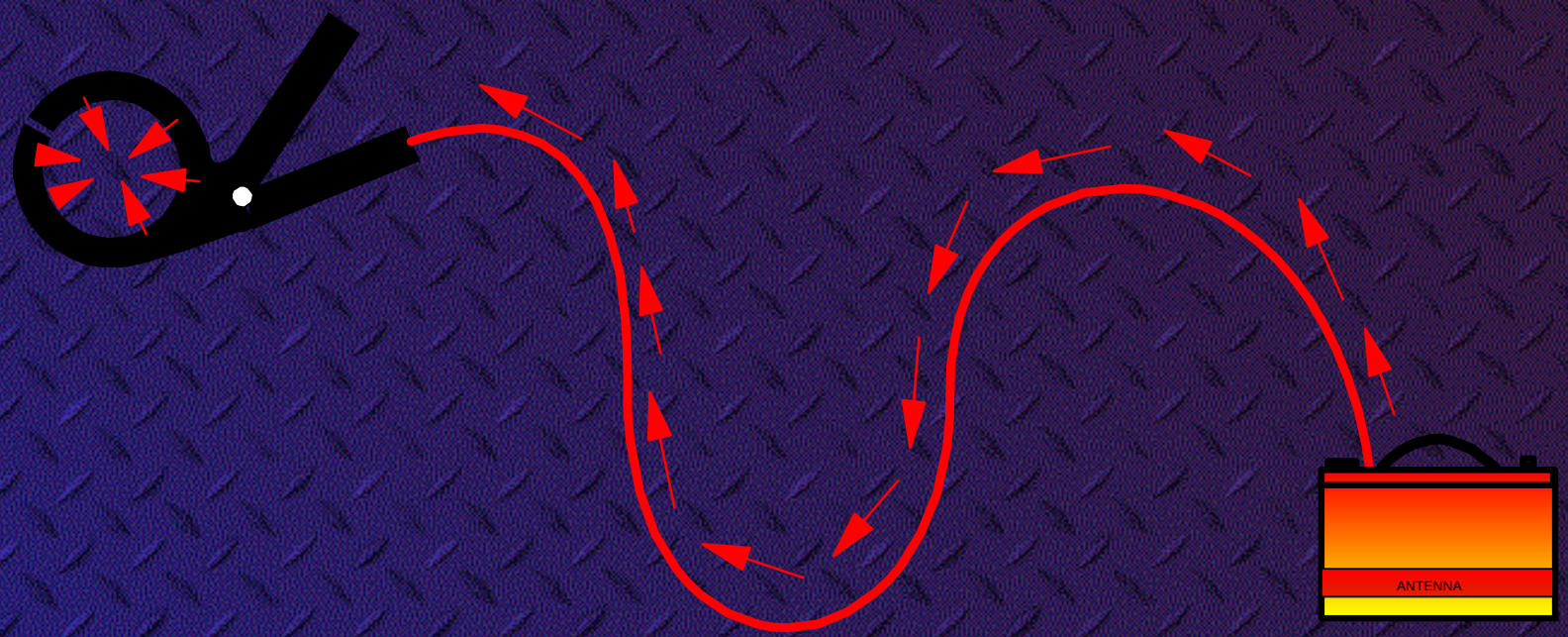
Use this method when:

- You have no access to direct connect.
- You are tracing energized primary or secondary cable.
- It is convenient and effective.
- Conductors are common bor

Caution: both ends of cable must be grounded

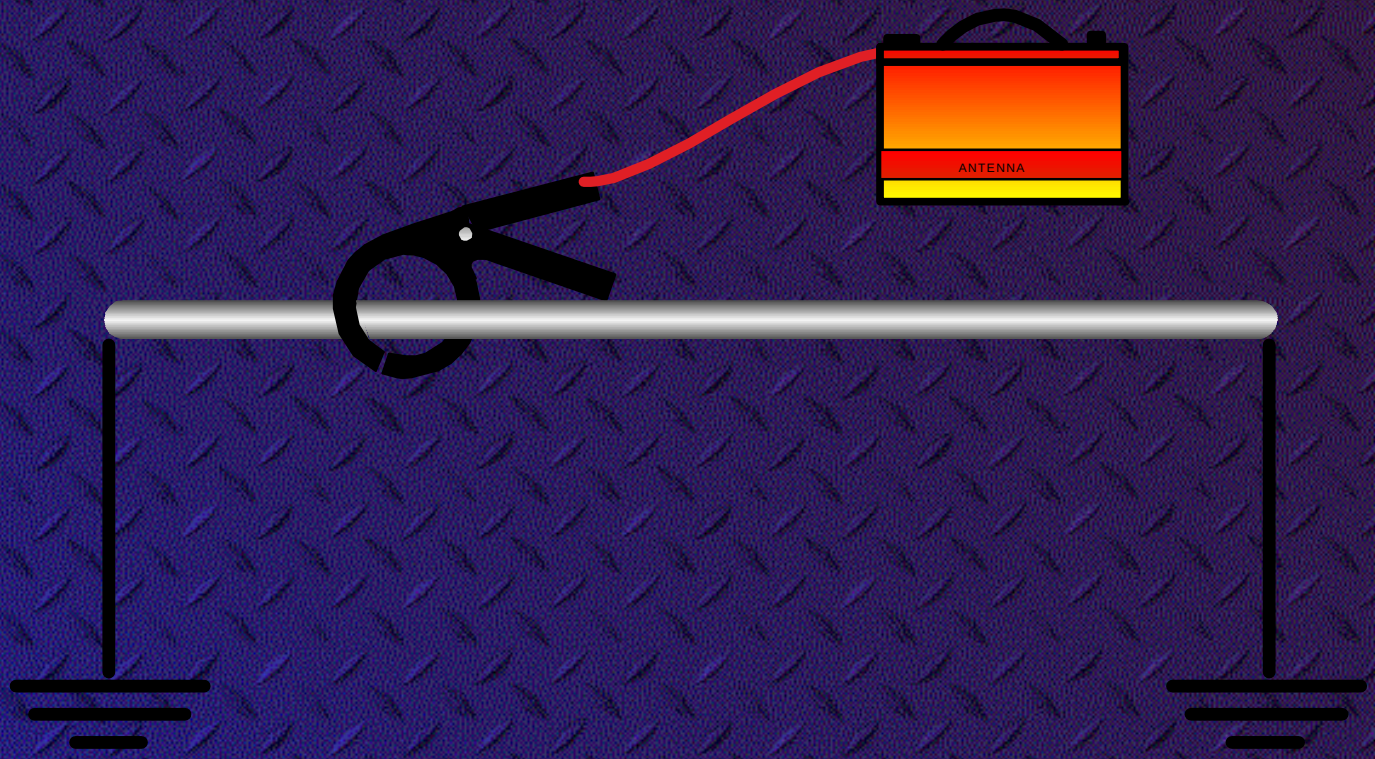
METROTECH

Inductive Coupling (Clamp)



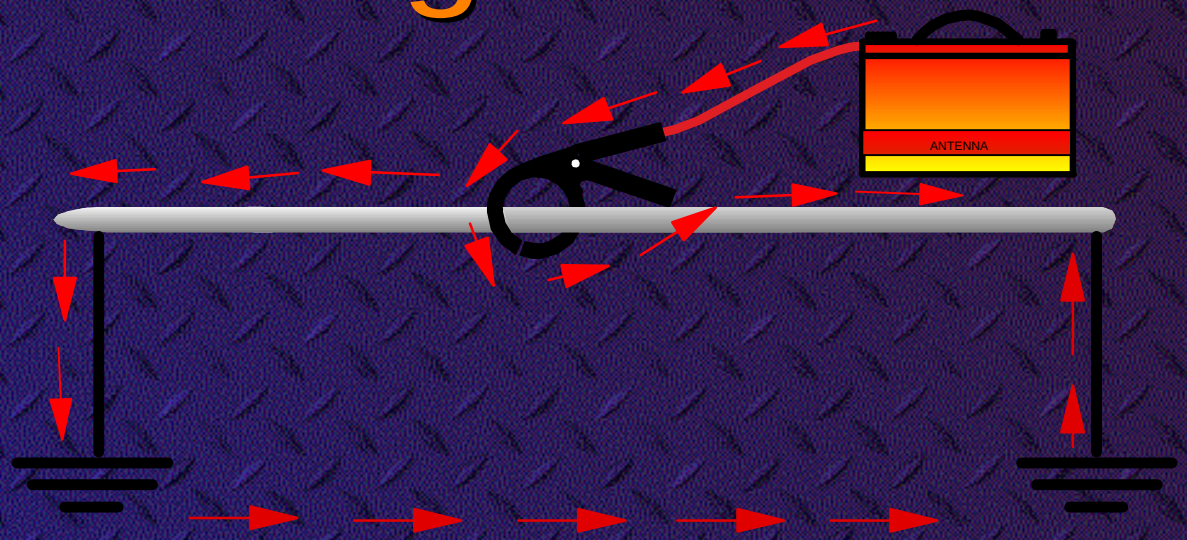
Signal travels from the Transmitter around and around the clamp. This sets up a magnetic field which is induced onto your target conductor.

Clamps only work when the conductor is grounded at both ends!



METROTECH

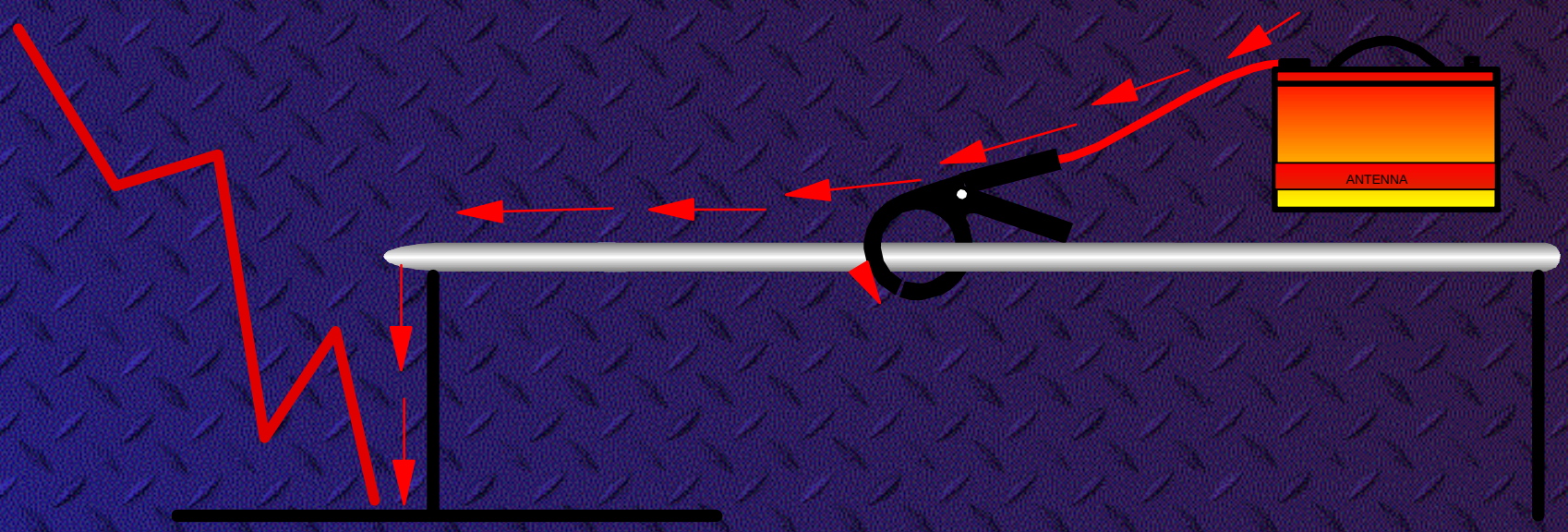
Grounds at Both Ends Allows Signal Path



The placement of the grounds may not be obvious to the user. Normally grounds are found at splices or other connection points, intentionally placed in the normal course of safe utility construction practices. This allows the signal to move along a circuit path.

METROTECH

If You Cannot Get A Signal with Your Receiver - the Grounds Are Missing



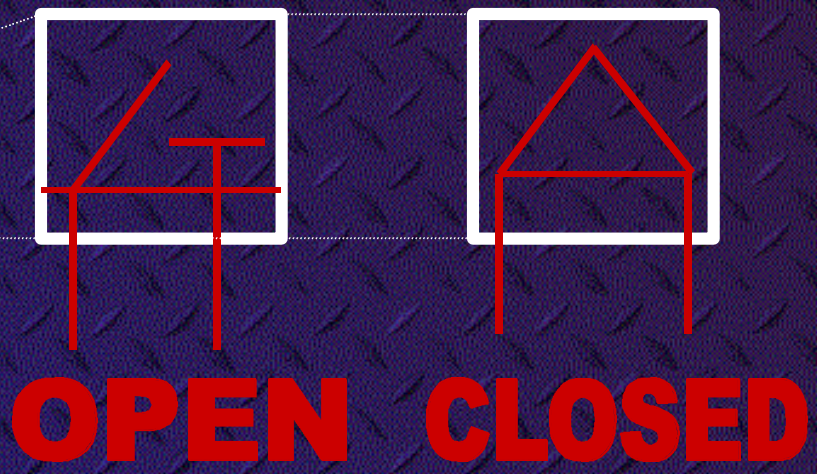
This could be for a variety of reasons - improper construction, someone before you forgot to replace the bonding straps, etc.

METROTECH

Inductive Coupling Tips

- Clamp does not transmit lowaudio

- Street lights with photo electric cells form opens.



Clamp Hints

Does Your Clamp Work?

Use handles do not pull on wires

Be Sure the Clamp is completely closed

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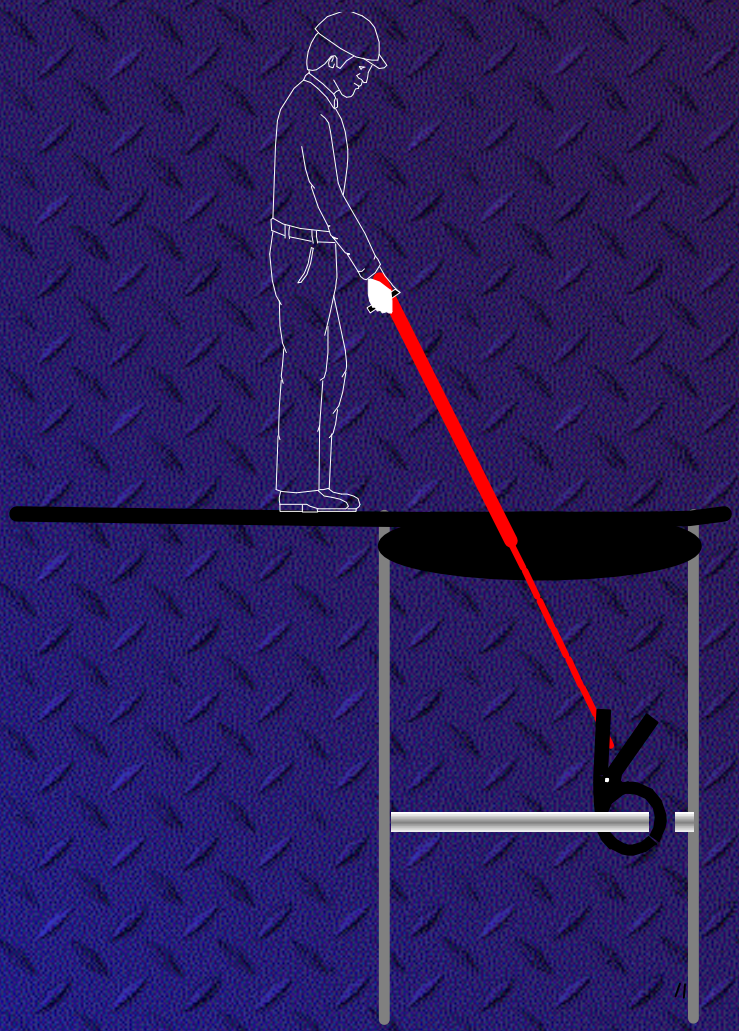
Additional Clamp Uses



A "hot stick" can be attached to a clamp for inserting into a confined space or manhole without having to ventilate.

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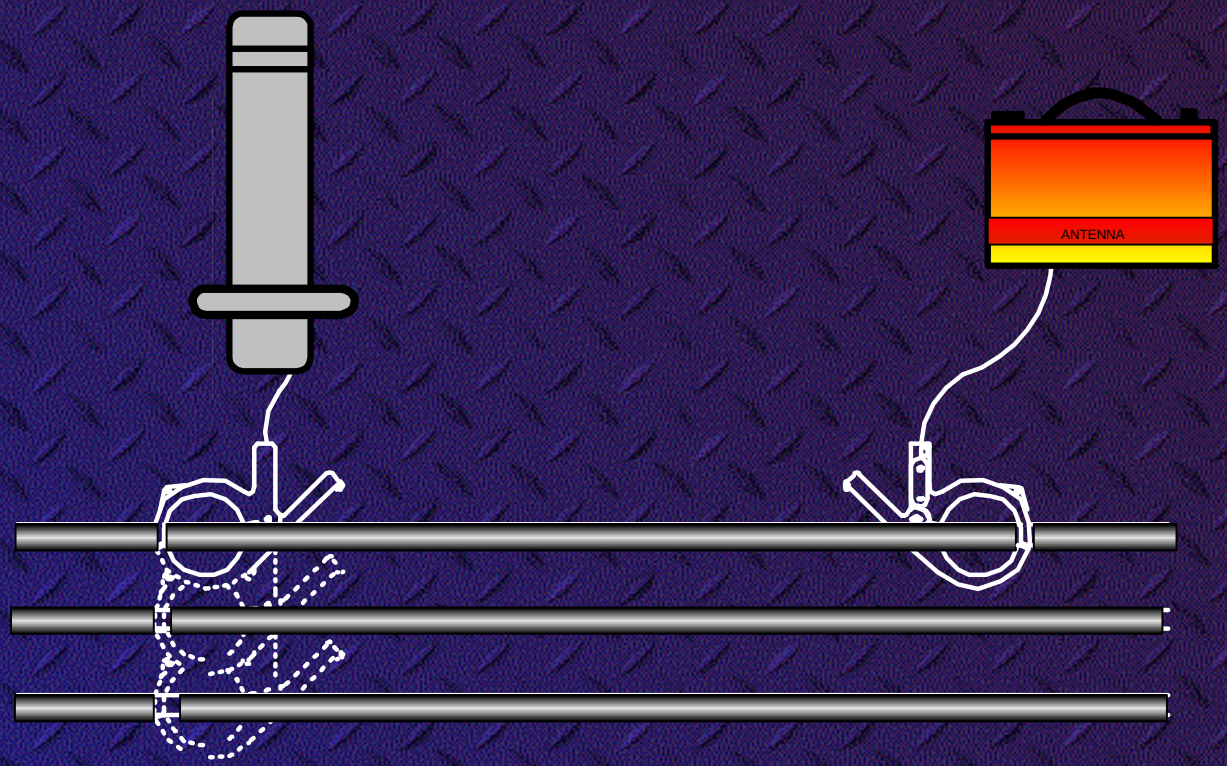
Use Two Clamps to Isolate Your Conductor Among Multiple Conductors



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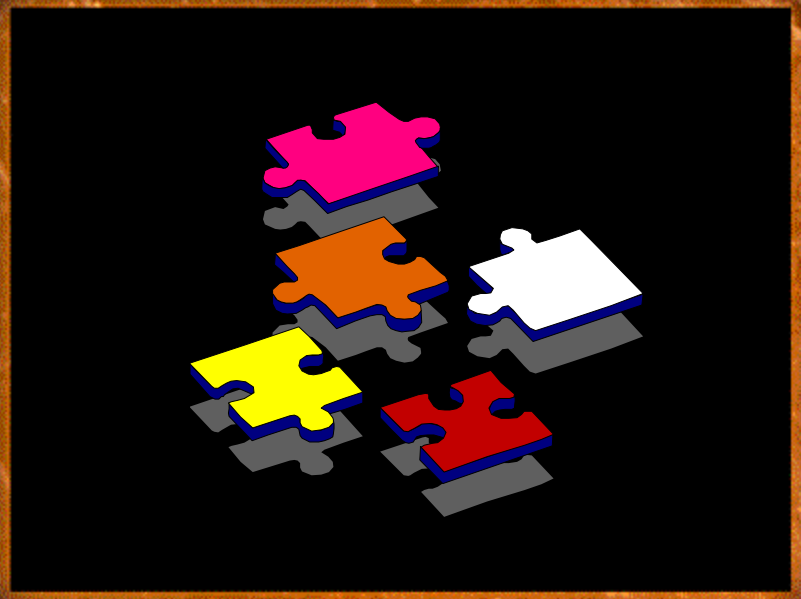
Section 5

Inductive (Box) Locating



METROTECH

Inductive (Box) Locating

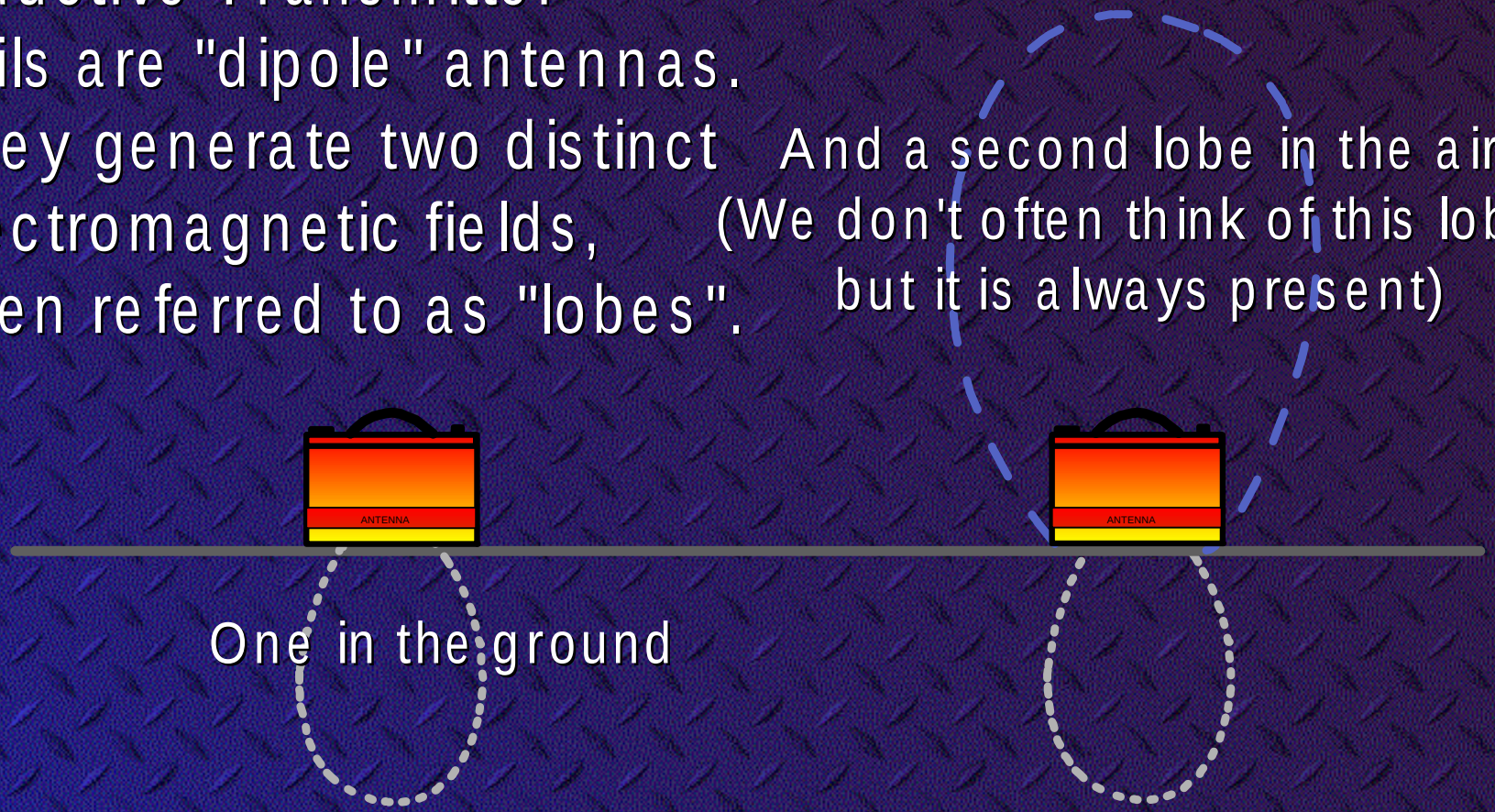
For Induction, remove direct connect leads or clamp from Transmitter.

If no connectors are plugged into the Transmitter, it will transmit signal from antenna.

How Induction Works

Inductive Transmitter
coils are "dipole" antennas.
They generate two distinct
electromagnetic fields,
often referred to as "lobes".

And a second lobe in the air
(We don't often think of this lobe,
but it is always present)



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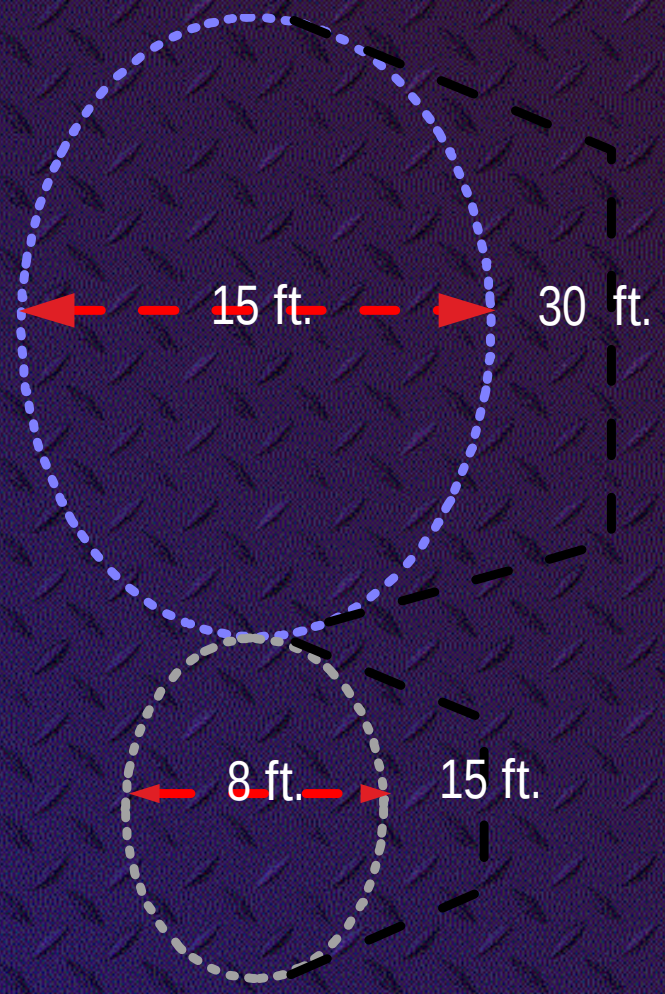
Inductive Signal

Just to give a general idea of scale, the upper lobe (air) is nearly twice the size of the lower lobe (ground).

This size difference is caused by the dampening effect of the soil on the lower lobe.



Air Coupling and Overhead Signal

Because of this dipole field, two problems can occur during inductive locating.

Air-coupling and Apparent Overhead "Interference"

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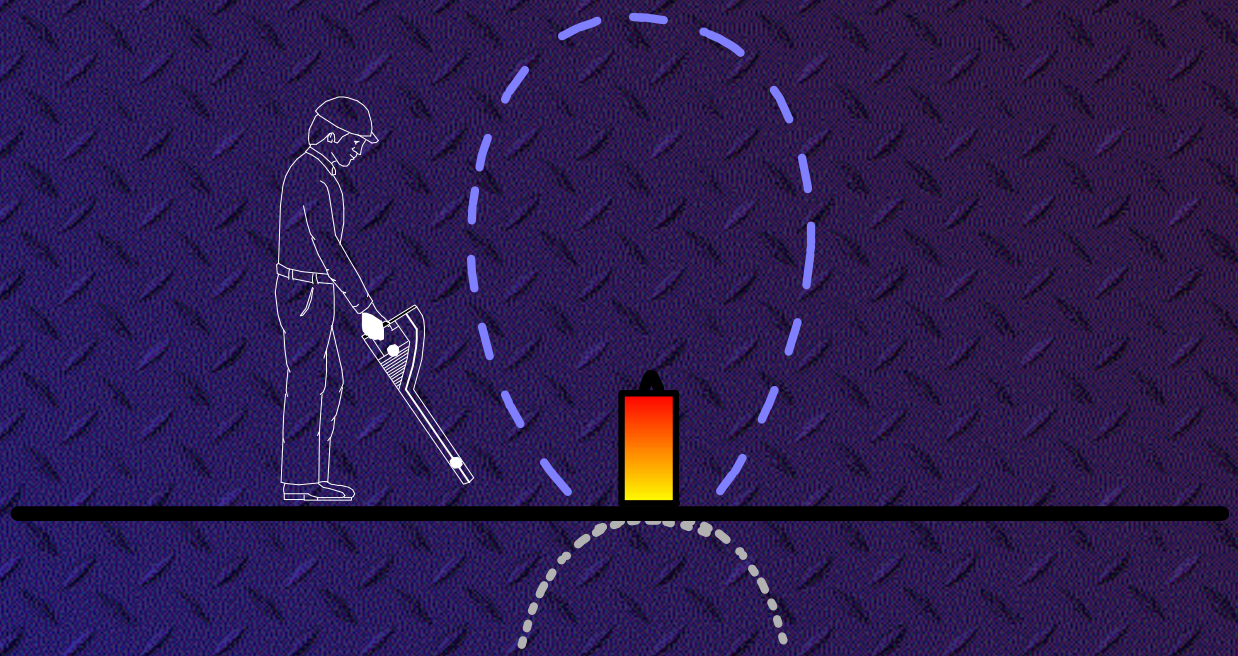
Air-coupling



Air coupling occurs when the Receiver is too close to the Transmitter and it appears as if the Receiver is detecting a pipe or cable. In fact, the Receiver is seeing the Transmitter signal directly through the air.

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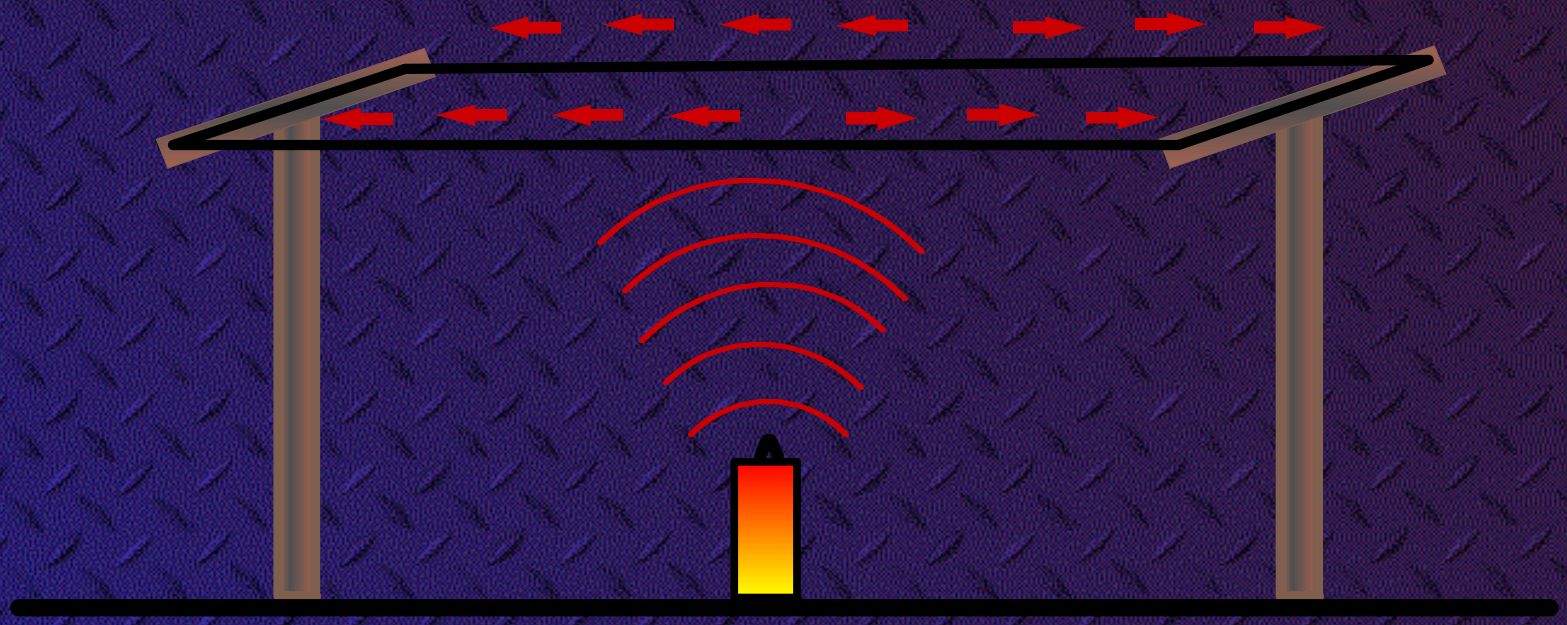
Apparent Overhead "Interference"



This phenomenon is similar to "air-coupling". In this case, the user, unaware of the existence of the upper lobe and/or visually missing the overhead utility lines, inadvertently transmits the inductive signal directly onto the overhead lines through the air. Users often mistake this self-caused event as some sort of "interference" from overhead power.

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What Do You Do to Check for Air-Coupling or Apparent Overhead "Interference"?

Think about it . . .

If you go further away from the pipe or cable,

your field strength should go . . .

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So... if you raise the Receiver straight up into the air, your field strength should go:

A. Up

B. Down

C. None of the Above

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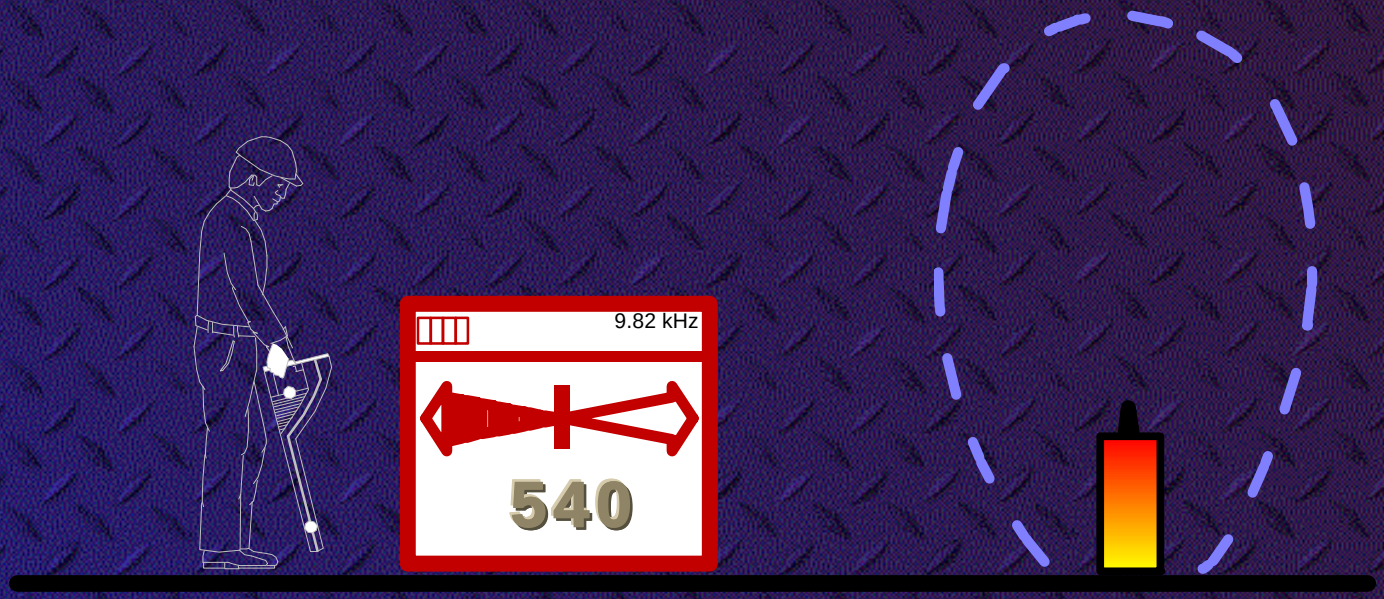
Lift Receiver From This Position



You are air coupled if the signal strength increases as you raise the Receiver above the ground.

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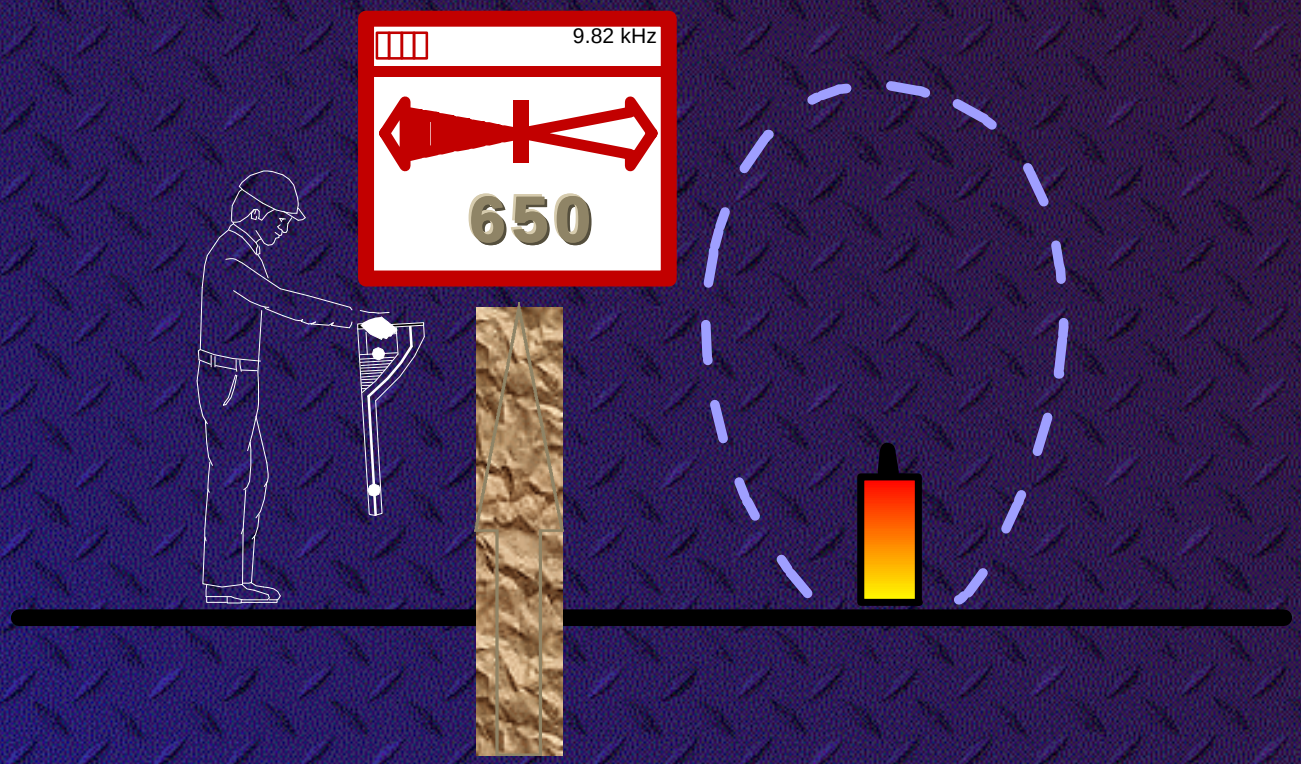
Lift Receiver Straight Up



Air coupling occurs when the Receiver is too close to the Transmitter and it appears as if the Receiver is detecting a pipe or cable. In fact, the Receiver is seeing the Transmitter signal directly through the air.

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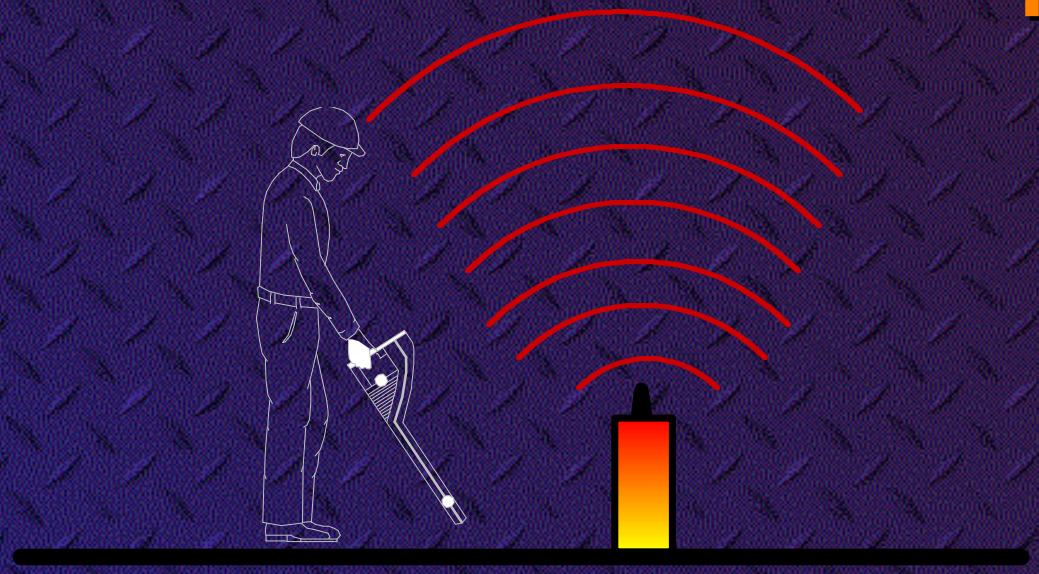
Solution for Air-Coupling



Move the Receiver further away from the Transmitter until you are out of the upper lobe signal field. (Double check for air-coupling.)

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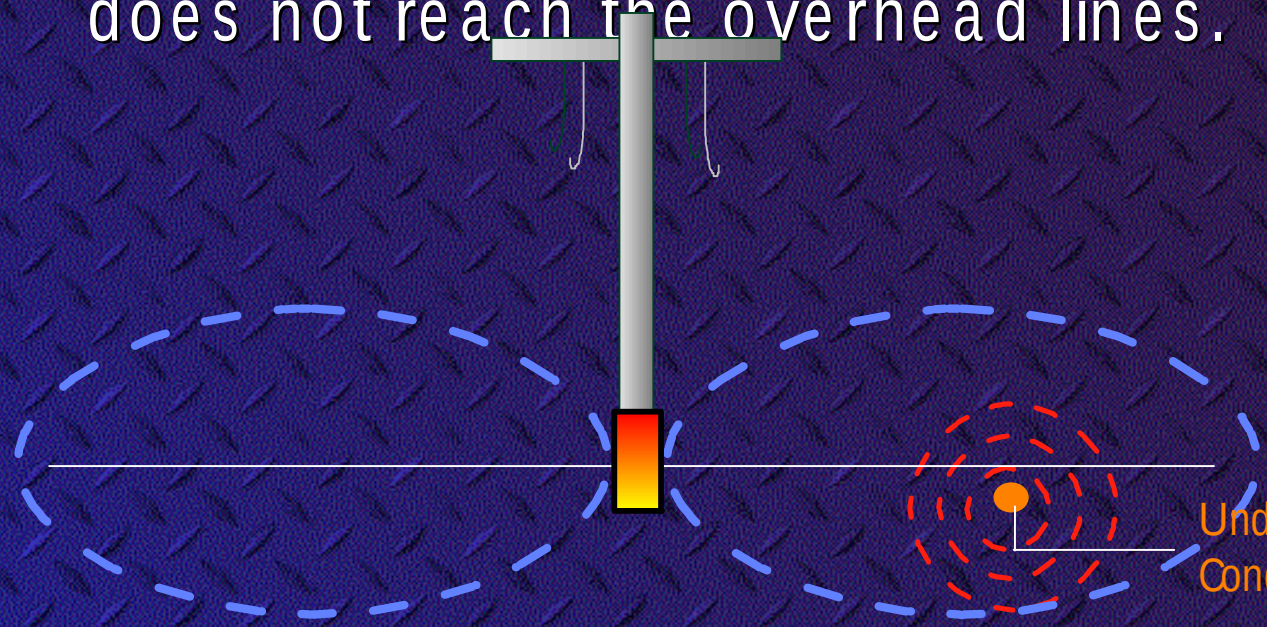
Solution for Overhead "Interference"

Reposition the Transmitter -

Move it away from the overhead lines. Or re-position the Transmitter on its side, directly under the overhead lines, so that the signal does not reach the overhead lines.



CAUTION

Common Bonds may cause overhead interference.

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Position of Transmitter for Inductive Locating

Two types of Transmitter antennas-

<u>Ferrite Antenna</u> -

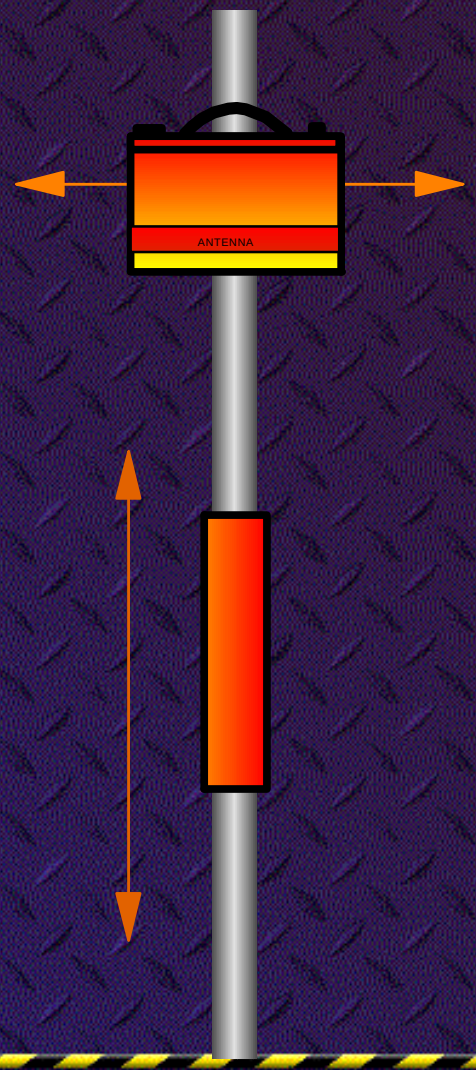
Most upright locators

Position Across Conductor

<u>Loop Antenna</u> -

All split-boxes

Position Parallel to Conductor



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Radio Frequency

The most effective inductive Transmitters use a high frequency between 33kHz and 400kHz. These Transmitters are commonly called "radio frequency" locators.

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Inductive Locating Benefits & Drawbacks

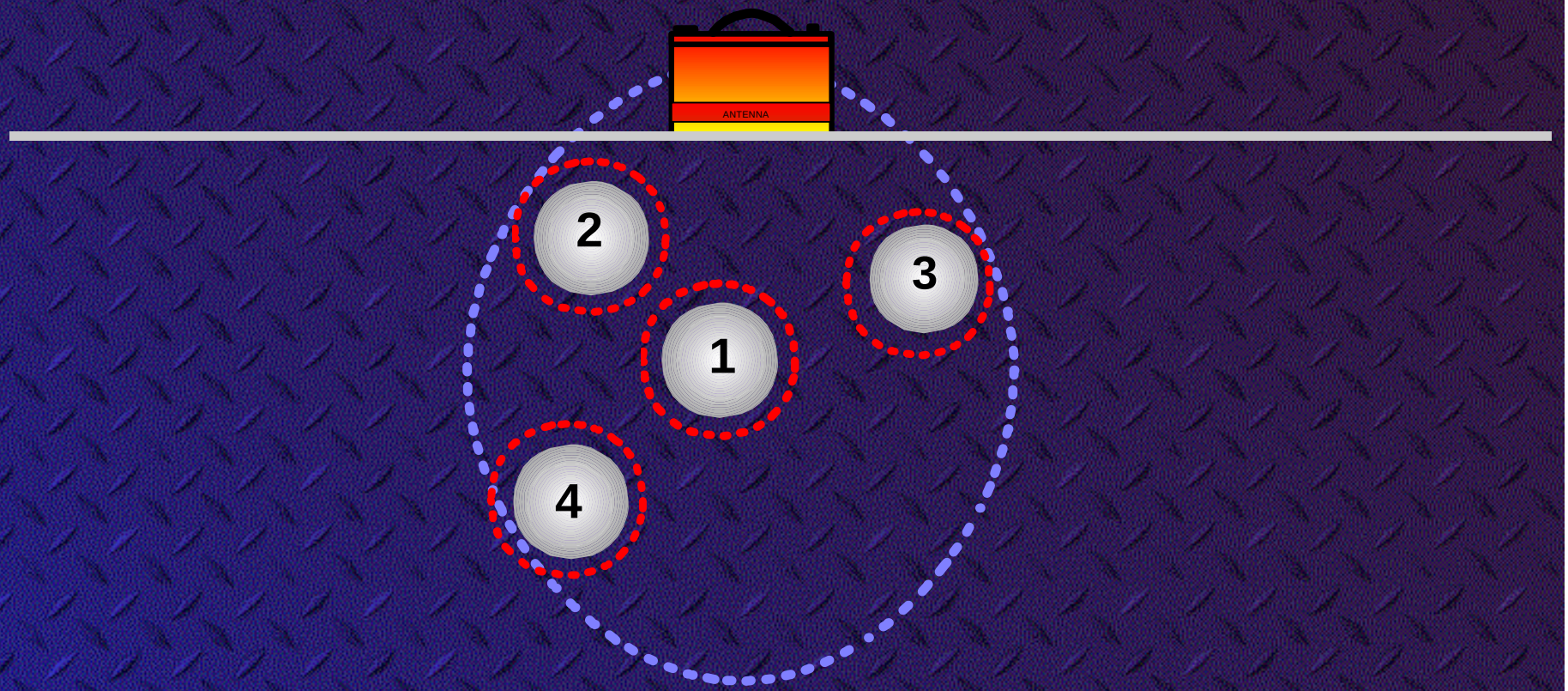
Benefits of High Frequency:

- Ability to penetrate insulators.
- Less dependent on the "electrical circuit" theory - signal returns more easily through the ground.

Drawbacks of High Frequency:

- Disperses quickly - Attenuation.
- Shorter locating distance.
- Bleeds off - "lights up" everything in the area.
- Prone to signal distortion.

High Frequency "Bleed Off" - Lights Up Everything



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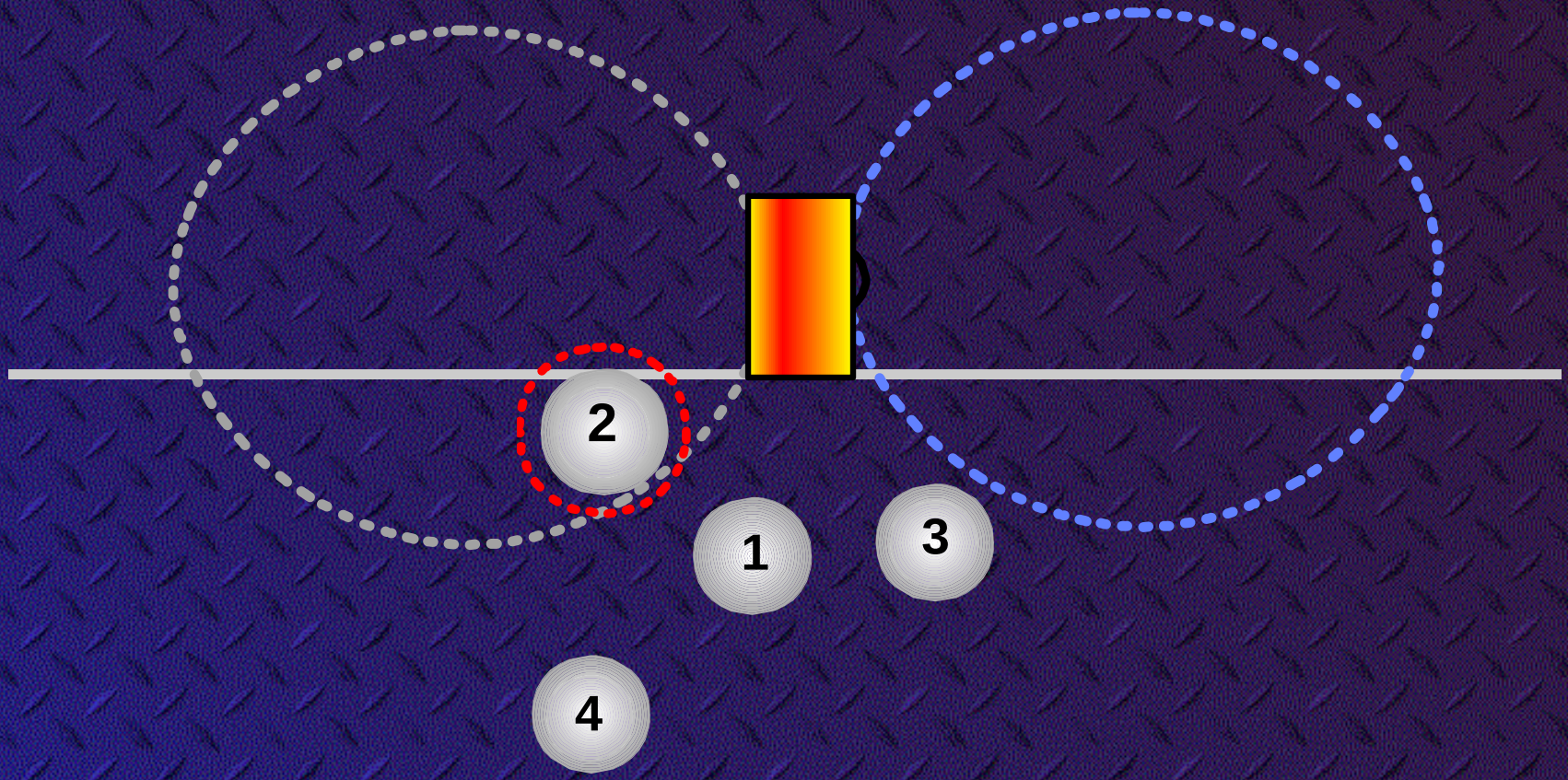
To Isolate Conductors



Stand Transmitter on End to Redirect Signal

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Inductive Locating Conclusion

- Use only when all other methods fail.
- Requires higher frequency.
- Be aware of bleed over caused by high frequency.

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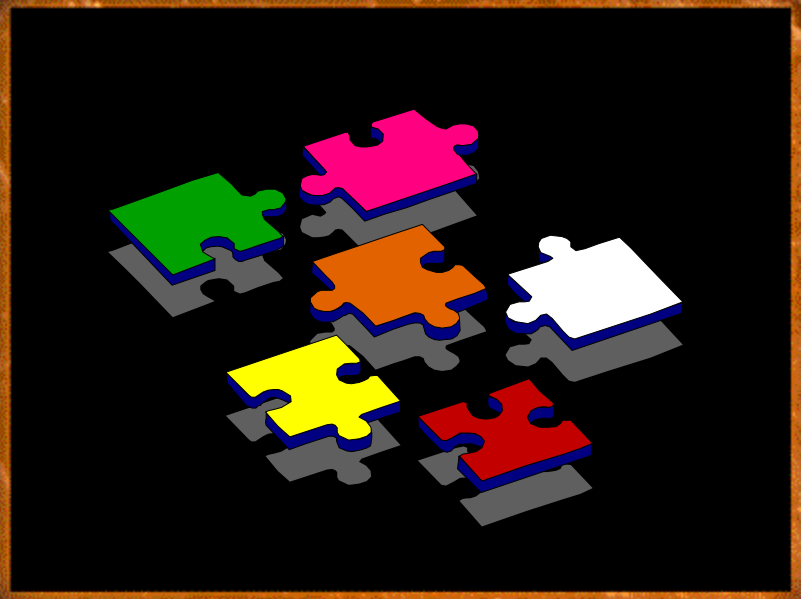
Section 6

Choice of Frequency



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Choice of Frequency

High interruptions, 65kHz & above	-	Penetrates bleed-off liability
Medium 8kHz & above	-	Requires continuity moderate distance
Low continuity, 1kHz & below	-	Requires perfect greater distance

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High (Radio)

Use on conductors (usually pipe) which are "insulated" by:

- Earth (in Inductive)
- Gaskets
- Corrosion
- Plastic Joints
- Resistive Joints
- Street Lighting (high resistance open)

Medium (Audio)

Good Direct Connect Frequency -

Use on:

- Power, Telephone, and CATV cables
- "Coated" pipes (gas)
- "Uncoated" pipe (depending on condition)
- Pipeline (good cathodic protection)
- Irrigation Control Wire

Low (Audio)

Use on long, uninterrupted conductor (usually cable), such as:

Fiber

Gas Transmission lines with good coating integrity

Trunk or Toll cables

or where ever not common bonded. Disconnected Power Lines.

Different Ranges of frequencies react differently when
they encounter a path to ground.

High Frequency - Short distance, and not easily distracted.

Medium Frequency - Moderate travel, easily distracted.

Low Frequency - Capable of goin long distance, but will take route of first distraction.

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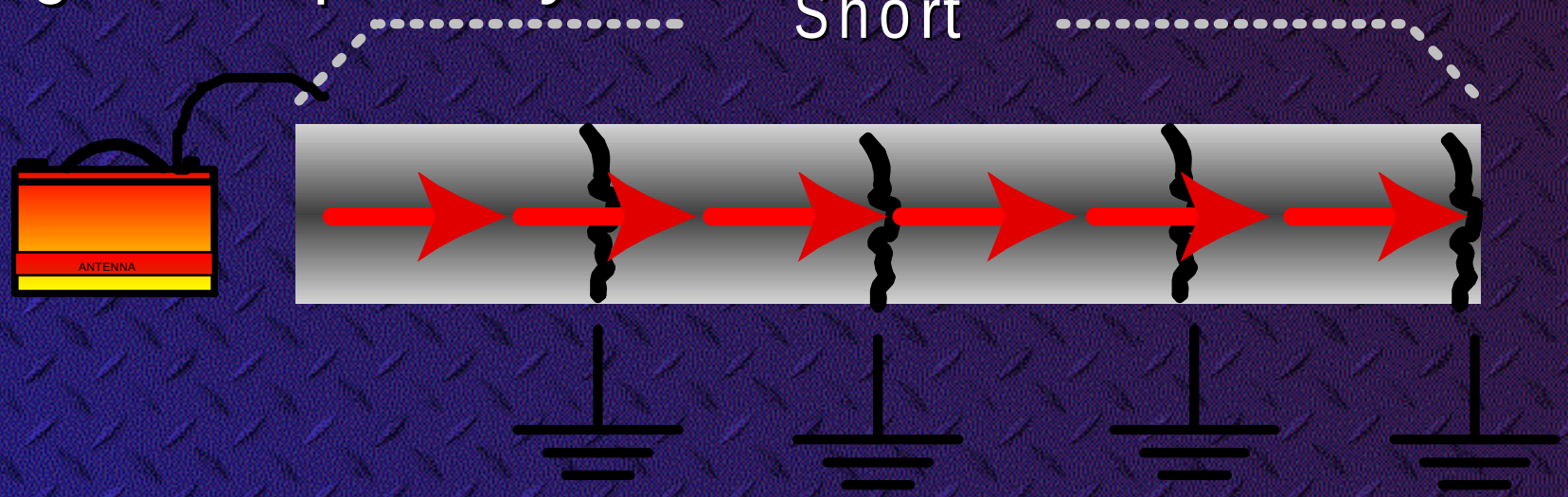
Consider Earth/Ground Conditions When Selecting Frequency

High Frequency



Short Distance, and not easily distracted.

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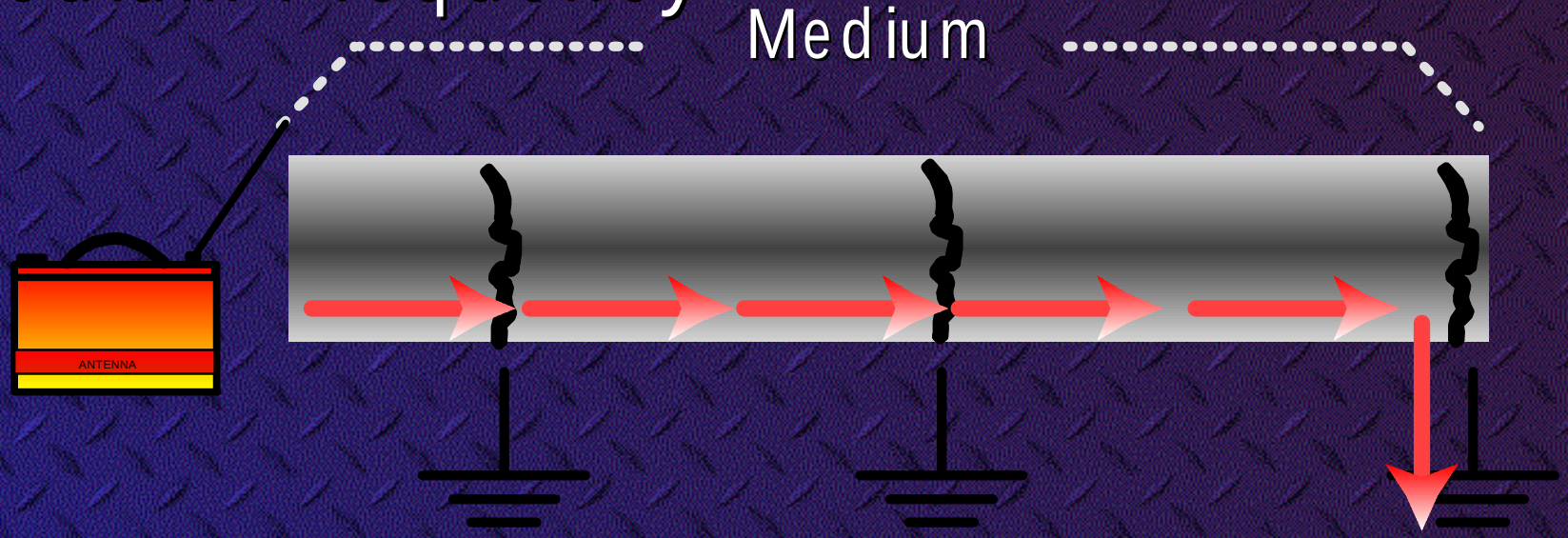
Medium Frequency



Moderate travel, easily distracted.

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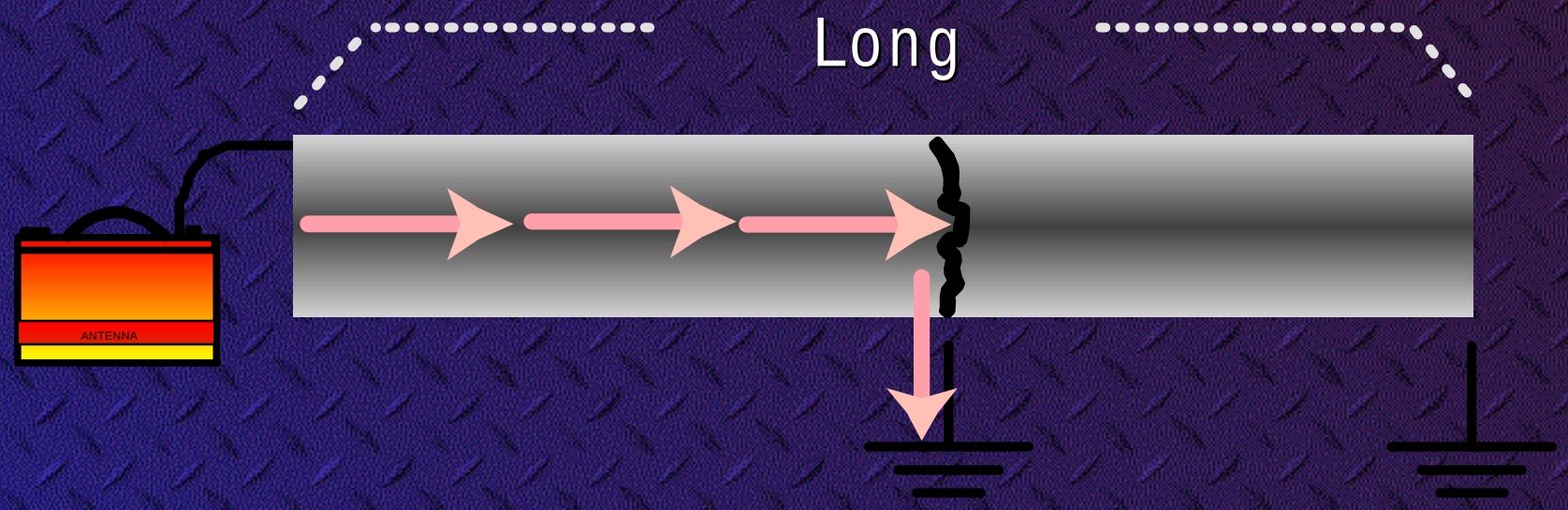
Low Frequency



Long distance, will take route of first distraction.

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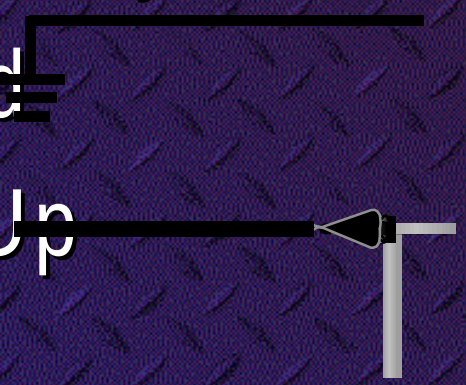
Having Locating Problems? Evaluate Factors

Conductor/Conductivity -

Improve Ground

Improve Hook Up



Frequency Choice -

Change to higher or lower

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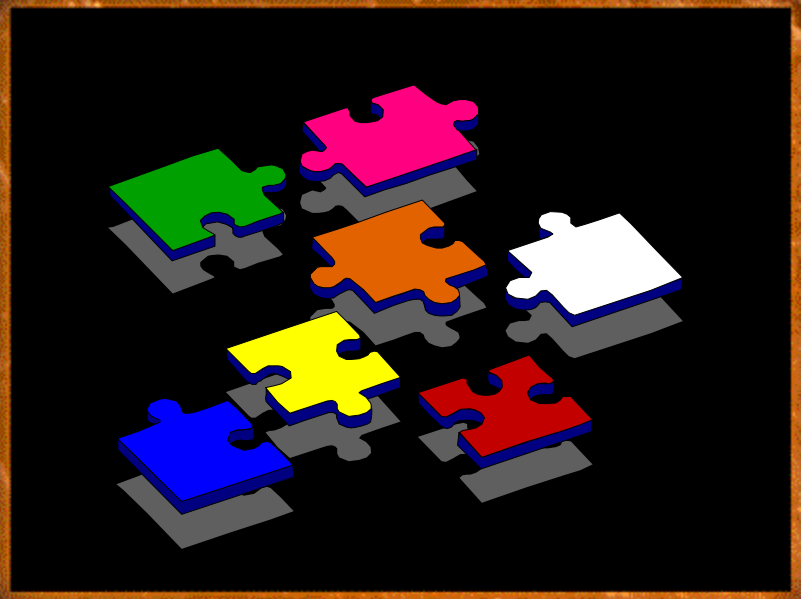
Section 7

Summary



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"The Locating Picture"

Combine your technical knowledge of your instrument with common sense to do your job w e.

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Each Element Contributes To Your Confidence In Locating

Locator Capabilities 30%

Visual 15%

Conductor Material 15%
(Copper, steel, aluminum, iron,etc.)

Transmission Method 15%

Ground/Earth 15%

Blueprints 5 to 10%

Depth 10%

End Point Negative 30%

End Point Positive 15%

Signal Strength 30%

Ultimately, the Success of Your Locate Depends Mostly On YOU!

- Your Own Resourcefulness and Problem-Solving Abilities.
- Type and Condition of Soil.
- Type and Condition of Target Conductor.
- Your Choice of Connection.
- Your Choice of Frequency and Power Setting.

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Qualities of a Locating Champion

Good Problem Solver

Quick at the Trial and Error Process

Unafraid of Experimentation and Minor Setbacks

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Now You Have All the Knowledge to:

TAKE CHARGE of YOUR Locates -

GO FOR IT!!

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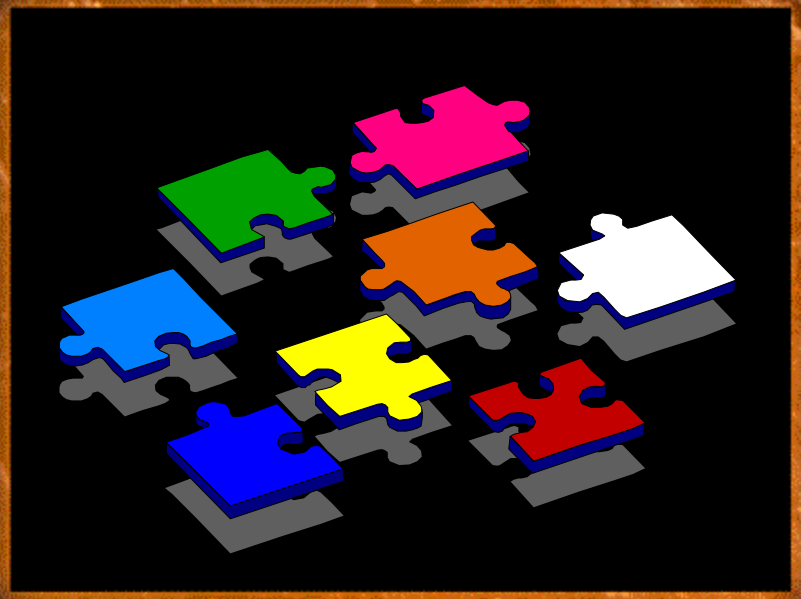
Section 8

Field Calibration



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Combine Technical Knowledge with Common Sense To Do Your Job With Confidence

Begin Your Locate In Control

Establish Your Confidence in the Locator's Accuracy

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Before Starting Your Locate-

Be Sure Your Instrument is Working by Te

Establish Your Own Test Site at a conven
place, such as your home or work place.

Choose a "Known Conduct
Your Test Site.

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Choose a "Known Conductor" at Your Test Site

This will become your benchmark for measurement accu

Choose:

- A utility at approximately 3 feet in depth (average depth for a utility).
- Establish the signal strength and depth of this conductor.
- Mark the site for future reference.
- Use this information for instrument test comparison.
- A utility with an access point for direct connection

When to Test Your Instrument

If your instrument is new.

Before leaving for your job - the night before in case you need to recharge.

After someone else has used your locator.

If you have problems during your locate.

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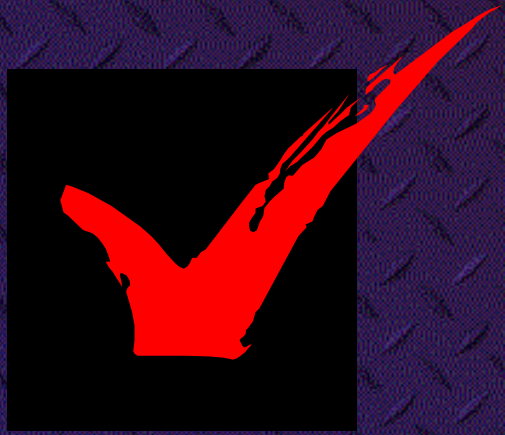
Check Your Instrument

Check the Batteries -

- ✓ Transmitter and Receiver

Check the Operating Features -

- ✓ Left/Right, Signal Strength (Receiver)
- ✓ Depth (Receiver)
- ✓ Direct Connection Leads



Check the Battery Power

15 % of instruments into repair are in need of new batteries

Both Transmitter and Receiver -

- ✓ If battery power is low

Recharge or Replace (depending on model)

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Check the Instrument Operation

Left/Right Indicator and Signal Strength:

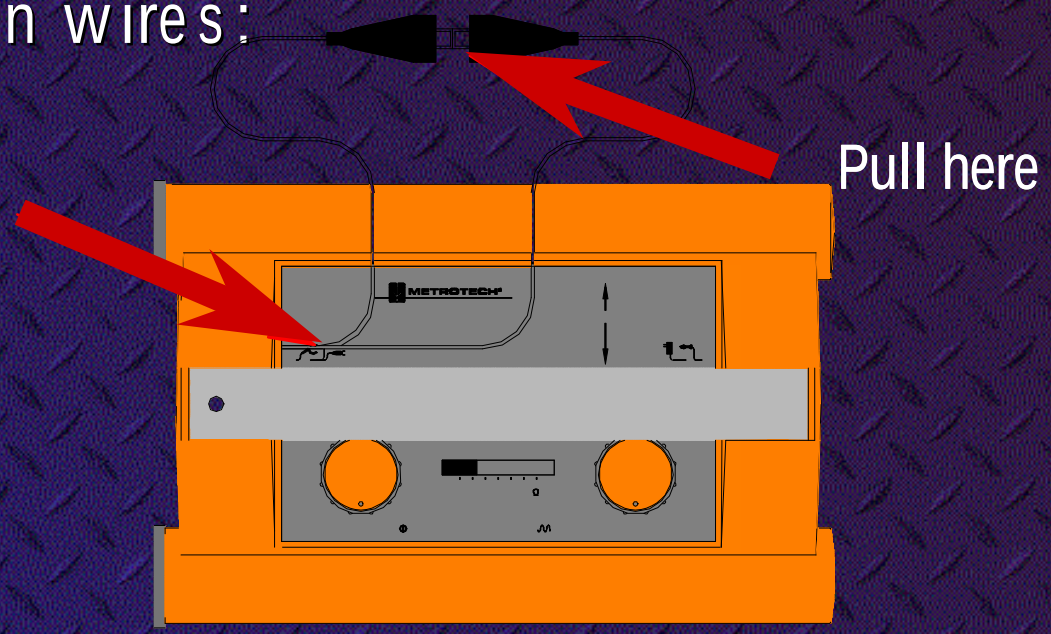
- ✓ Apply signal onto your conductor
- ✓ Turn the Receiver "ON"
- ✓ Move the Receiver back & forth over your conductor
- ✓ Look for your known centerline and signal strength

Depth:

- ✓ Take a depth measurement
- ✓ Compare with a known depth

Check the Direct Connection Leads

Test for loose or broken wires:



With the Transmitter "OFF", plug the Direct Connection Leads into the Transmitter and attach them to each other.

- Turn the Transmitter "ON".
- Turn the Receiver "ON". Note the signal strength - pull on the wires near the attachment points (clip and jack). Signal fluctuation indicates loose or broken wires.

Check Inductive Clamp

- Plug the joined Direct Leads into the Receiver AUX jack.

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Check Inductive Clamp

- Plug the Clamp into the Transmitter jack.

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Check Inductive Clamp

- Turn the Transmitter "ON".

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Check Inductive Clamp

- Note Receiver signal strength - pull on the wires near the attachment points (clamp and jack) signal fluctuation indicates loose or broken wire.

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Check the Transmitter Inductive Coil

1 Turn the Transmitter "ON" in the Inductive mode.

2 Wave the Receiver toward the Transmitter.

3 Check the Left/Right and Signal Strength functions on the Receiver.

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Metrotech wishes you many successes!

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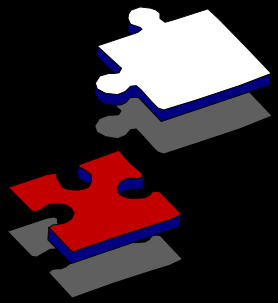
SECTION 2

Importance of Earthing



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Importance of Earthing

Earthing is the Most Important Factor in the Direct Connect Method

- The signal (current) must "flow" in a loop to be detected by the Receiver.
- A metal earth/ground provides a focal point for the signal to travel back to the signal source - closing the circuit (loop).
- The larger the metallic surface, the stronger the signal loop.

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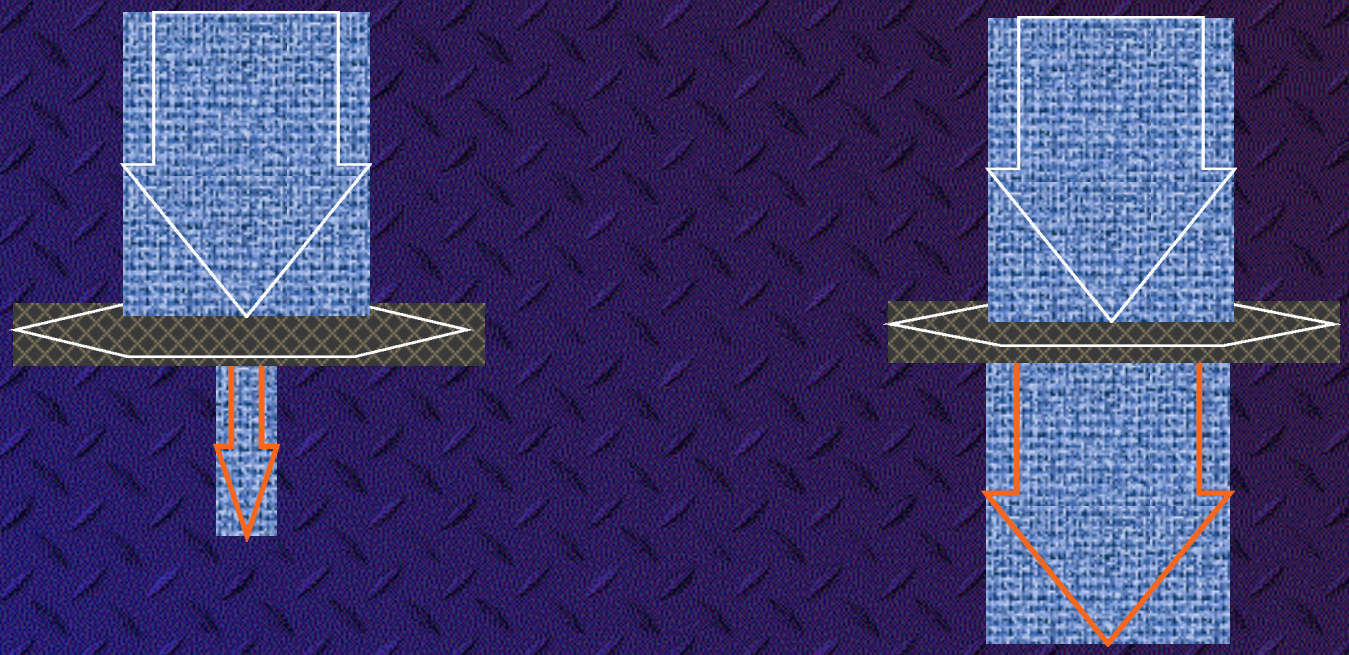
Principle of Earthing



If the current was water, the earth/ground would be a

drain - the better the drain, the better the water flow.

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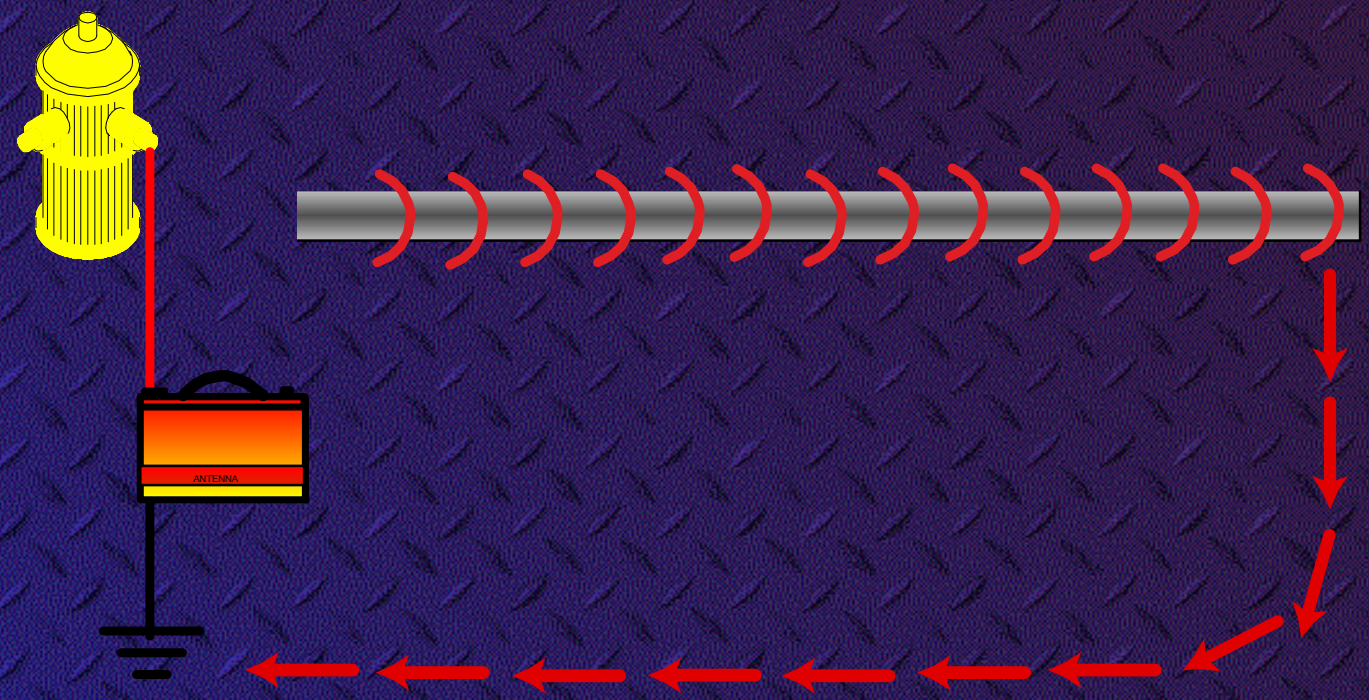
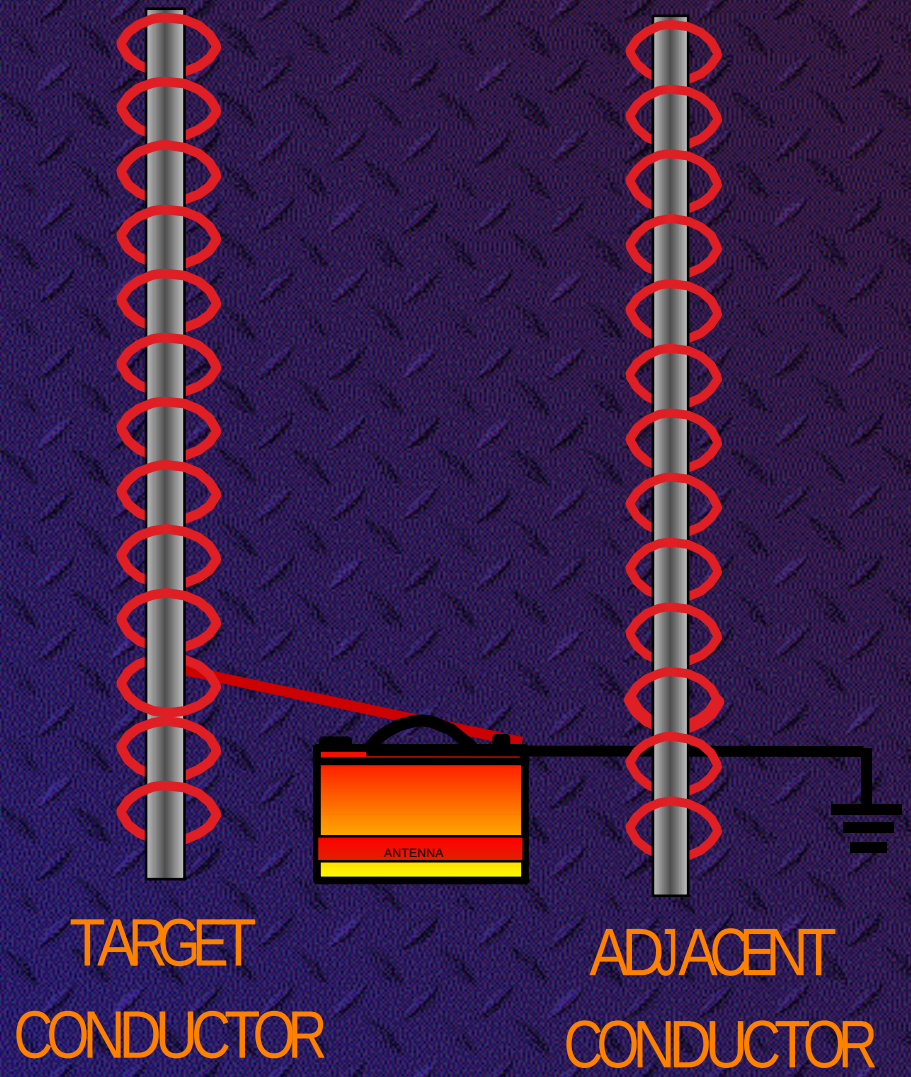
Ground Rod Placement



Attach Black Lead to Ground Rod at right angle to

METROTECH



Crossing over an adjacent conductor places unwanted signal on that conductor.

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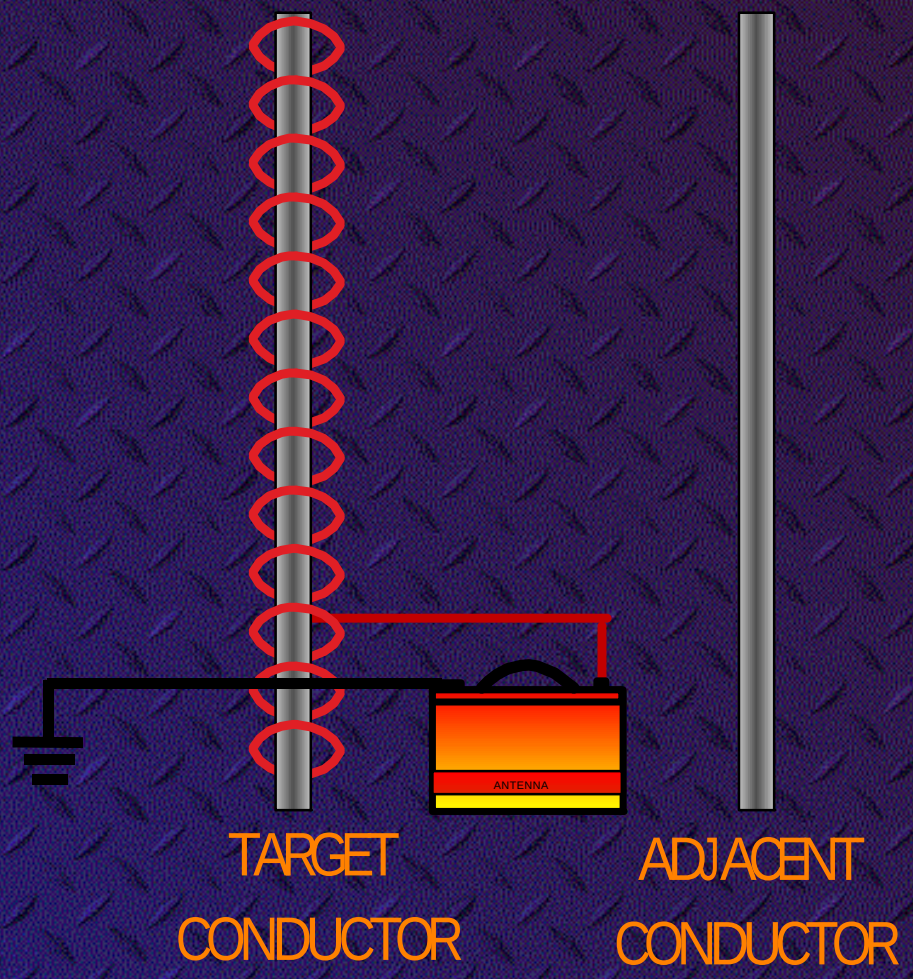

Place ground lead away from other conductors.

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Avoid "Destructive Interference"

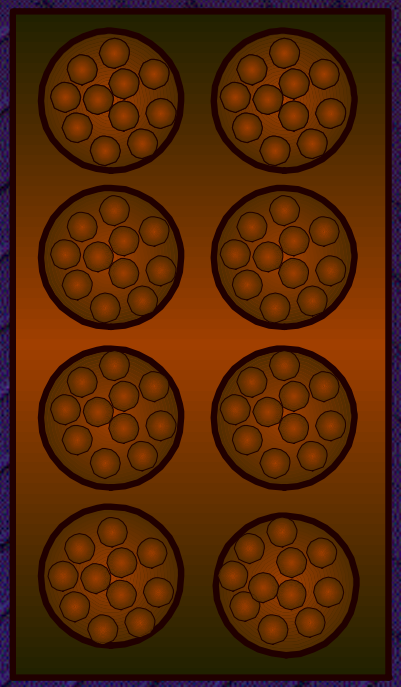
Connect Earth/Ground at right angle.

This rare situation most commonly

occurs when two (or more) conductors

are physically connected.

e.g. common trenching



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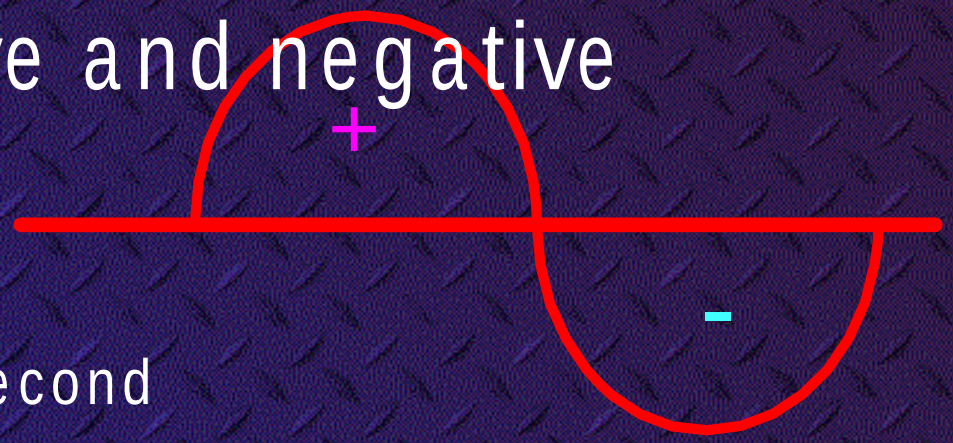
A Few Important Terms Describing Alternating Current:

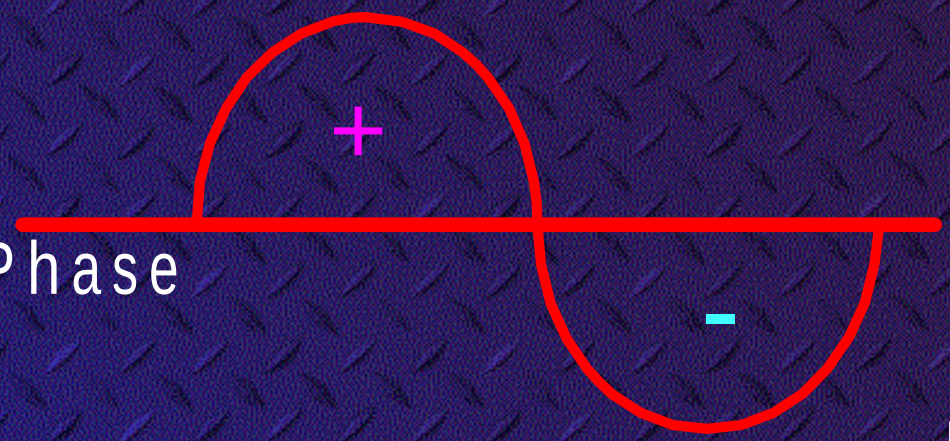
<u>Cycle</u> One round of "up and down" or positive and negative potential.



One cycle per second

"Alternating Current" Terms

<u>Phase</u> Signal goes both "up" and "down".



Positive Phase

Negative Phase

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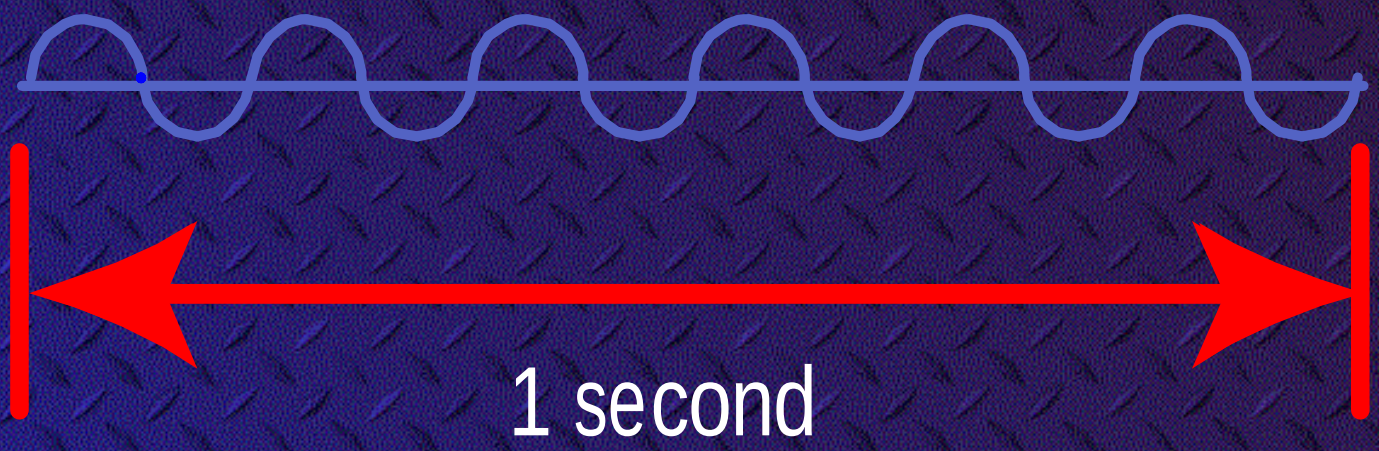
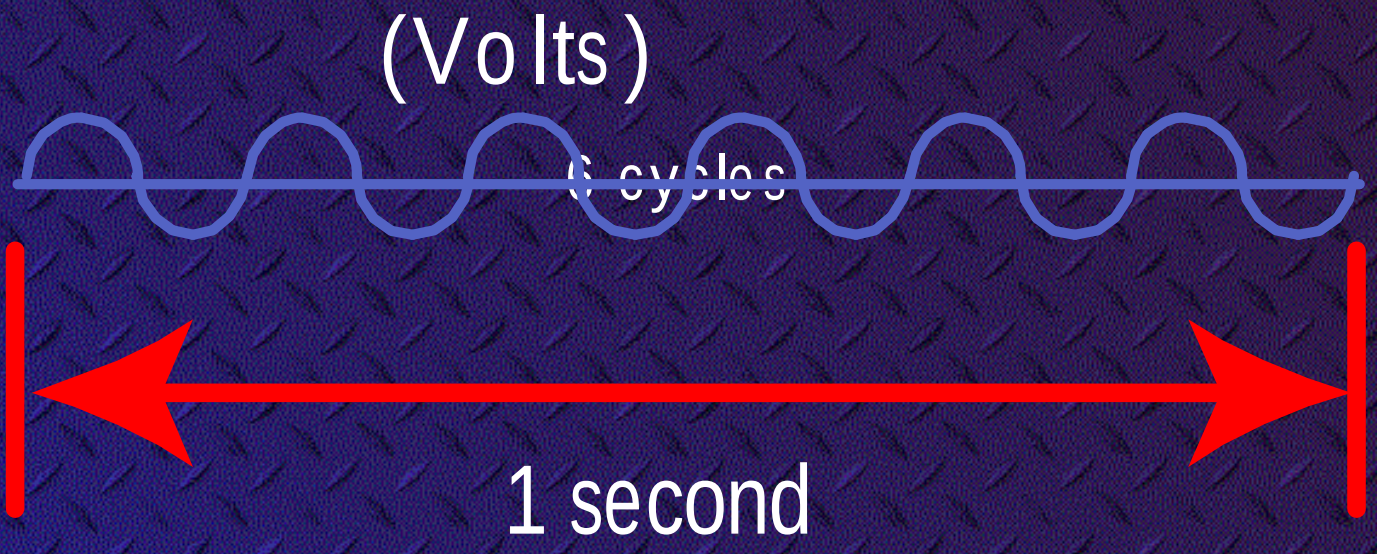
"Alternating Current" Terms

<u>Frequency</u> The number of cycles that occur within one second.



"Alternating Current" Terms

<u>Amplitude</u> The height (or depth) of a phase.



6 cycles per second = 6 Hz

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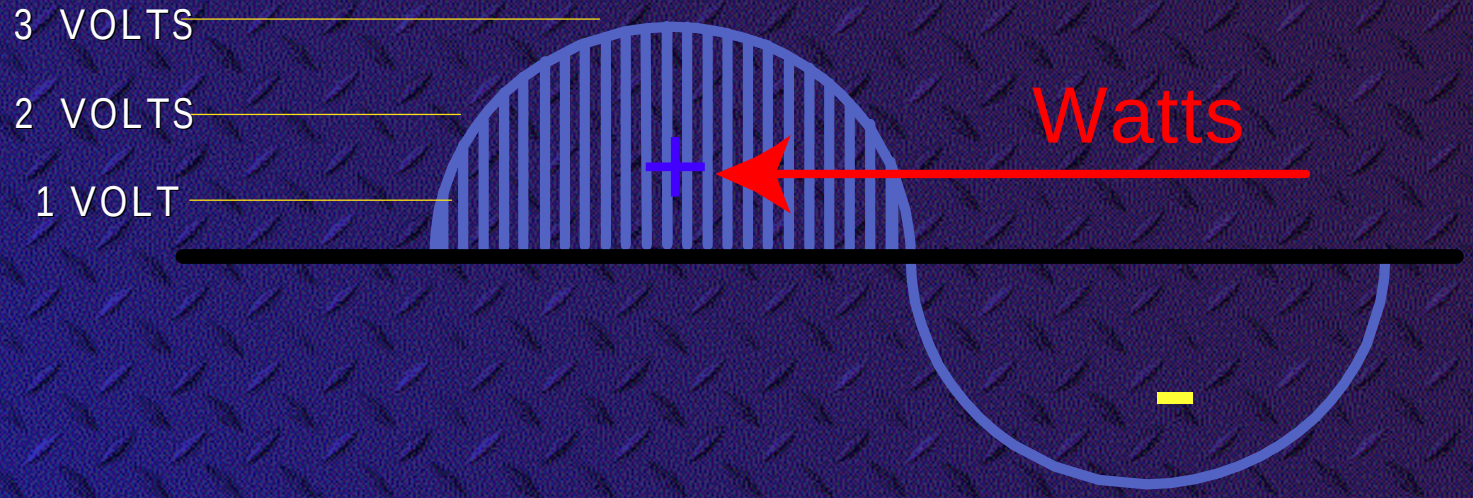
"Alternating Current" Terms

<u>Power</u> The area under the curve. (Watts)



"Alternating Current" Terms

<u>Cycle</u>

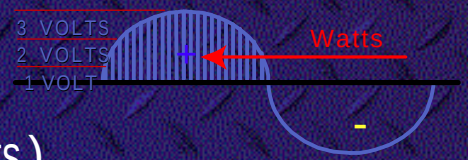
One "up and down" or positive and negative potential.

<u>Phase</u>

Signal is going both "up" and "down".

<u>Frequency</u>

Number of cycles occuring within one second.

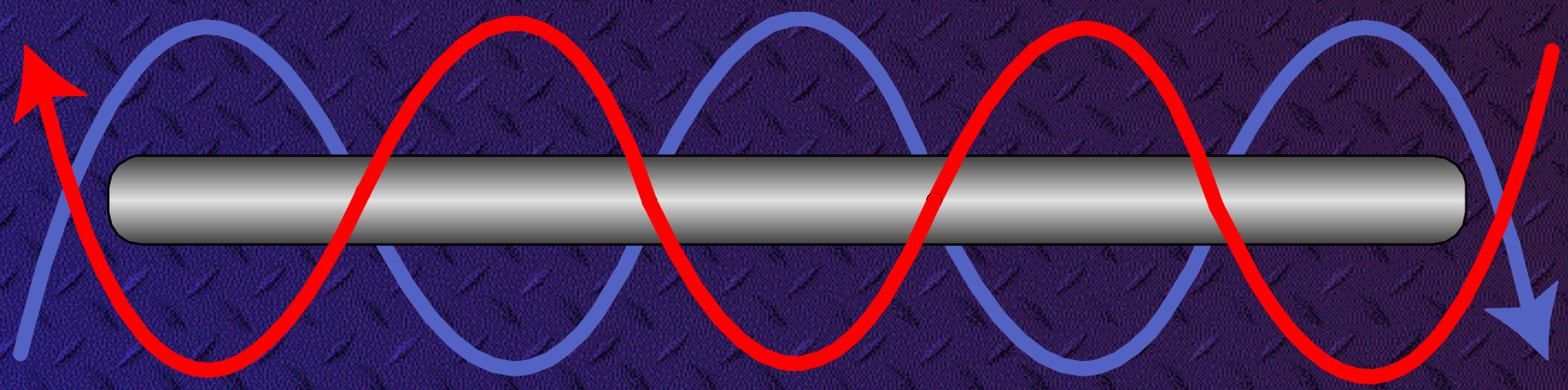
<u>Amplitude</u> (Volts) 

Height (or depth) of a phase.

<u>Power</u> (Watts) Area under the curve.

METROTECH

“Destructive Interference”



When a transmitted signal on the target conductor meets a returning signal in the opposite phase, the signals cancel or distort each other.

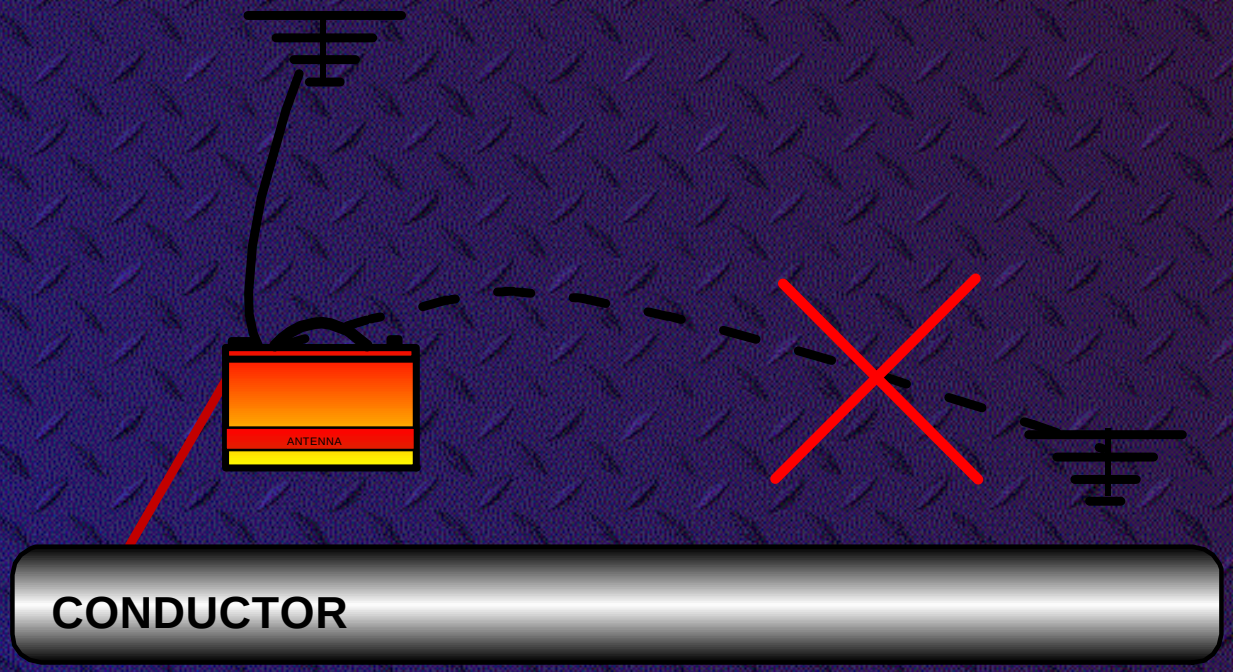
METROTECH

Symptoms of "Destructive Interference" or Poor/No Earth

- Fluctuating signal strength (by a constant 50+ points up and down).
- Inconsistent Centerline or Peak.
- Inconsistent or Non-repeatable Depth Readings.

METROTECH

Avoid
"Destructive Interference"



Determine probable path of your conductor and move your ground rod accordingly.

METROTECH

Destructive Interference May Be Unavoidable

Locating through Destructive Interference is possible when the cause is recognized and determined,
e.g. common bonding.

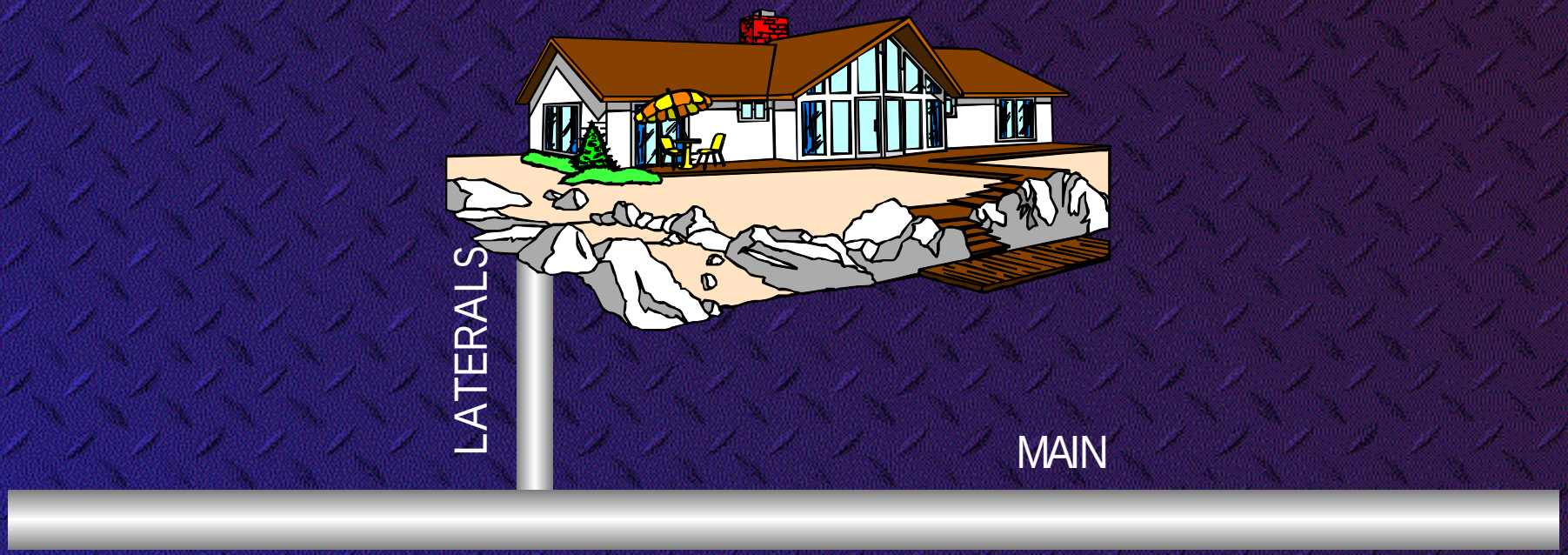
METROTECH

I know I am supposed to attach the earth at right angles to the conductor

How do I know which way the conductor is running?

METROTECH

“ Read the Street”



"Large delivery" (water main) is typically parallel to the street. Small delivery (laterals, house connections) is perpendicular to the street.

METROTECH

Industry Terms for Delivery Systems

Water - Main and Lateral (Service)

Gas - Main and Lateral (Service)

Power - Primary and Secondary

Telephone - Underground and Aerial Cables (F1 and F2) and Service

METROTECH

More Clues to the Probable Path of Your Conductor

Note Positions of:

Water - valves, curb stops, meters, hose bibs

Gas - meters, ETS points

Power - transformer boxes, switch gear, risers

Telephone - pedestal boxes, risers, manholes, terminals, protector

METROTECH

When Placing Your Ground Rod

Do not lay attachment parallel to your target or adjacent conductor. (To avoid "Destructive Interference")

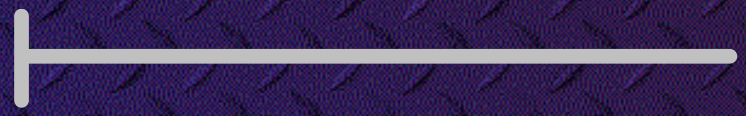
Do not cross over adjacent conductor. (To avoid transmitting signal onto an unwanted conductor)

METROTECH

Methods to Improve Your Earth

Create larger surface area to attract signal -

- Longer ground rod - be careful not to penetrate another line

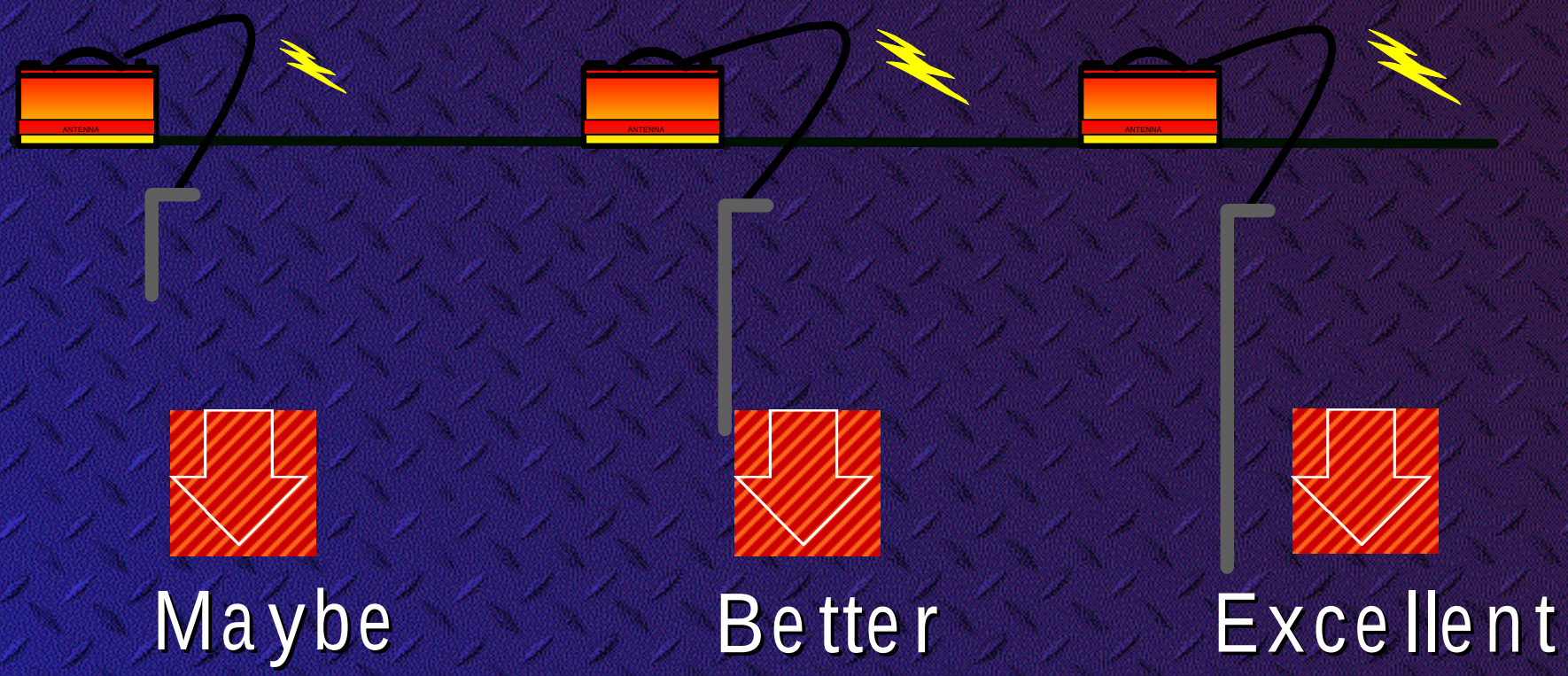


- Multiple rods connected

- Use an available earth that is deeply buried

- Water/moisture improves conduction

Larger Surface Area Attracts More Signal (Current)



METROTECH

Convenient Available Earths That Provide More Surface Area

Stop Sign/Street Sign

Metal fence post

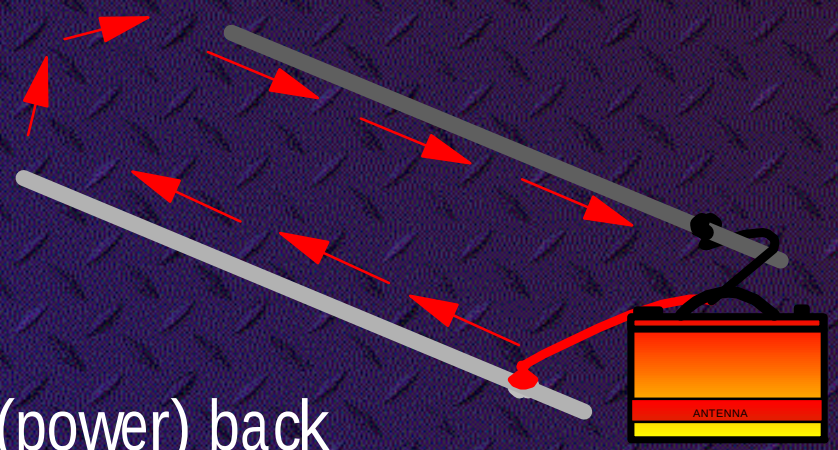
Alternative Earth

If you are cautious - it is possible to use a parallel utility as your return signal path.

When you do this, verify that you start out and end up at a termination point that is specific to the utility that you are tracing.

Parallel Utility Earth - Return Locate

Convenient for user who is locating multiple utilities (such as a contract locator).



If grounded to adjacent utility -
Locate one (water) out and the other (power) back
You don't need to move your Transmitter

Important to verify terminations

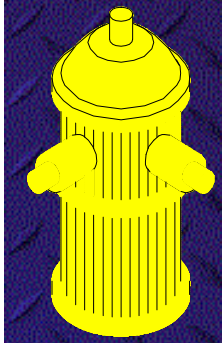
METROTECH

In Conclusion –

Direct Connect Provides a Superior Locate Because It:

- Isolates conductor from adjacent conductors.
- Get more signal distance - don't need to move Transmitter.
- Provides the strongest signal to the best Receiver, resulting in the best Receiver accuracy.

METROTECH



METROTECH

Grounding of Electrical Systems and Associated Problems (Mark Regan)

Understanding Grounding of Electrical Systems Los Alamos National Lab

Mark E. Regan-Project Leader
Technical Training and Consultation

DOE Electrical Safety Meeting
June 21-25, 1999

Special Thanks

- International Association of Electrical Inspectors- Richardson, TX
- Mike Holt Enterprises- Orlando, FL
- Mike Johnston, IAEI

Objective

This presentation is intended to familiarize you with the terms and concepts associated with grounding of electrical systems for safety

Agenda

- Ohm's Law
- Overview of Electrical Systems
- Purpose of Bonding and Grounding
- Overcurrent Protection
- Special Applications
- Summary

Ohm's Law
V=IR

V-Voltage -potential difference
-electromotive force
-electrical pressure

I- Intensity of current- charge moving past a certain point in a given amount of time

R-Resistance- opposition to the flow of current

Overview of Electrical Systems

- Wiring Concepts
- What Is Power?
- Delivering Power

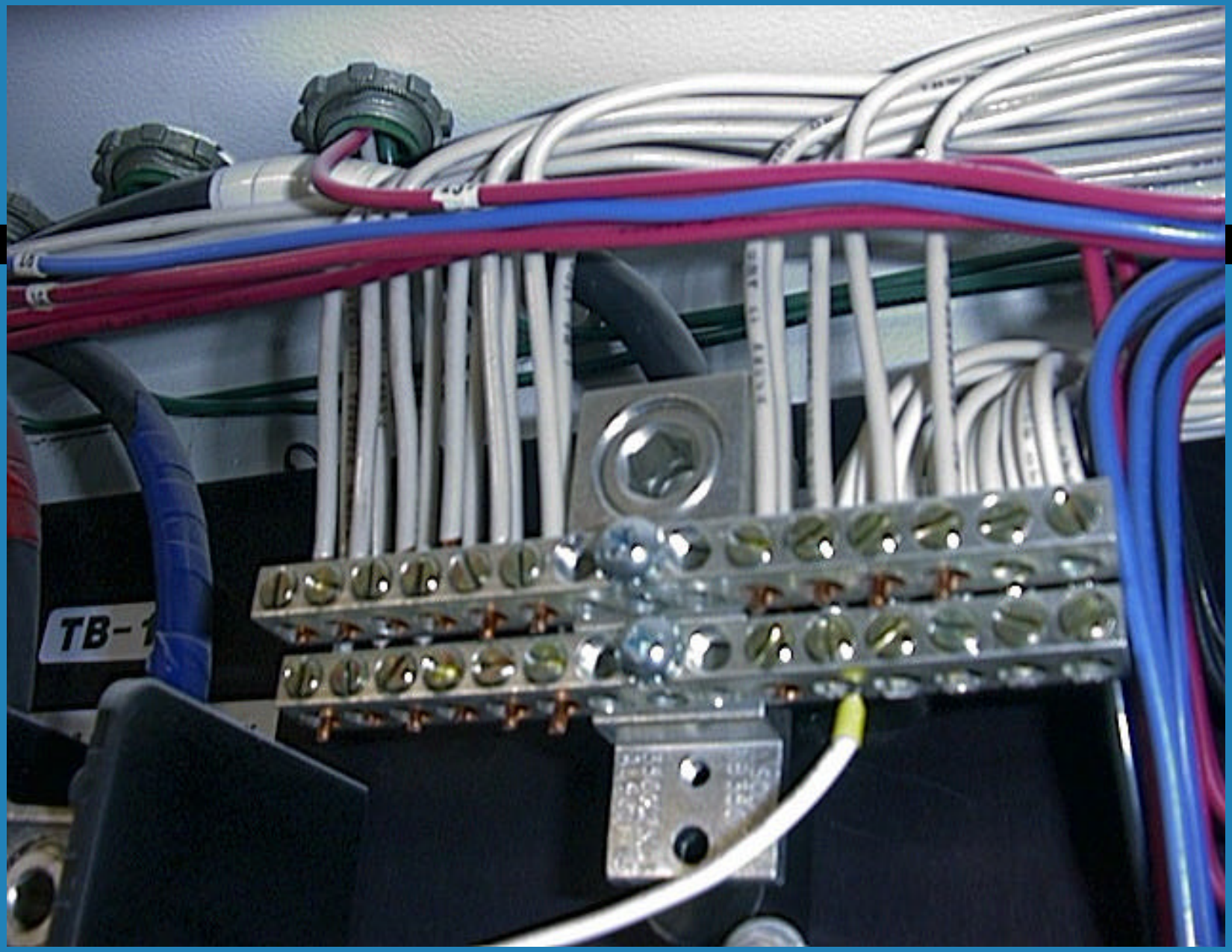
Wiring Concepts

- Single or Three Phase Systems
- Conductors

Wiring concepts

- Ungrounded Conductors
  - Black Wire or Hot
- Grounded Conductors
  - White Wire or “Neutral”
- Equipment Grounding Conductor
  - Green Wire or Metal Raceways

CURRENT LIMITING


TB-1

TIGHTENING TORQUE
FOR ALL
INSULATING SUPPORTS
TO BE
20 FT./LBS.

What is Power?

The time rate at which energy is transformed or transferred

$$P=IV$$

Power= (Intensity of Current) x (Voltage)

(watts)= (amperes) x (volts)

Delivering Power

- Utility to premises served
- Premises wiring

Delivering Power

Utility to premises served

- Service
- Service Conductors
- Service Point
- Service Entrance Conductors
- Service Equipment

Service

The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served

Service Conductors

The conductors from the service point to the service disconnecting means

Service Point

The point of connection between the facilities of the serving utility and the premises wiring

Service Entrance Conductors

The service conductors between the terminals of the service equipment and a point usually outside the building clear of building walls, where joined by tap or splice to the service drop

Service Equipment

The necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the load end of service conductors to a building or other structure, or an otherwise designated area, and intended to constitute the main control and cutoff of the supply

Delivering Power

Premises wiring

- Service Equipment
- Feeders
- Branch circuits
- Devices
- Utilization equipment

Feeders

All circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device

Branch Circuit

The circuit conductors between the final overcurrent device protecting the circuit and outlet(s)

59 3
LP 2

Devices

A unit of an electrical system that is intended to carry but not utilize electric energy

LP. R. CKT. 20

Utilization Equipment

Equipment that utilizes electric energy

.60

Bonding and Grounding

- Purpose
- Definitions
- Location
  - Grounding Electrode System
    - Table 250-66
  - Equipment Grounding
    - Table 250-122

Definitions

- Bonding
- Ground
- Grounded
- Grounded, Effectively

Bonding
NEC 250-90

- The permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed

Why is Bonding Necessary?

- To make the system electrically continuous
- Keep the equipment at the same potential or voltage
- Create a low impedance path to clear faults

Why Do We Ground?

Decrease hazards on systems and equipment

- Fire
- Shock
- Electrocution

Purpose of Grounding

- Stabilize Voltage
- Limit Voltage to Ground During Normal Operations

Ground

A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth

Conducting Body Serving in Place of Earth

Grounded

Connected to the earth or to some conducting body that serves in place of the earth

Effectively Grounded

- NEC 250-2 (d)
- Permanent and continuous
- Lowest possible Impedance
- Capacity to conduct any fault current likely to be imposed
- Earth not to be used as the sole Equipment Grounding Conductor

Equipment Definitions

- Grounded Conductor
- Grounding Conductor
- Equipment Grounding Conductor
- Grounding Electrode Conductor
- Grounding Electrode

Grounded Conductor

A system or circuit conductor that is intentionally grounded

Grounding Conductor

A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes

Equipment Grounding Conductor

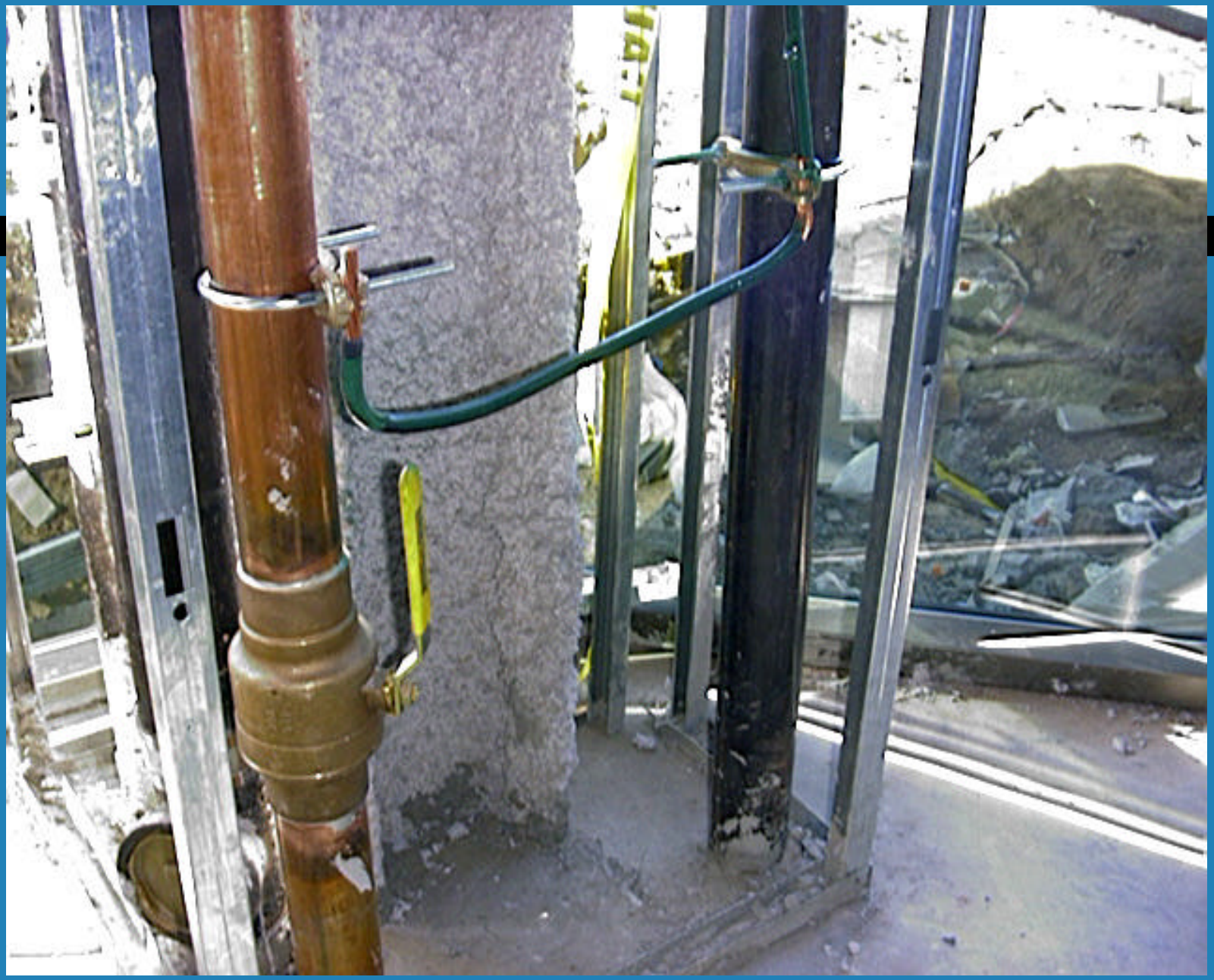
The conductor used to connect the noncurrent-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor, the grounding electrode conductor, or both, at the service equipment or at the source of a separately derived system

Grounding Electrode Conductor

The conductor used to connect the grounding electrode to the equipment grounded conductor, to the grounded conductor or to both, of the circuit at the service equipment or at the source of a separately derived system

Grounding Electrode

The conductor used to connect the grounding electrode to the equipment grounding conductor, to the grounded conductor, or to both, or a circuit at the service equipment or at the source of a separately derived system



Grounding

- Bonding
- Grounding
- System grounding
- Equipment grounding

What Grounding Will Do

System Grounding

- Stabilize voltage on system
- Prevent excessive voltages due to lightning strikes and line surges

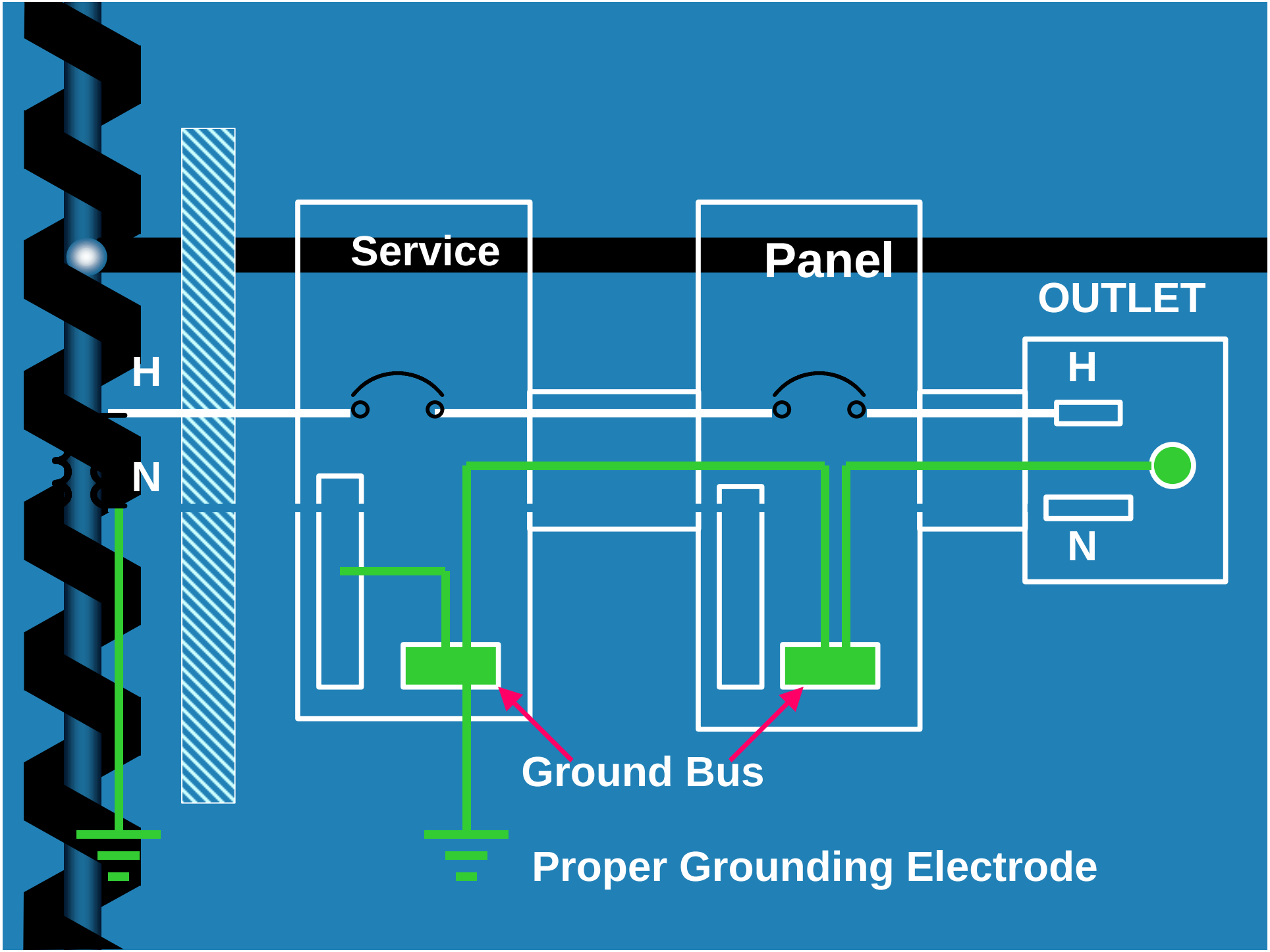
What Grounding Will Do

Equipment Grounding

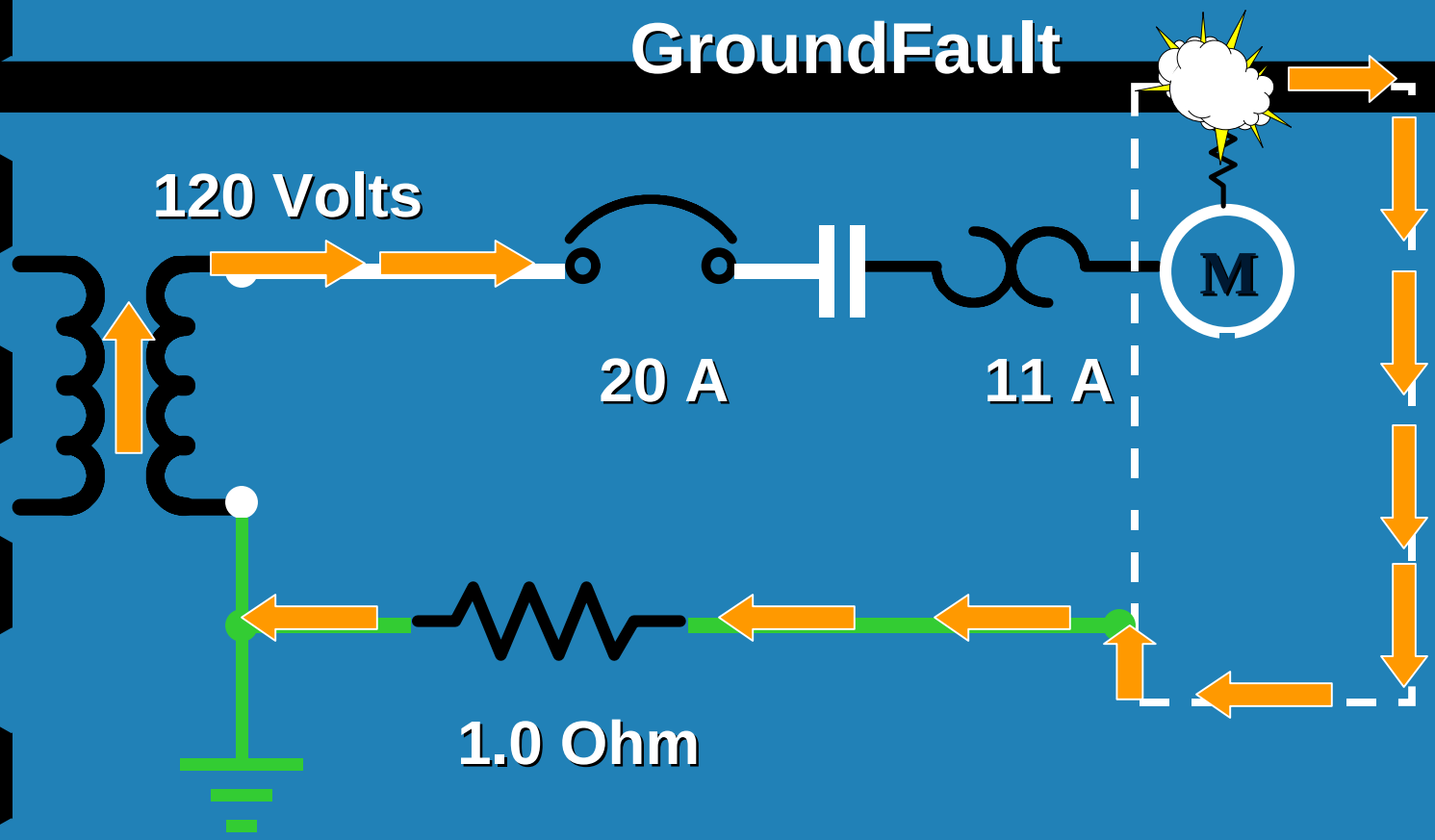
- Bond all equipment together to establish equipotential plane
- Provide low impedance fault path back to the source of electricity
- Facilitate the operation of the overcurrent protection devices

Impedance “Z”

The following slides indicate a resistance value for the purposes of simplifying the calculation and making a point. Normally the AC circuit impedance includes the inductive reactance and capacitance components along with the resistance element.

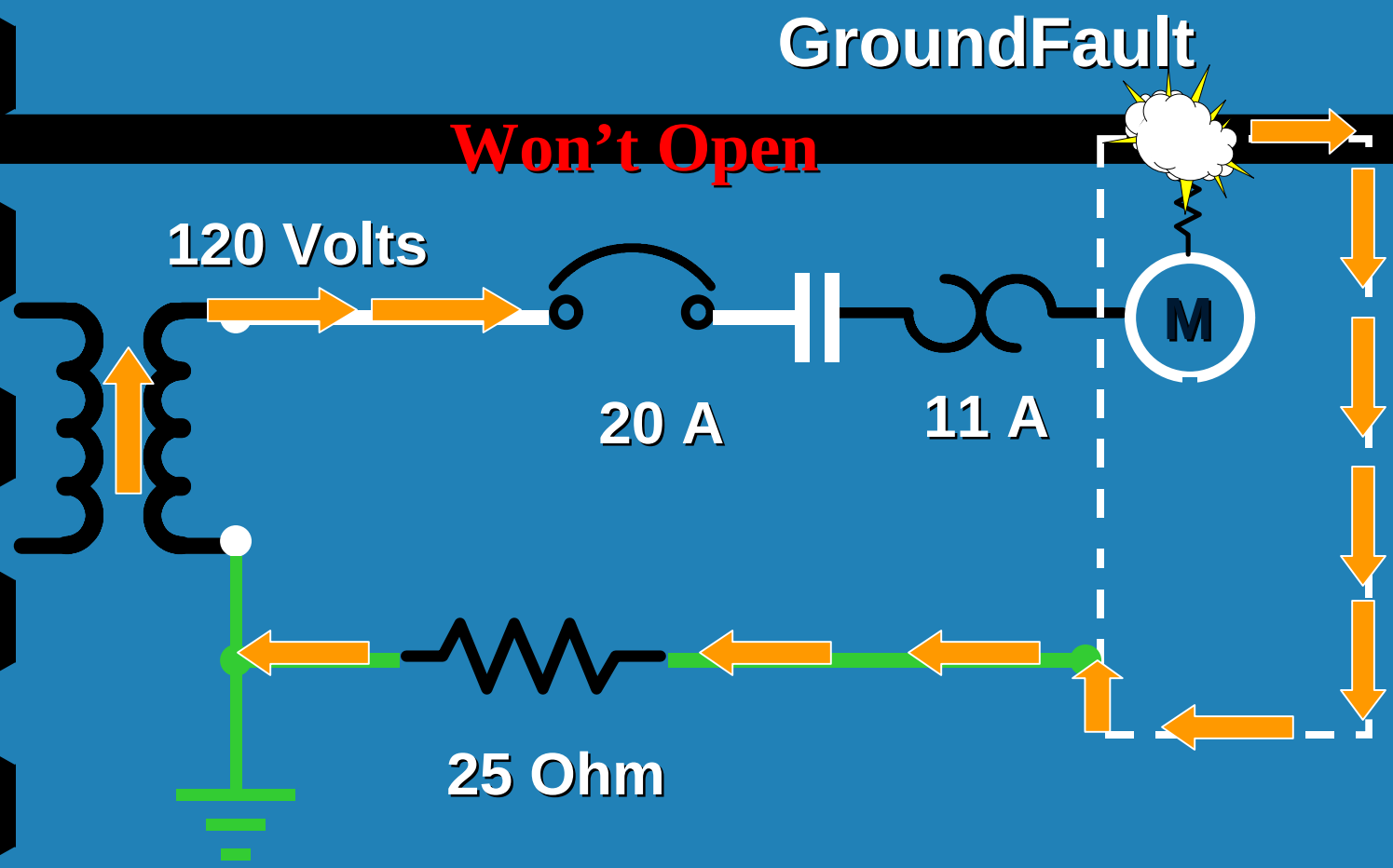

Service
Panel
OUTLET
H
N
H
N
Ground Bus
Proper Grounding Electrode

Effectively Grounded



Effective Fault Clearing Path

Ineffectively Grounded

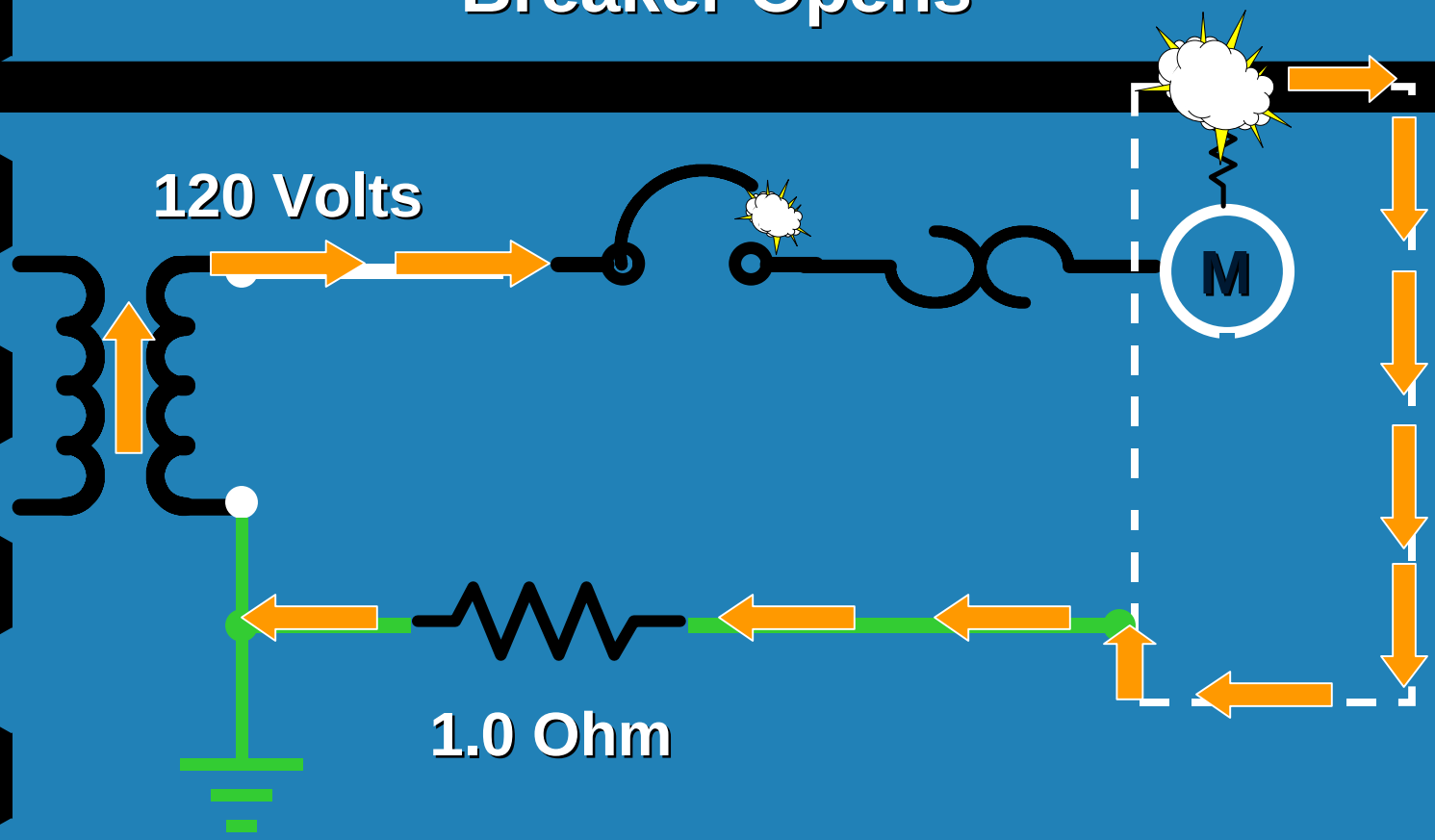


Ineffective Fault Clearing Path

$$\frac{120\text{Volts}}{25\text{ Ohms}} = 4.8\text{ Amps}$$

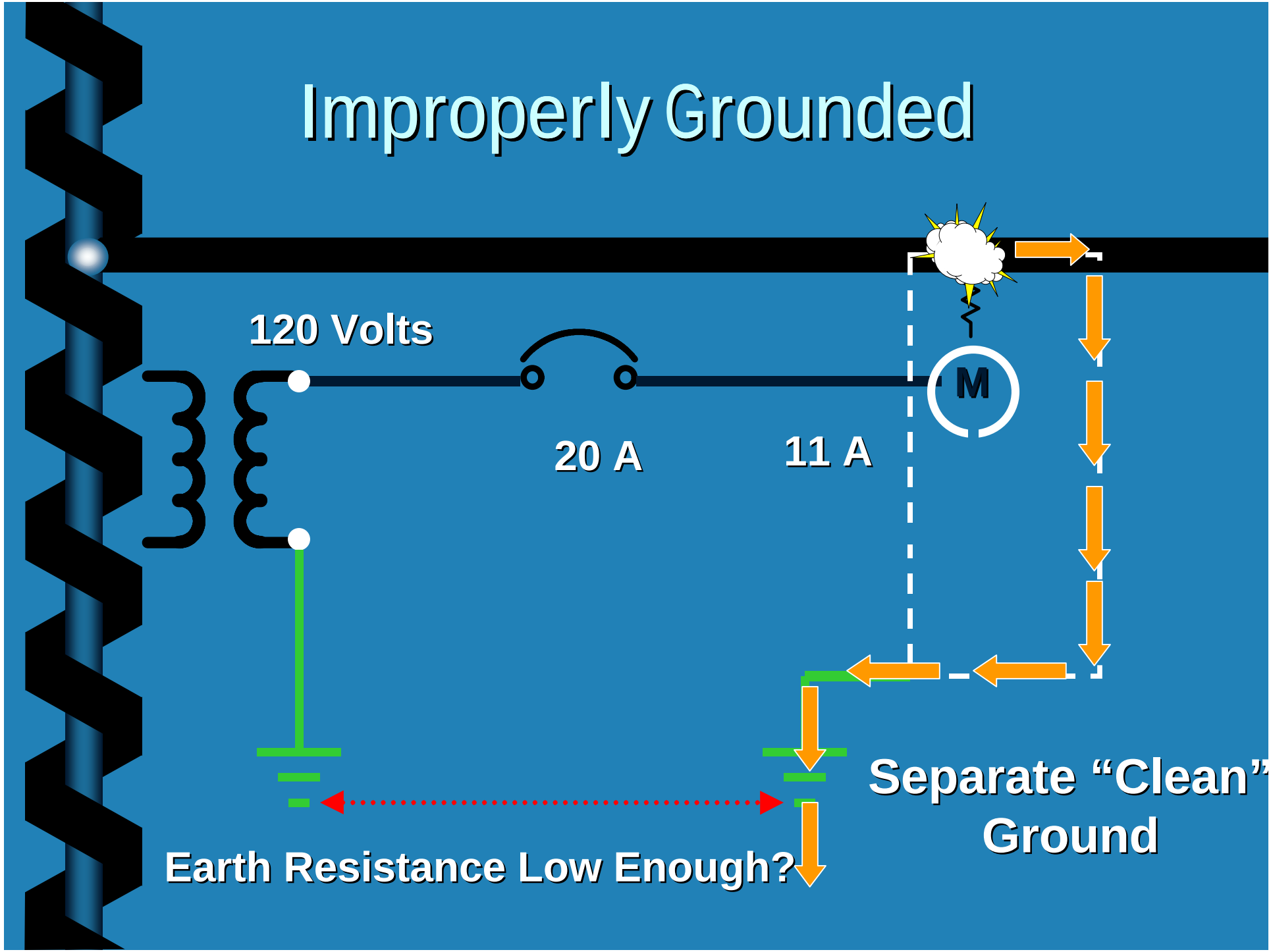
Effectively Grounded

Breaker Opens



Effective Fault Clearing Path $\frac{120\text{Volts}}{1.0\text{ Ohms}} = 120$ Amps

Improperly Grounded



What System Grounding *Won't* Do

System Grounding *Will Not-*

- Change the power quality coming into the facility
- Operate the overcurrent protection devices
- Create stray voltage

What Grounding *Won't* Do

Equipment Grounding *Will Not-*

- Eliminate all electrical hazards
- Create Stray Voltage

Overcurrent Protection

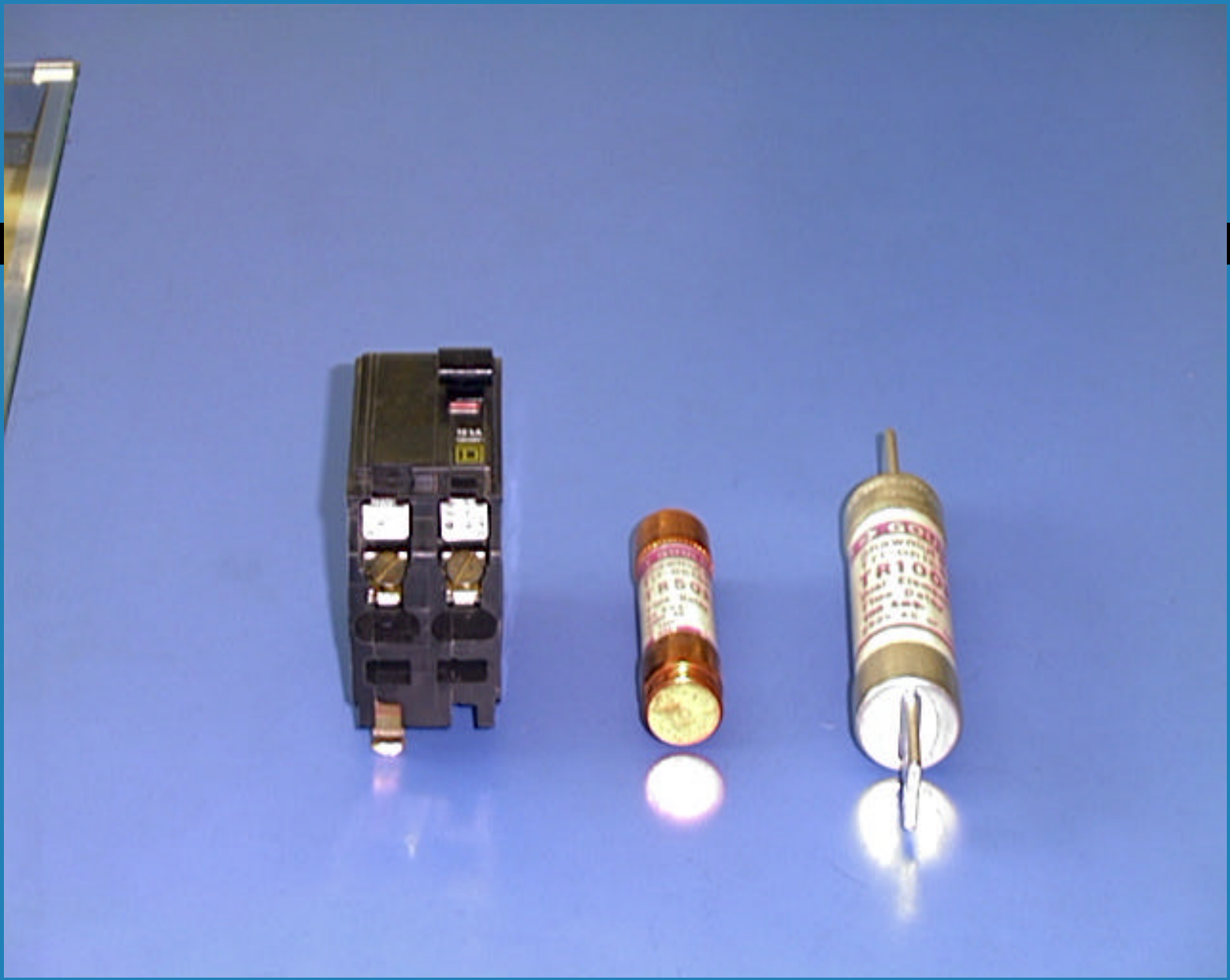
- Definition
- Overload
- Short Circuit
- Ground Fault

Overcurrent Protection

- Overcurrent- any current in excess of the rating of the equipment or conductors
- Overload- operation of equipment or conductors in excess of normal rating that would cause damage or overheating
- Short Circuit- phase to phase or phase to grounded conductor
- Ground Fault- phase to equipment

Why do we have OCPD?

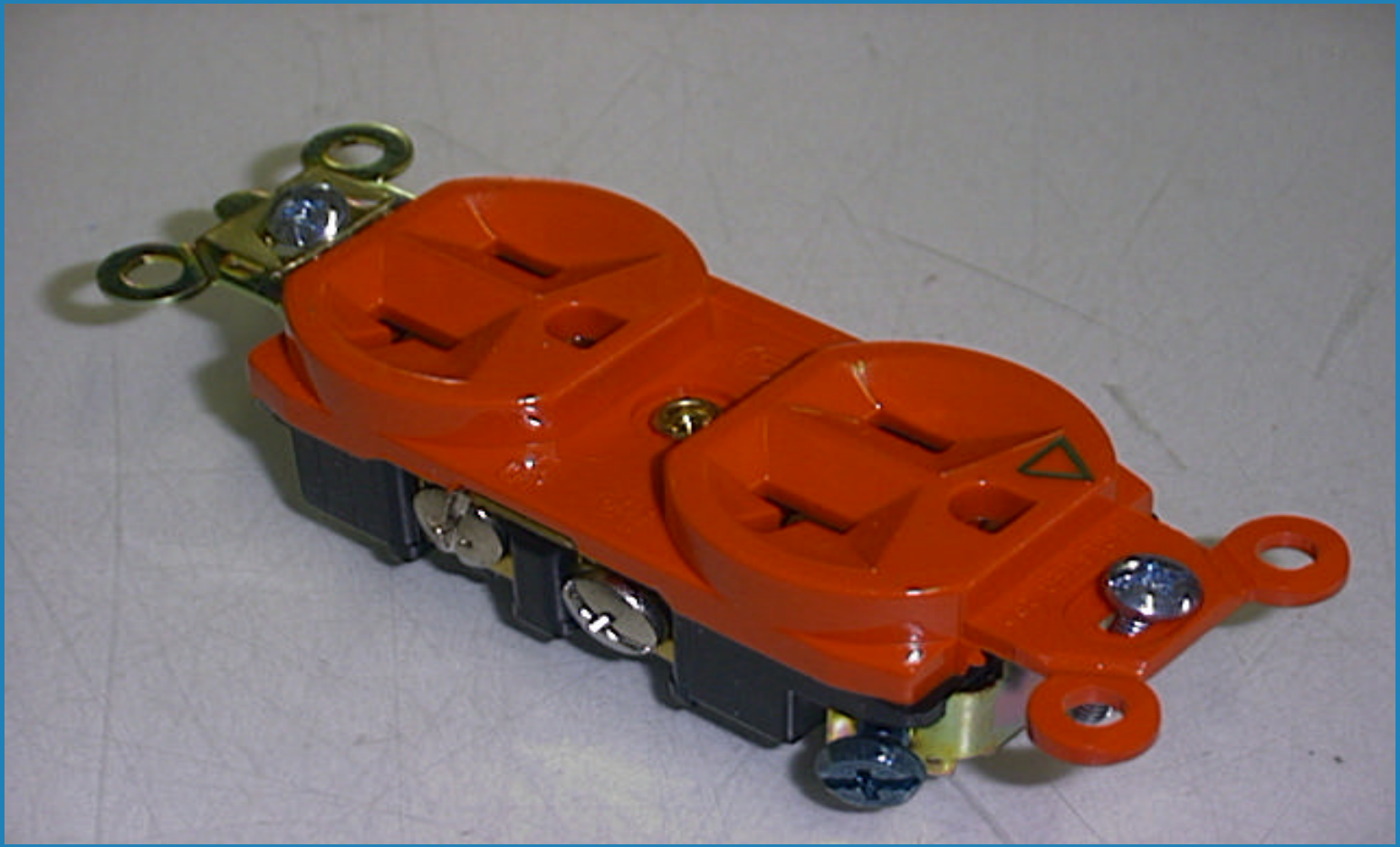
- Examples of OCPD
- What does trip mean?
- Does the circuit breaker always trip?
- Trip characteristics
- What is the overcurrent device protecting?



Special Applications

- Isolated Ground Receptacles
- Arc Fault Circuit Interrupters
- Ground Fault Circuit Interrupters
- Separately Derived Systems

Isolated Ground Receptacle

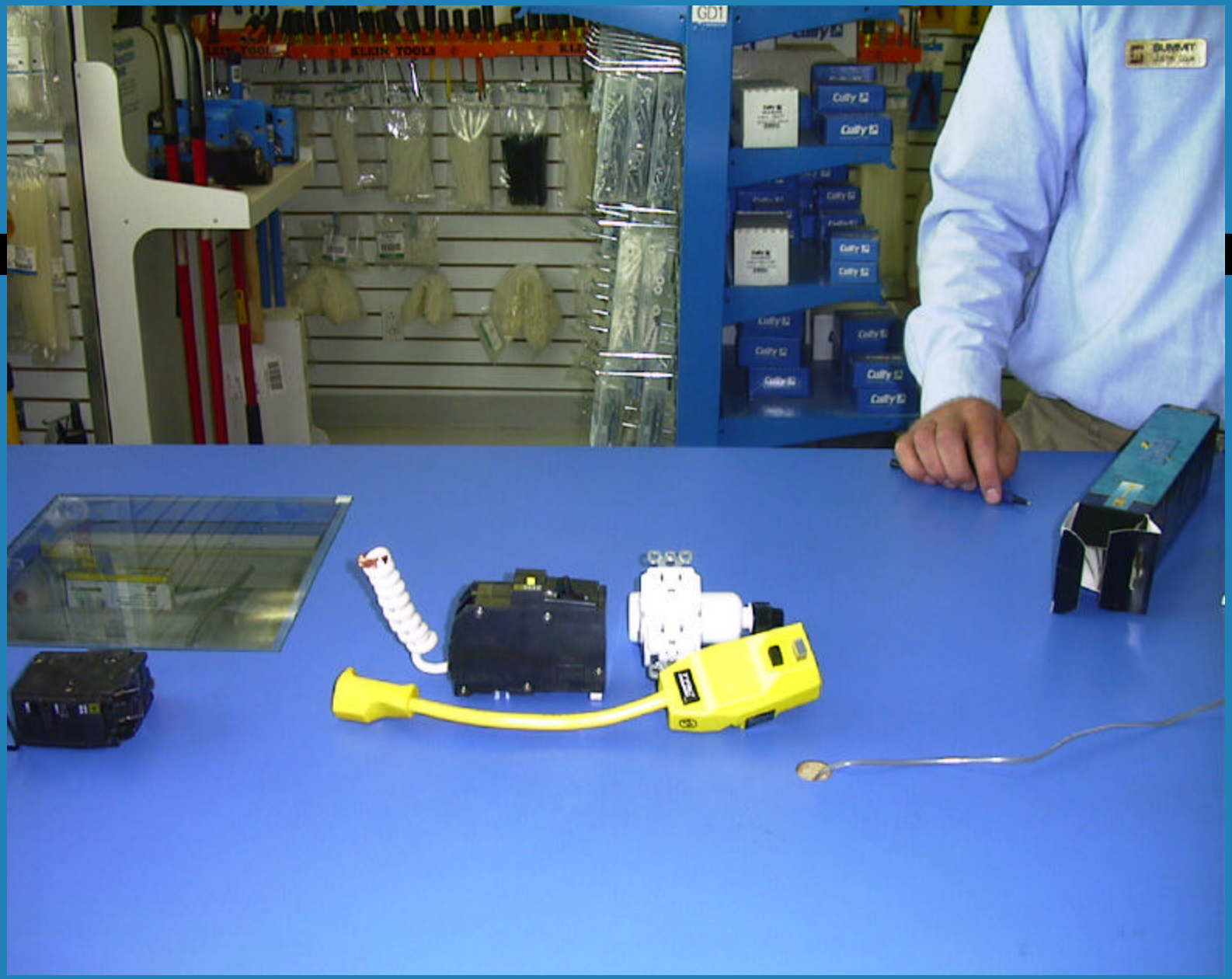


Arc Fault Circuit Interrupters

A device used to open a circuit by detecting arcing conditions that may cause a fire. (Not an overcurrent protection device.)

What a GFCI Does

- Interrupts the circuit to the load at a predetermined value that is less than what is required to operate the overcurrent protection device of the circuit

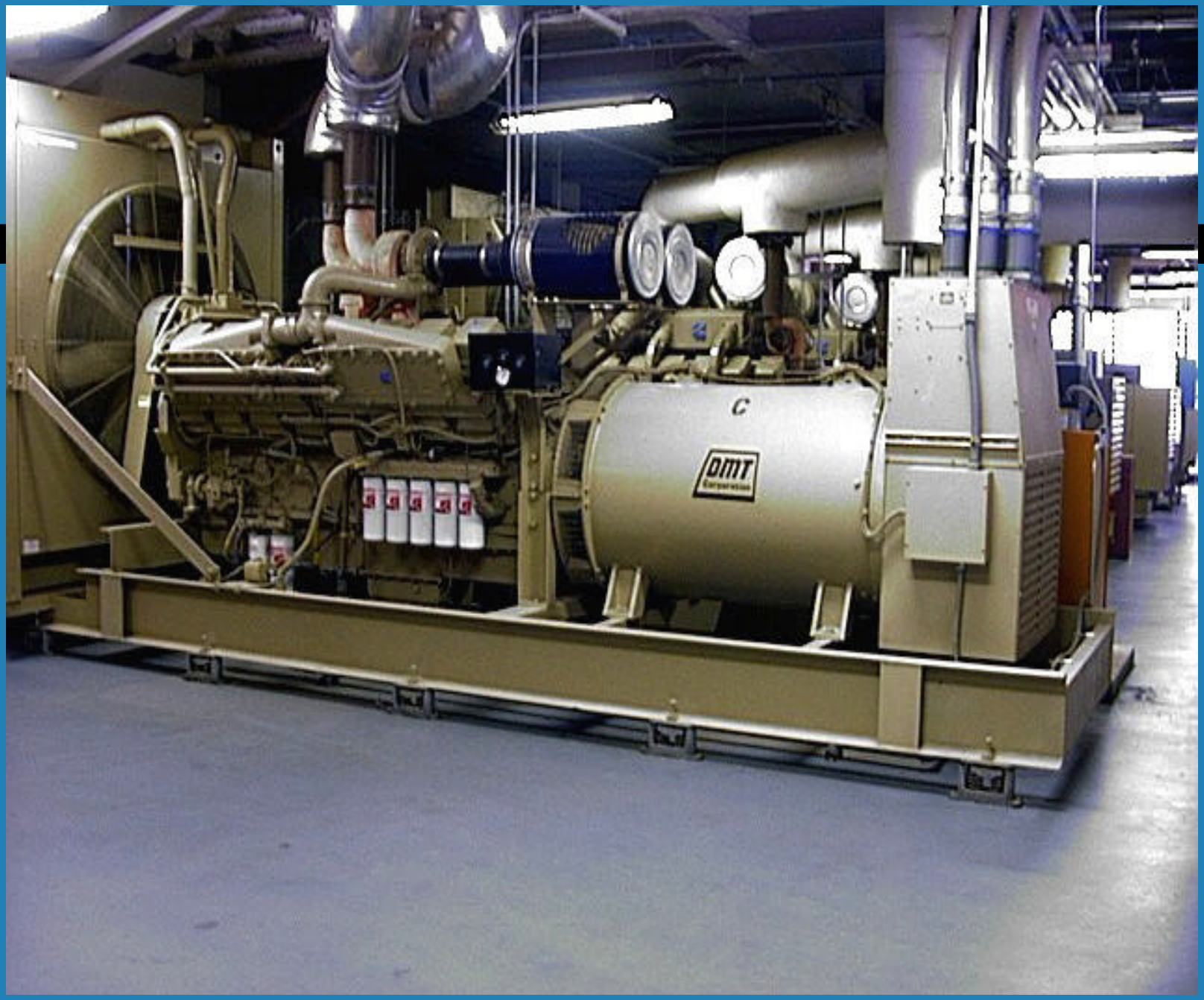

KLEIN TOOLS
GDI
Cully

Separately Derived Systems

- Definition
- Examples
- Problems

Separately Derived Systems

A premises wiring system whose power is derived from a battery, a solar photovoltaic system, a generator, transformer or converter windings, and has no direct electrical connection, including a solidly connected grounded circuit conductor to supply conductors originating in another system

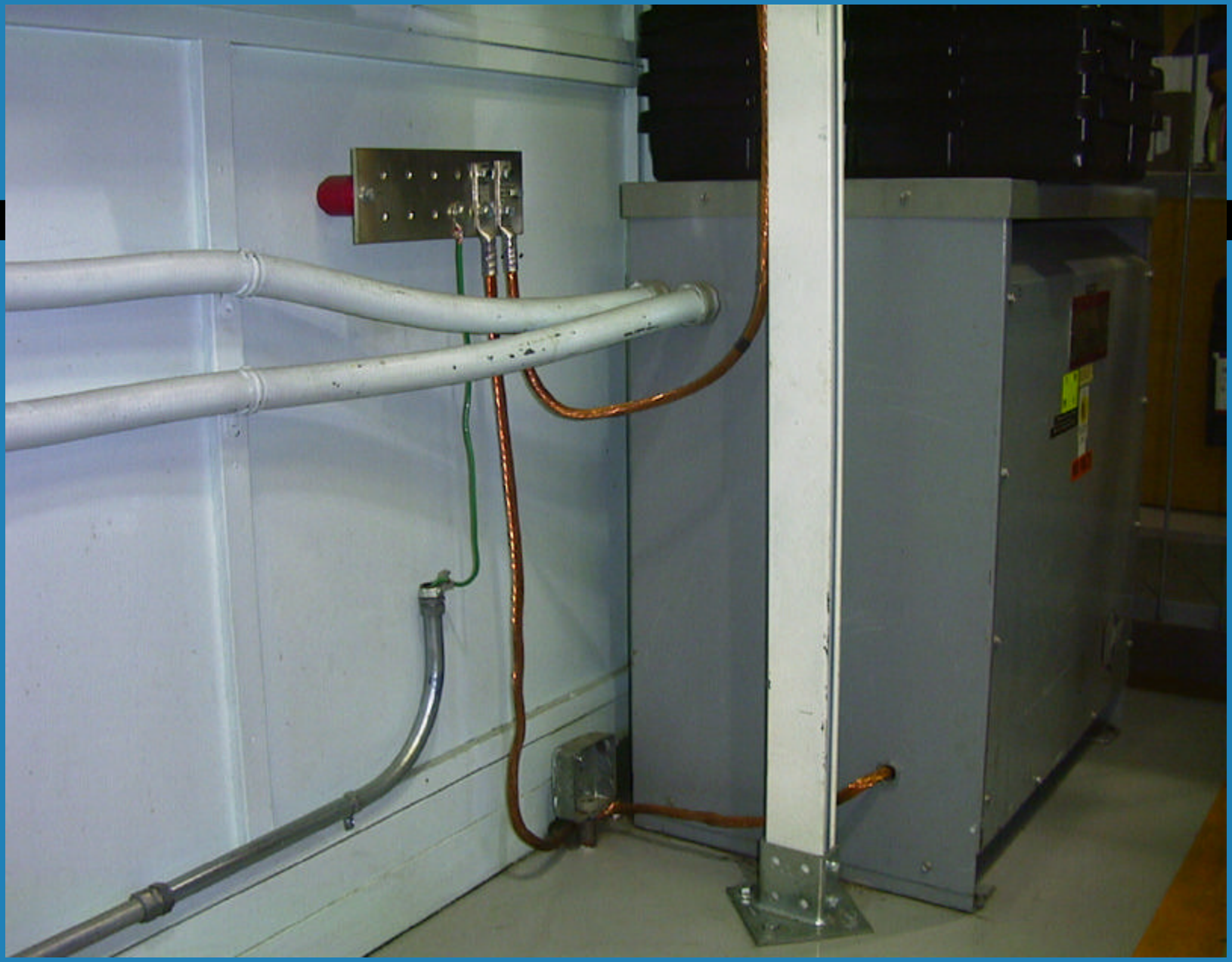

DMT

DANGER
480 VOLTS
120/208 VOLTS

WypAll Plus
480 VOLTS

Concerns

- Ground reference must be reestablished
- Equipotential plane must be maintained on primary and secondary sides



Summary

- Grounding is your first line of defense
- If you can't ground it-Guard It
- If you can't guard it-Isolate it
- Remember-The power is Always on!

Thank You!

Drillco Devices (Nick Lacey)

Nick Lacey told the audience about the DS-69A Drill Stop Box. He explained how it works and the manufacturer's intent for use. For more information you may contact Nick Lacey at 718-726-9800.

Grounding of Generators Below and Above 5Kv (Gordon Johnson)

PROPER GROUNDING OF ON-SITE ELECTRICAL POWER SYSTEMS

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***Abstract* - This paper is based on the new grounding chapter in the recently published third edition of *On-Site Power Generation: A Reference Book.* [1] It applies to low voltage power systems rated 600 volts and less, and explains types of grounding, fault protection, code requirements, and appropriate solutions. The interrelationship of grounding, ground-fault sensing and transfer switching is discussed. The importance of safety to personnel, protection of equipment and continuity of power to electrical loads is stressed**.

I. INTRODUCTION

For optimum safety of personnel, protection of equipment and continuity of power to electrical loads, proper grounding of on-site power systems is essential. If the on-site power is the sole source of power, then its grounding is relatively straight forward and follows the National Electrical Code Article 250. However, if the on-site power system serves an alternate source of power (i.e., emergency or standby power), then grounding of the system becomes more complex. Furthemore, portable and mobile generators have special grounding requirements.

Special consideration should be given to location of ground connections, means of minimizing circulating ground currents and providing proper ground-fault sensing. This paper discusses recommended practices for both system and equipment grounding without detracting from the ability of alternate power sources to provide reliable emergency power. It also provides some design guidelines in selecting transfer switching equipment, as necessary to meet code requirements and assure proper system grounding.

There are unique circumstances relating to emergency power systems that require special grounding considerations. In large building complexes, consideration should be given to possible power disruption within the facility and the need for area protection. At the same time, due consideration should be given to effects of multiple ground connections, proper sensing of ground faults and conformance to current code requirements.

Electrical power systems require two types of grounding, namely *system grounding* and *equipment grounding*. As will be shown, each has its own functions.

II. SYSTEM GROUNDING

System grounding pertains to the nature and location of an intentional interconnection between the electric system conductors and grounding electrode systems which provide an effective connection to ground (earth). In other words, it relates to how and where the grounded conductor is connected to earth.

Purpose of System Grounding: According to Section 250-2 of the National Electrical Code (NEC), system and circuit conductors are grounded to limit voltages due to lightning, line surges, or unintentional contact with higher voltage lines, and to stabilize the voltage to ground during normal operation. Systems are solidly grounded to facilitate overcurrent device operation in case of ground faults.

Power Systems: The following emergency power systems are commonly used to supply phase-to-neutral loads and should be solidly grounded:

120/240 volt, single-phase, three-wire system
208Y/120 volt, three-phase, four-wire wye system
480Y/277 volt, three-phase, four-wire wye system
600/347 volt, three-phase, four-wire wye system
240/120 volt, three-phase, four-wire delta system

Solidly Grounded Systems: To facilitate overcurrent device operation the equipment grounding conductors for solidly grounded systems are required to be bonded to the system grounded conductor at the service equipment and at the source of a separately derived system (standby or emergency power). This bond completes the ground-fault current return path from the equipment grounding conductors to the system grounded conductor. System grounding conductors and grounding electrodes are not intended to conduct the ground-fault current that is due to a ground-fault in equipment, raceways, and other enclosures. In solidly grounded systems, the ground-fault current flows through the equipment grounding path.

Solidly grounded systems exercise the greatest control of overvoltages but result in the highest magnitudes of ground-fault current. However, the inherent regulation of alternate source generators generally limits the available fault current. If line-to-neutral loads must be served, high resistance grounding of the generator neutral is not permitted because the neutral should never be used as a circuit conductor in systems that are grounded through a high resistance.

High Resistance Grounding: Where line-to-neutral loads need not be served, there is a growing trend toward high-resistance grounding of the neutral conductor. This is particularly true in industrial applications and where medium voltage generators are used for emergency power. High resistance grounding combines the advantages of ungrounded systems and solidly grounded systems. Fault current is limited to a value that will permit continued operation of the emergency power system until the normal power is restored. System overvoltages are held to acceptable levels and faults are easier to locate than on an ungrounded system. For these reasons, high resistance grounding is often used in process industries where an unscheduled outage can have serious consequences.

III. EQUIPMENT GROUNDING

It is important that all exposed metallic parts of electrical equipment be bonded to a grounding electrode. This includes metallic parts such as generator frames and engines of engine generator sets, mounting bases, electrical conduit and enclosures.

Purpose of Equipment Grounding: The purpose of equipment grounding is to assure the following functions:

1. To maintain a low potential difference between nearby metallic members and thereby protect people in the area from electric shock.

2. To facilitate the operation of circuit protective devices by providing low impedance conducting paths for ground-fault currents.

3. To provide an effective electrical conductor system over which ground-fault currents can flow without creating a fire or explosive hazard.

Equipment Grounding Paths: Only by providing adequate equipment grounding paths for metallic enclosures, frame of an engine generator set, etc., in a manner which assures adequate current-carrying capability and an adequately low value of ground-fault circuit impedance, can both electric-shock hazard and fire hazard be avoided. Technical investigations have pointed out that it is important to have good electric junctions between sections of conduit or metal raceways that are used as equipment grounding paths, and to assure adequate cross-sectional area and conductivity of these grounding paths. Where systems are solidly grounded, equipment grounding conductors are bonded to the system grounded conductor and the grounding electrode conductor at the service equipment and at the source of a separately derived system in accordance with the requirements of sections 250-30, 250-64 and 250-130 of the National Electrical Code (NEC).

The same network of equipment grounding paths is required for systems that are solidly grounded, high resistance grounded, or ungrounded. The equipment grounding paths in high-resistance grounded or ungrounded systems provide shock protection and a conducting path for phase-to-phase fault current if two ground faults occur simultaneously on different phase conductors.

Engine Generator Frame*:* The engine generator frame, automatic transfer switch enclosure, conduits and other exposed components of an emergency power systems should be permanently bonded together and connected to the grounded conductor of the service equipment providing normal power and/or the grounded conductor of the engine generator set. By means of grounding electrode conductors, these grounded conductors are connected to grounding electrodes at their respective locations.

The National Electrical Code permits the grounding electrode to be a metal underground water pipe which may be part of a municipal water piping system or a well on the premises. However, buried portions of a water pipe system less than 10 feet in length or that may include plastic or cement materials should not be used. For small emergency power systems where the ground currents are of relatively low magnitude, existing buried water pipe systems are usually preferred as electrodes because they are economical in first cost. Nevertheless, before reliance can be placed on any existing electrodes, it is essential that their resistance to earth be measured to insure that some unforeseen discontinuity has not seriously affected its suitability. Also, care should be exercised to insure that all parts which might become disconnected are effectively bonded with flexible bonding jumpers.

Larger emergency power systems in industrial and commercial buildings often use the effectively grounded metal frame of the building and concrete-encased metal below ground level as a grounding electrode. The concrete encasement of steel, in addition to contributing to low grounding resistance, serves to provide some measure of corrosion protection compared to direct contact with the earth. Due consideration must also be given to the ampacity of the equipment grounding path in order to handle the higher available ground-fault current.

Another alternative is to use “made” electrodes such as driven electrodes, buried cables and plates. The type selected will depend upon the type of soil encountered and the available depth. Although the National Electrical Code permits up to 25 ohms resistance to ground for “made” electrodes, grounding electrodes for engine generator sets in industrial and commercial installations should be kept to a minimum and preferably below five ohms. Where the building steel is bonded to the ground grid system as well as most pipe lines, it is not unusual to obtain an impedance as low as 0.1 to 0.2 ohms. Although the National Electrical Code requires only *one* electrode, sometimes more than one is necessary.

Another reason for positive grounding is that the radio frequency noise suppressors in some generators are connected to the engine generator frame. Inadequate frame grounding can result in interference to communication or audio equipment and improper operation of electronic governors. If the engine generator set is mounted on flexible or resilient pads, a flexible bonding jumper must be used.

Supplemental Equipment Bonding: Possibility of electrical shock can be reduced by additional supplemental equipment bonding between the conductive enclosures for conductors and equipment and adjacent conductive materials. This additional equipment bonding helps minimize any potential between exposed noncurrent-carrying metal parts of the electric system and adjacent grounded building steel when ground faults occur. The inductive reactance of the ground-fault circuit will normally prevent a significant amount of ground-fault current from flowing through the supplemental bonding connections.

Ground-fault current will flow through the path that provides the lowest ground-fault circuit impedance. The ground-fault current path that minimizes the inductive reactance of the ground-fault circuit is through the equipment-grounding conductors that are required to run with or enclose the circuit conductors. Therefore, practically all of the ground-fault current will flow through the equipment-grounding conductors, and the ground-fault current through the supplemental bonding connections will be no more than required to equalize the potential at the bonding locations.

IV. GROUND-FAULT SENSING AND PROTECTION

Providing reliable ground-fault protection in electrical systems having alternate emergency or standby power can be difficult unless adequate equipment is selected and properly coordinated. Multiple neutral-to-ground connections may prevent adequate sensing of ground-fault currents and may also cause nuisance tripping of circuit breakers. To assure proper ground-fault protection, understanding the evolution of code requirements can be helpful.

National Electrical Code: Prior to 1971, most automatic transfer switches for three-phase four-wire systems had three poles with no provisions for switching the neutral conductor. The neutral conductor was grounded at both sources of power. When ground-fault protection of equipment became a requirement in 1971 (NEC Section 230-95), application problems began to appear in new emergency and standby power system installations.
The problems dealt primarily with obtaining proper sensing of ground-fault currents because of multiple neutral-to-ground connections. Under some conditions, the ground-fault sensors would fail to detect fault currents. Under other conditions, unbalanced loads would cause ground-fault sensors to trip breakers, even though a ground fault or short-circuit did not exist.

Becoming aware of the above problems, the National Fire Protection Association (NFPA) decided to form a technical committee (including coauthors René Castenschiold and Gordon Johnson) to recommend changes to the NEC. At that time, the 1975 NEC included the following:

1. Section 230-95 stated "Ground-fault protection of equipment shall be provided for solidly-grounded wye electrical services of more than 150 volts to ground, but not exceeding 600 volts phase-to-phase for each service disconnecting means rated 1000 amperes or more."

2. Section 250-5(d) stated "A premises wiring system whose power is derived from generator, transformer, or converter windings and has no direct electrical connection to supply conductors originating in another supply system."

3. Section 445-1 stated "Generators and their associated wiring and equipment shall be considered to be separately derived systems and shall comply with the applicable provisions of Articles 230, 250, 700 and 750."

The technical committee made recommendations (not unanimously however) which resulted in the following two changes in the 1978 NEC:

1. The definition for separately derived systems per Section 250-5(d) was changed by adding the phrase "including a solidly-grounded circuit conductor" and to read as follows: "A premises wiring system whose power is derived from generator, transformer, or converter windings and has no direct electrical connection, *including a solidly grounded circuit conductor,* to supply conductors originating in another supply system . . . ".

(Note - this definition was removed from Article 250 in the 1999 NEC, but retained in Article 100).

2. Section 445-1 was changed by deleting the phrase requiring generators to be considered as separately derived systems. The section now reads as follows: "Generators and their associated wiring and equipment shall comply with the applicable provisions of Articles 230, 250, 700 and 750."

Effects of the Above Changes: The net effect of the 1978 code changes was that an alternate power source, such as engine generator set, could no longer be interpreted as a separately derived system if its neutral conductor is directly connected with the neutral of the normal source of power.

An emergency source could now only be considered to be a separately derived system and have its neutral terminal separately grounded when the associated transfer switch provided switching of the neutral conductor. In order to comply with the new definition for separately derived systems, grounding of the engine generator's neutral conductor could therefore only be done by one of two methods:

1. Permanently ground the neutral conductor of the emergency source generator at only the grounding electrode of the incoming service for the normal utility source. There would be no switching of the neutral conductor, and the emergency source would not therefore be considered a separately derived system. It later became apparent that this method did not resolve all ground-fault sensing problems.

2. Permanently ground the neutral conductor of the emergency source generator at its location. This would require transfer switching of the neutral conductor, and the emergency source would be defined as a separately derived system. ***Additional Code Changes:*** For emergency power systems the 1984 NEC added section 700-7(e) requiring sensing and indication of ground-fault currents under certain conditions when the engine generator set(s) is feeding the load. In subsequent NEC editions this requirement is identified as 700-7(d). To accomplish this properly the emergency source should be a separately derived system. The 1993 NEC added section 700-8 requiring a sign to identify all sources connected to a grounding electrode when it is remote from the engine generator set(s). Article 250 in the 1999 NEC was completely rewritten.

V. TRANSFER SWITCHING

There are three approaches to consider in meeting the current requirements of the National Electrical Code. For a three phase 4 wire grounded system, they include (1) using a 3 pole transfer switch with the engine generator set considered as a *non-separately derived* source, (2) using a 4 pole transfer switch with the engine generator set considered as *separately derived* source, and (3) using a 3 pole transfer switch with overlapping neutral contacts with the engine generator set considered as a *separately derived* source. However, just meeting the minimal requirements of the code, does not necessarily provide the degree of reliability needed for a good emergency power system. The system designer should consider the following:

An engine generator set is often remotely located from the grounded utility service entrance and the ground potentials of the two locations may not be the same.

Good engineering practice requires the automatic transfer switch to be located as close to the load as possible to provide maximum protection against power failure due to cable or equipment failures within the

facility (area protection). Thus, the distance of cable between incoming service and the transfer switch and then to the engine generator set may be substantial. Consider what would happen if a cable failure occurred, as in Figure 1, with the engine generator not grounded to its own grounding electrode. The load would be automatically transferred to an *ungrounded* emergency power system. This, in turn, could jeopardize emergency service continuity and possible lead to additional failures. Concurrent failure of equipment or cable failure (break-down between line and equipment ground) after transfer to emergency may not be detected. Thus the generator frame may approach line potential, causing a substantial voltage difference between the generator frame and the grounded conductor (neutral).

Some local codes require ground-fault protection while the engine generator is operating. This may present a sensing problem if the neutral conductor of the generator is not connected to a grounding electrode at the generator site and proper isolation of neutrals is not provided. Furthermore, some local and state codes (Pennsylvania and Massachusetts) require area protection which may create additional problems unless the neutral conductor of the generator is isolated and grounded at the generator location.

When the transfer switch is in the emergency position, other problems may occur if the engine generator set is not properly grounded. For example, a ground-fault condition, could cause nuisance tripping of a normal source ground-fault circuit breaker even though load current is not flowing through the breaker. This would prevent automatic retransfer to the normal source and isolation of the fault condition. This would not be in accord with Section 230-95 of the National Electrical Code which since 1978 states, "Where ground-fault protection is provided for the service disconnecting means and interconnection is made with another supply system by a transfer device, means or devices may be needed to assure proper ground-fault sensing by the ground-fault protection equipment." Furthermore, both the normal neutral conductor and the emergency neutral conductor would be simultaneously vulnerable to the same ground-fault current. Thus a single fault could jeopardize power to critical loads even though both utility and emergency power are available. Such a condition may be in violation of codes requiring independent wiring and separate emergency feeders.

Three Pole Transfer Switching: Using three pole transfer switches is the least expensive approach and requires less space. However, ground-fault currents may trip the normal source breaker when the load is connected to the engine generator set. See diagram in figure 2. Furthermore, use of 3 pole transfer switches does not provide area protection within the facility and this could lead to an ungrounded power system in the event of cable failure. See diagram in figure 1. Finally, with the neutral conductor connected to the incoming normal service, it is difficult to provide ground-fault sensing on the emergency side as required to meet section 700-7 (d) of the National Electrical Code.

Four Pole Transfer Switching: A better solution is to use a four pole transfer switch which provides complete isolation of service and generator neutral conductors. This eliminates possible improper ground-fault sensing and nuisance tripping caused by multiple neutral-to-ground connections. When this is done the generator will comply with the current National Electrical Code definition of a separately derived system. With the neutrals thus isolated, ground-fault protection with conventional sensors can be added to the generator output.

Four pole transfer switches have been satisfactorily applied on applications where the loads are passive and relatively balanced. However, unbalanced loads may cause abnormal voltages for as long as 10 to 15 milliseconds when the neutral conductor is momentarily opened during transfer of the load. Transfer switches are frequently called upon to operate during total load unbalance caused by a single phasing condition. Inductive loads may cause additional high transient voltages in the microsecond range. Furthermore, it should be remembered that the contacts of the fourth switch pole do interrupt neutral currents and are, therefore, subject to arcing and contact erosion. However, contact erosion of the fourth pole can be minimized if the fourth pole is designed to open last (after the three other poles interrupt the load current) and make first without contact bounce. In any event, a good maintenance program must reaffirm at intervals the integrity of the fourth pole as a current-carrying member with sufficiently low impedance.

Both the National Electrical Code and Underwriters Laboratories, Inc. recognize the use of four pole transfer switches for 3 phase, 4 wire systems. In some European countries, including Germany and France, it is mandatory to use 4 pole switching devices.

Overlapping Neutral Contacts: Another method for isolating the normal and emergency source neutrals is for a 3 pole automatic transfer switch to include overlapping neutral transfer contacts. This feature provides the necessary isolation between neutrals and at the same time minimizes abnormal switching voltages. By means of overlapping contacts, the only time the neutrals of the normal and emergency power sources are connected together is during transfer and retransfer. With a solenoid-operated conventional double throw transfer switch, this duration can be less than the operating time of the ground-fault sensor which is usually set anywhere from 6 to 24 cycles (100 to 400 milliseconds).

Figure 3 shows a typical system utilizing a three pole transfer switch with overlapping neutral transfer contacts for isolating the neutral conductors. Note that there is no possible flow of fault current through the neutral conductor that would detract from or effectively reduce ground-fault detection. Furthermore, there is no possible flow of unbalanced current through the generator neutral to alter the response level of the ground-fault sensor and possibly cause nuisance breaker tripping. As with four pole transfer switches, conventional ground-fault sensing can be readily added to the emergency side. As shown in Figure 3, ground-fault sensing on the emergency side is often used for actuating an alarm circuit rather than tripping a breaker, such as required per section 700-7(d) of the National Electrical Code.

With overlapping neutral transfer contacts, the load neutral is always connected to one source of power. In that there is no momentary opening of the neutral conductor when the transfer switch operates, abnormal and transient voltages are kept to a minimum. Another advantage is that, there is no erosion of the overlapping contacts due to arcing, thus assuring current-carrying integrity and no increase in impedance of the neutral circuit. It should be noted that a 3 pole transfer switch with over lapping neutral contacts should not be specified as a 4 pole switch, according to Underwriters Laboratories Standard UL-1008 and the National Electrical Code. [4] [2]

Selecting Transfer Switching Equipment: For three phase four wire systems involving *one* transfer switch and *one* engine generator set, response to the questions in Table 1 serve as a guide in selecting the type of transfer switch needed for a particular application.

TABLE 1

QUESTIONS	YES	NO
a. Is the application for emergency power per Article 700 of the National Electrical Code?		
b. Is the incoming service of the normal source rated 1000 amperes or more?		
c. Is the service solidly-grounded wye and rated more than 150 volts to ground?		
d. If the engine generator set is located remote from the normal incoming service, is area protection required?		
e. Is sensing and alarm indication of a ground fault on the emergency or standby source required?		

If the response to the first three questions (a, b and c) are all “yes”, it is necessary to use a 4 pole transfer switch or a 3 pole transfer switch with overlapping neutral contacts in order to satisfy the requirements of the 1999 National Electrical Code. If the answer is “no” to any one of these questions, then proceed with questions d and e.

If the response is “yes” to either question d or e, use a 4 pole transfer switch or a 3 pole transfer switch with overlapping neutral contacts in order to satisfy the requirements of the National Electrical Code. If the answer is “no” to both questions, a less expensive 3 pole transfer switch without overlapping neutral contacts can be used. Then the neutral terminal of the generator should be grounded at the incoming service of the normal source.

Although the above questions apply to three phase four wire systems, the same approach can be taken for single phase three wire systems to determine the transfer switching equipment. However, most single phase systems are 400 amperes or less, and therefore can be satisfied with 2 pole transfer switches. It should be kept in mind that the above selection approach only applies to applications with one engine generator set and one transfer switch.

VI. OTHER CONSIDERATIONS

Because of the variety of emergency and standby power systems, it is not always feasible to provide fixed recommended practices. Each installation should be evaluated and designed to satisfy specific load, customer and code requirements. Examples of other special conditions are as follows:

Multiple Transfer Switches: Multiple transfer switches, located close to the loads, are often used rather than one transfer switch for the entire load. In such cases, consideration should be given to the possibility of cable or equipment failure between the service equipment and the transfer switches, thus possibly causing an emergency or standby power system to become ungrounded. This is particularly important if a solidly interconnected neutral conductor is grounded at the service equipment only.

Under such conditions, there is a possibility of tripping the ground-fault circuits when no ground fault exists. Figure 4 illustrates a typical system with multiple three-pole transfer switches. When power is supplied from the normal source to the load through a transfer switch the neutral current will divide between two neutral conductors. Some of the current will return by the normal return path. The remainder of the current will flow to the neutral terminal of the engine generator and through the neutral conductor of the other transfer switch to the normal source. This can cause tripping of either ground-fault circuit breaker even when no ground-fault exists. The problem can be corrected by the use of the three-pole transfer switches with overlapping neutral or four-pole transfer switches.

Multiple Engine-Generator Sets: When multiple engine- generator sets are connected in parallel and serve as a common source of power, each generator neutral is usually connected to a common neutral bus within the paralleling switchgear which, in turn, is grounded. The associated switchgear containing the neutral bus should be located in the vicinity of the generator sets. A single system-grounding conductor between the neutral bus and ground simplifies the addition of ground-fault sensing equipment.

It may be argued when individual grounding resistors are used, circulation of harmonic currents between paralleled generators is not a problem, since the resistance limits the circulating current to negligible values. However, if third harmonics are suppressed in the engine-generator sets, circulating currents are usually not a problem.

Engine generator sets which are physically separated and used for isolated loads may necessitate additional neutral-to-ground connections. By using multiple four-pole transfer switches or three-pole switches with overlapping neutral contacts, proper isolation and ground-fault sensing can be obtained.

Lightning Protection: Protection from power failures caused by lightning storms is a prime purpose for providing emergency power systems. It, therefore, seems only logical that the emergency power system be properly protected against lightning. Particular concern should be given to buildings housing emergency power equipment that are constructed of minimal nonconducting materials. When engine generator sets are installed on roof tops, additional consideration may have to be given to the installation of surge arresters and grounded metallic masts.

Since lightning currents (direct or through arresters) may flow through various equipment ground components, the connection to earth is a most important part of the equipment ground system. Arrester grounds which are normally secured by driven ground rods near the arrester should not exceed 5 ohms.

A grounding reactor is sometimes preferred in medium voltage applications where the feeders from the generators are exposed to lightning surges (overhead power line). For the low frequencies (50 and 60 Hz), the reactor forms a low impedance to ground. For the lightning and switching surges, which are high frequency, the reactor forms a higher impedance thus limiting the current without allowing the high overvoltages associated with an ungrounded system. However, it should be kept in mind that the neutral can not be used as a circuit conductor where the system is grounded through an impedance. Damage to structures and equipment due to surge effects is a subject in itself, and protection against this type of damage is not within the scope of this paper. For additional information and references, see Chapter 3 of IEEE Standard 142-1991 (Green Book). [3]

Mobile Engine Generator Sets: Though somewhat more difficult, proper grounding of mobile engine generator sets is extremely important. The mobility of such equipment often precludes the installation of a predesigned ground mat such as might be employed as a fixed installation. The portable equipment must be designed and grounded to permit personnel to approach (and touch) the apparatus without risk of dangerous electric shock.

Providing sensitive fast operating ground-fault protection with mobile engine generator sets provides additional protection. Switching devices or connectors should not be installed in the grounding conductor which may be subject to loss of conductivity. Grounding of the engine generator frame and vehicle chassis should be positive and thoroughly tested prior to engine starting.

Plate electrodes are sometimes used for grounding mobile engine generator sets. In addition to the minimum requirements of Section 250-52 (d) of the 1999 National Electrical Code, the following conditions are recommended: [5]

1. 1.5 square feet of the plate surface should be below the surface and a linear distance of at least one (1) foot is common to earth and air above the earth.

2. The electrode should be located within a distance of no more than three (3) feet from the exterior surface of the generator set.

3. The electrode should be exposed to rain or moisture at least to the same degree as is the housing or exterior metal surfaces of the generator set.

Connection to the plate electrode would be in addition to a solid connection to the equipment grounding conductors of the facility or building to which the mobile power is being served. There is no restriction on the number of grounding electrodes conductors or electrodes that may be used. The more the better from a safety standpoint.

Small Portable Generator Sets: Grounding small portable generator sets presents a different problem. It is often impractical at construction and similar sites to ground the generator set. Section 305.6(a) Exception No. 1 of the National Electrical Code permits leaving such sets ungrounded as long as the only loads are connected to receptacles mounted on the generator set. The code does require that such sets have GFCI (ground fault circuit interrupters) for personnel protection either on the receptacles or the extension cord, and as with all electrical equipment an equipment ground system be used. An exception (Section 305.6(a)

Exception No. 1) to the GFCI requirement is allowed for 120 volt two wire sets, not over 5kW, that has both its electrical conductors insulated from ground.

Generator Sets Mounted in Vehicles: Section 250.34 (b) of the National Electrical Code does permit the frame of a vehicle to serve as the grounding electrode for a system supplied by a generator located on a vehicle, provided that:

1 The frame of the generator is bonded to the vehicle frame, and

2. The generator supplies only equipment located on the vehicle and/or cord and plug connected equipment through receptacles mounted on the vehicle or the generator, and

3. The noncurrent-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are bonded to the generator frame, and

4. The system complies with all other provisions of Article 250 of the National Electrical Code.

Using the frame of a vehicle as the grounding electrode is practical when the generator is the sole source of power, particularly if other grounding means are not readily available. However, if the generator serves as an alternate source of power (i.e., emergency or standby power), then grounding as explained above for mobile engine generator sets may be more appropriate. This would assure solid grounding of the generator frame to equipment grounding conductors of the facility or building to which the mobile power is being served. Furthermore, ground-fault sensing and whether or not the generator set is to be considered as a separately derived source are factors to consider. In either case, it is important that the frame of the generator is bonded to the vehicle frame.

Upgrading Transfer Switching Equipment: Upgrading older transfer switch equipment to present codes and standards can be a real challenge, particularly for larger and more complex industrial and commercial facilities. Awareness that three-pole transfer switches may not always provide complete isolation and proper ground-fault sensing has not been too apparent in the past. With more emergency and standby power systems being updated, the concern regarding safety and product liability should not be treated too lightly. This concern provides another reason for upgraded installations to include adequate grounding and preferably new transfer switches that provide switching of the neutral conductor. Regardless of whether or not ground-fault sensing is required, proper switching of the neutral conductor is good engineering practice because of the system isolation, improved grounding and the extra safety it can provide. [6]

VII. CONCLUSIONS

There are a number of factors that should be considered when grounding on-site power systems. Simply conforming to minimum code requirements will not necessarily assure the degree of reliability required for such systems. Thorough consideration should be given to protecting against power disruption within the building or facility and providing adequate ground-fault protection. Techniques for both equipment grounding and system grounding should be such as to provide optimum safety and assure maximum continuity of power to essential loads. This includes proper grounding and ground-fault sensing when the transfer switch is in the emergency position as well as the normal position. Grounding instructions provided by the manufacturer of the equipment should be followed.

As a general rule, most applications requiring ground-fault sensing, area protection, multiple transfer switches, or multiple engine generator sets, the on-site power should be considered as a *separately derived system.* In such cases the neutral of the engine generator set is grounded at its location.

It is not intended for the scope of this paper to cover in detail all aspects of grounding on-site power systems. Those requiring more detailed information may find the following list of references helpful.

REFERENCES

[1] EGSA *On-Site Power Generation*: *A Reference Book, Third Edition*, Electrical Generating Systems Association, Coral Springs, FL (edited by coauthor Gordon Johnson).

[2] *National Electrical Code,* NFPA No. 70-1999, National Fire Protection Association, Quincy, MA.

[3] IEEE *Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book),* Standard 142-1991, Institute of Electrical and Electronic Engineers, New York, NY (chaired by coauthor Gordon Johnson).

[4] *Standard for Automatic Transfer Switches,* UL 1008, Underwriters Laboratories, Melville, NY.

[5] *Grounding of Alternate Power Sources,* by R. Castenschiold, IEEE Conference Record, Industry Applications Society Annual Meeting, October 1977, Institute of Electrical and Electronic Engineers, New York, NY.

[6] *Factors to Consider When Upgrading Transfer Switching to Present Codes and Standards,* by R. Castenschiold and L.F. Hogrebe, IEEE Transactions Industry Applications, Vol. 29, No. 3, May/June 1993, Institute of Electrical and Electronic Engineers, New York, NY.

BIBLIOGRAPHY

[B1] IEEE *Recommended Practice for Emergency and Standby Power Systems* (Orange Book), Standard 446-1995, Institute of Electrical and Electronic Engineers, New York, NY.

[B2] IAEI *Soares Book on Grounding, 6th Edition,* by J.P. Simmons, International Association, of Electrcial Inspectors, Richardson, TX.

[B3] *More About Standby Generator Grounding, GFP, and Currents that Go Bump in the Night* by Hugh O. Nash, Jr., IEEE Transactions Industry Applications, Vol. 33, No. 3, May/June 1997, Institute of Electrical and Electronic Engineers, New York, NY.

[B4] *National Electrical Grounding Research Project,* by T. Lindsey, IAEI News, May/June 1998, International Association of Electrical Inspectors, Richardson, TX.

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Industrial and Commercial power Systems Conference, Sparks, NV, May 4, 1999.

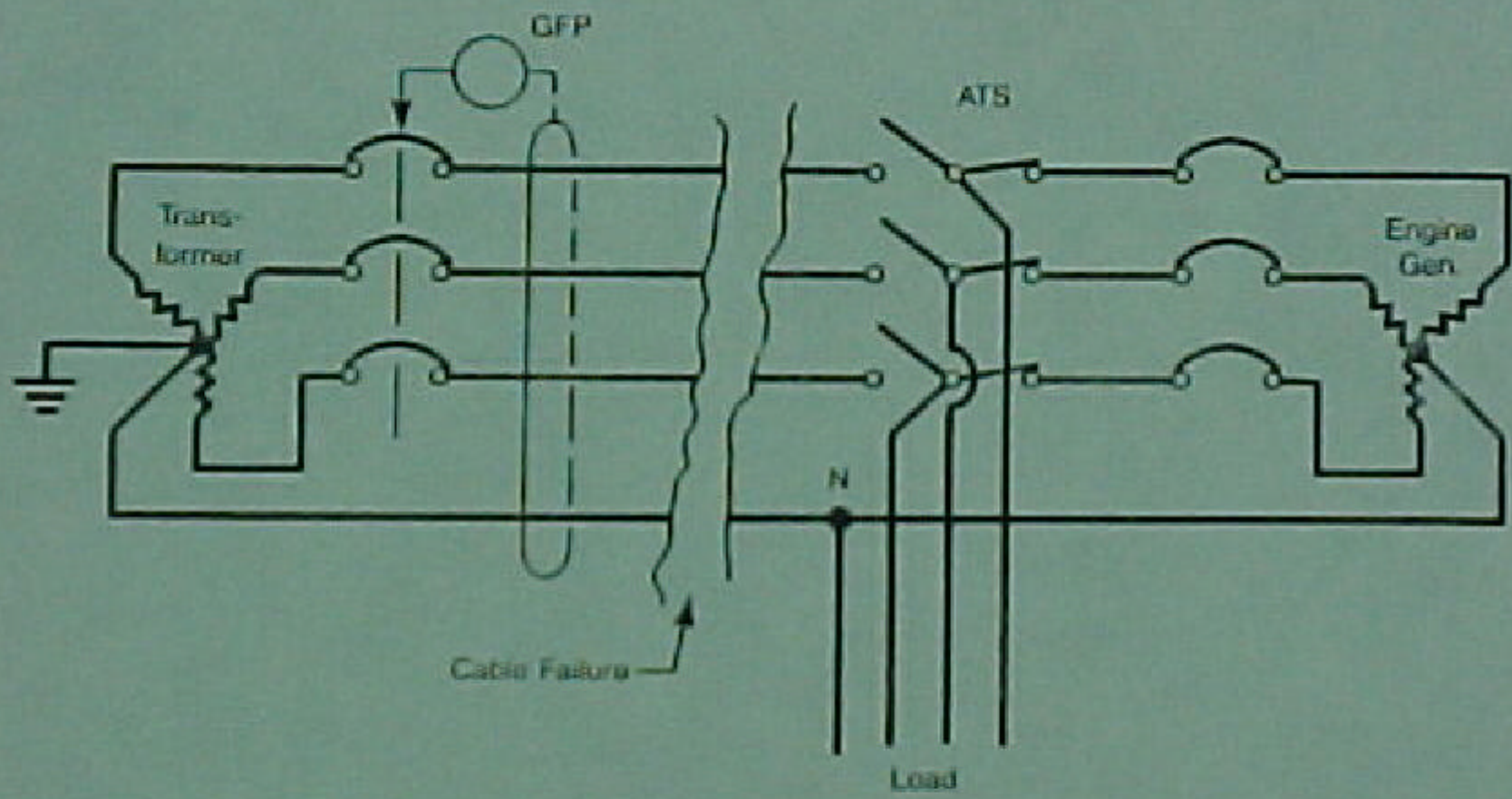


Fig. 1 No Area Protection with Ungrounded Engine Generator Set Providing Power to the Load

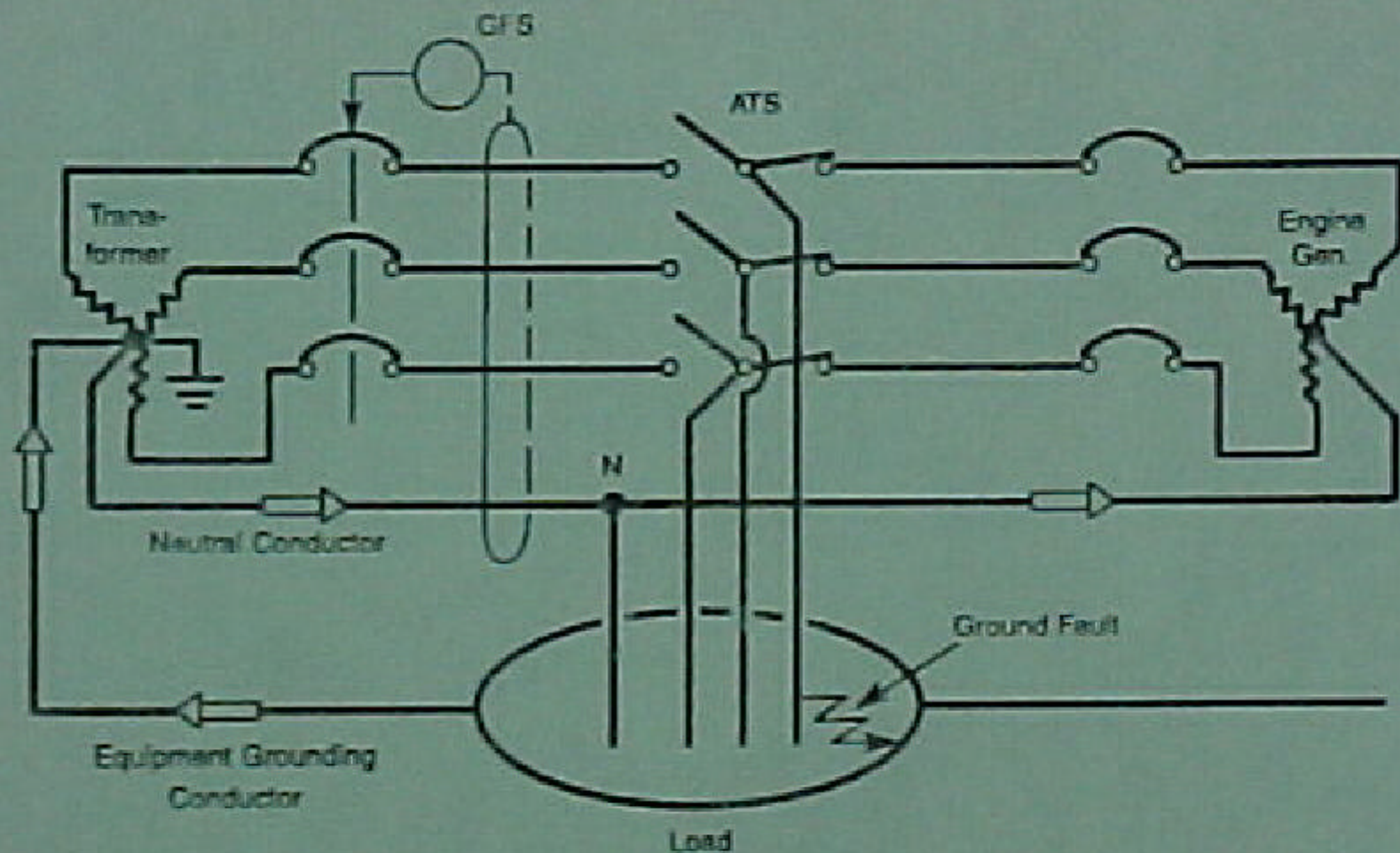


Fig. 2 Improper ground Fault Sensing

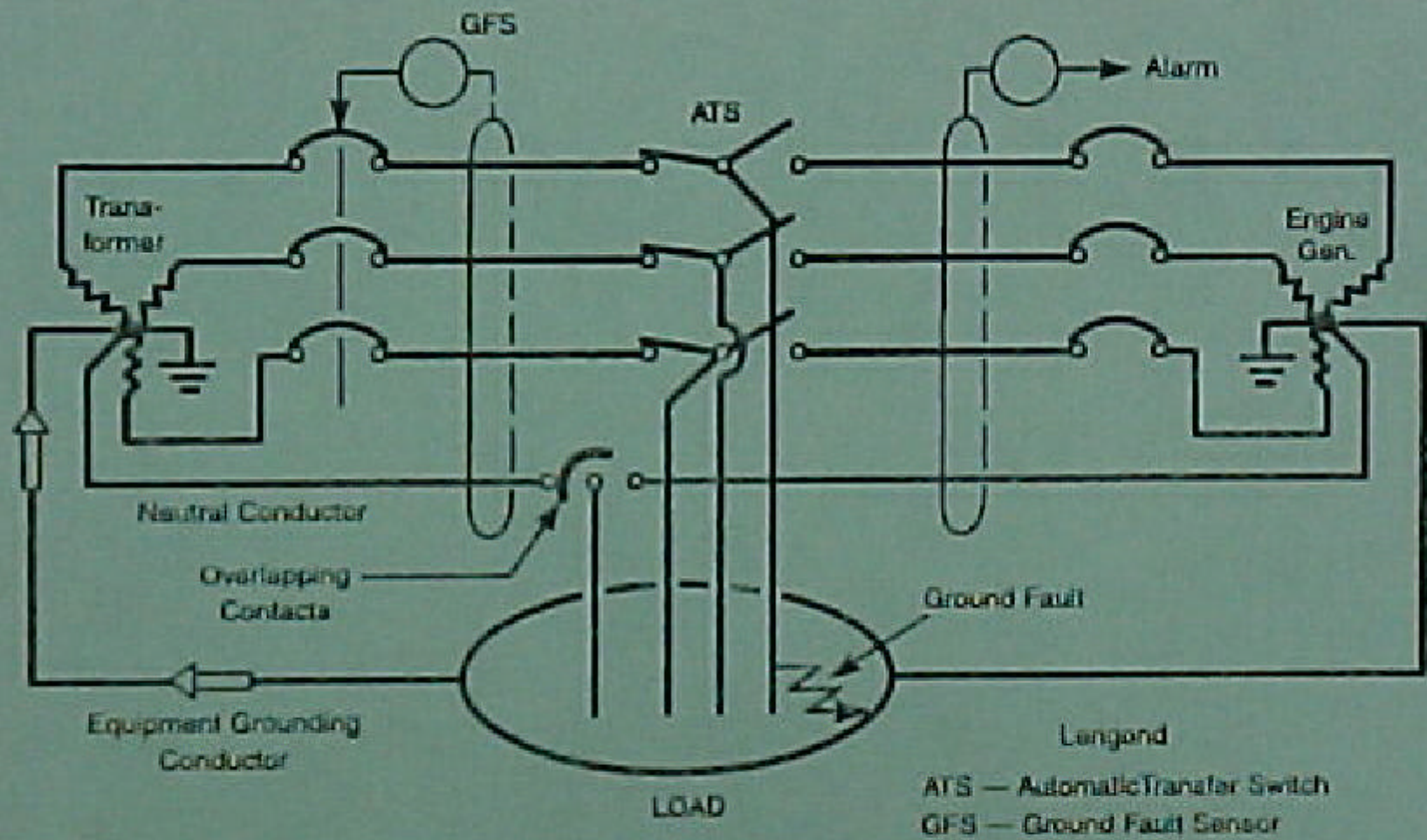


Fig. 3 System with Overlapping Neutral Contacts

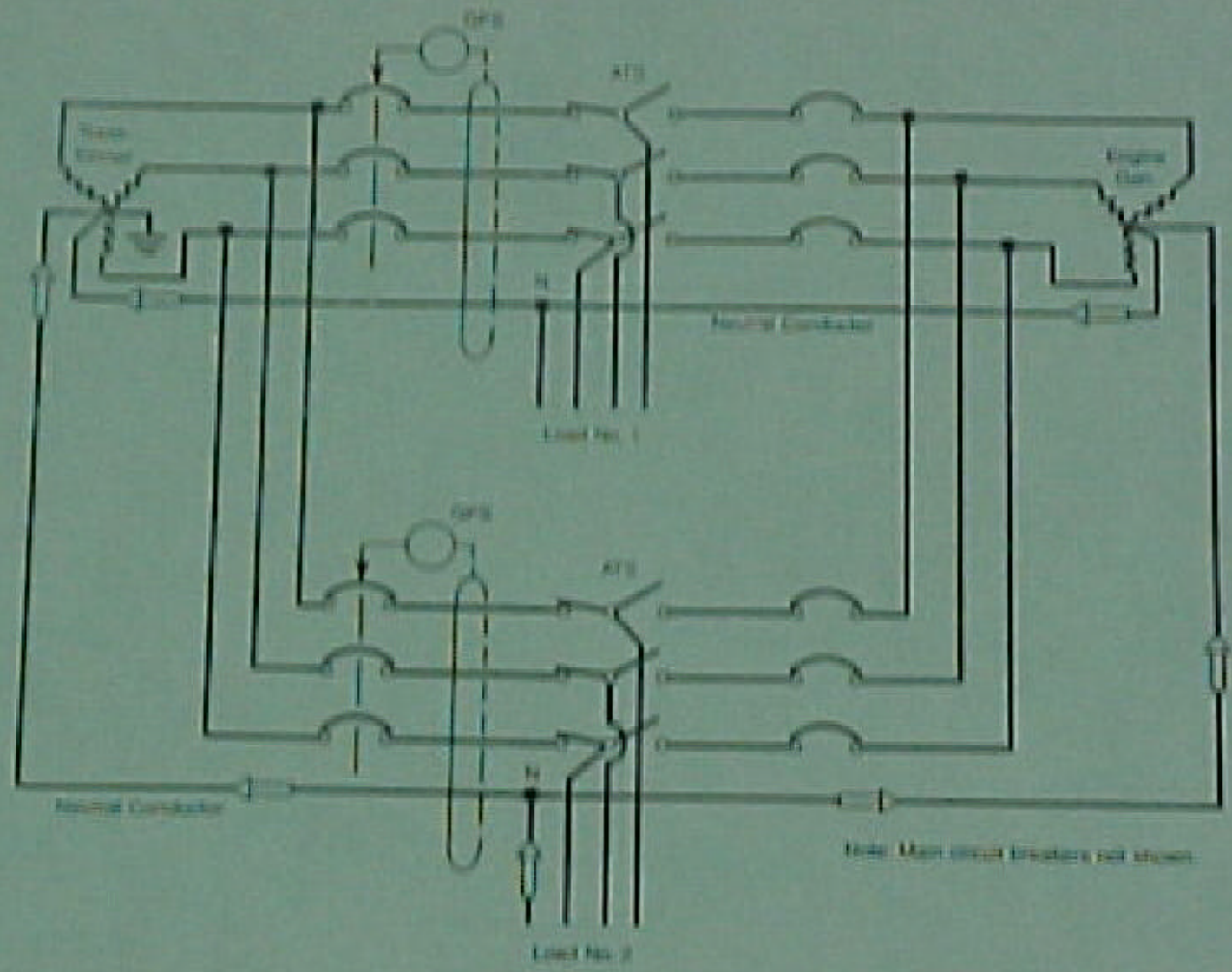


Fig. 4 Multiple Automatic Transfer Switches
With Improper Ground Fault Sensing

Electrical Safety During D&D Activities (Jim Craven)

INTEGRATION OF ELECTRICAL SAFETY

IN

FACILITY DISPOSITION ACTIVITIES

- FACILITY DISPOSITION (DEACTIVATION AND DECOMMISSIONING) ACTIVITIES INVOLVE UNIQUE WORK ACTIVITIES THAT INTRODUCE HAZARDS AND PROGAMMATIC CHALLENGES SELDOM ENCOUNTERED DURING NORMAL OPERATIONS
  - DEACTIVATION - IDEALLY BEGINS IMMEDIATELY AFTER OPERATION ENDS. STABILIZATION AND REMOVAL OF HAZARDOUS SUBSTANCES.
  - DECOMMISSIONING - REMOVAL OF CONTAMINATION AND RESIDUAL HAZARDOUS SUBSTANCES AND THEN REUSE OR DISMANTLEMENT OF SYSTEMS OR FACILITY.

- EFFECTIVELY ADDRESSING ELECTRICAL HAZARDS DURING D&D ACTIVITIES REQUIRES STRONG MANAGEMENT COMMITMENT AND REAL WORKER INVOLVEMENT.
  - INCREASE WORKER AWARENESS AND HAZARD RECOGNITION SKILLS.
  - IMPLEMENT EFFECTIVE, INTEGRATED HAZARDS MANAGEMENT TO IDENTIFY, ANALYZE, AND ESTABLISH CONTROLS FOR ALL HAZARDS.

- **WORK PLANNING FOR D&D ACTIVITIES**
  - **NORMALLY FOCUSES ON RADIOLOGICAL, CHEMICAL, AND ENVIRONMENTAL CONCERNS**
  - **ELECTRICAL SAFEY ISSUES ARE AN AFTERTHOUGHT IF DISCUSSED AT ALL. THEY CAN BE LEFT SOLELY TO "SKILL OF THE CRAFT" WITHOUT ELECTRICAL SAFETY PROFESSIONAL INVOLVEMENT.**
  - **RESOURCE PLANNING = ADEQUATE PERSONNEL WITH THE PROPER SKILLS**

- HAZARD IDENTIFICATION
  - UNDERSTAND CURRENT FACILITY STATUS
    - REVIEW DRAWINGS
    - INTERVIEW PAST AND PRESENT WORKERS
    - PHYSICALLY WALKDOWN AND EVALUATE WITH KNOWLEDGABLE PERSONNEL, INCLUDING ELECTRICAL
    - DOCUMENT HAZARDS AND ENSURE THAT PERSONNEL PERFORMING THE WORK ARE AWARE OF CONDITIONS IN THE FACILITY

- ESTABLISHING HAZARD CONTROL
  - ELIMINATE HAZARDS WHERE POSSIBLE BY TAKING SYSTEMS OUT OF SERVICE
  - WHERE HAZARDS CANNOT BE ELIMINATED, USE ADMINISTRATIVE CONTROLS SUCH AS LO/TO
    - KEEP SIMPLE AND MAKE SURE EVERYONE IN THE WORK AREA UNDERSTANDS THE CONTROLS
    - PROVIDE ADEQUATE TRAINING FOR QUALIFIED AND UNQUALIFIED WORKERS TO ENSURE THEY ARE FULLY AWARE OF HE HAZARDS.

- ESTABLISHING HAZARD CONTROL
  - PERSONAL PROTECTIVE EQUIPMENT
    - PROVIDE APPROPRIATE PPE FOR THE WORK
    - ENSURE PERSONNEL ARE TRAINED IN ITS INSPECTION AND USE

- WORK PERFORMANCE
  - MONITOR WORK ACTIVITIES
  - ESTABLISH CLEAR CHANGE CONTROL PROCESSES FOR WORK SCOPE AND TASK CHANGES.
    - UNEVALUATED HAZARDS
    - INADEQUATE CONTROLS
    - ENSURE ALL IMPACTED PERSONNEL ON THE WORK SITE ARE MADE AWARE OF THE CHANGES

- EXAMPLES
  - ENERGIZED WIRE CUT DURING POWERHOUSE DEMOLITION
  - CONDUIT AND ENERGIZED CONDUCTOR CUT DURING PARTIAL DISMANTLEMENT OF FACILITY
  - DAMAGE TO ELECTRICAL PANEL DURING DECONTAMINATION ACTIVITY.

Intrinsically Safe Equipment (Doug Lovette)

INTRINSIC SAFETY

JUNE 1999

DOE ELECTRICAL SAFETY CONFERENCE

ORLANDO, FLA.

Explosion Protection Concepts

- Explosion Confinement
  - Explosion-Proof Enclosures, external surfaces must be kept below autoignition temperature, gas group dependent
  - Designed to withstand an internal explosion and prevent ignition of the surrounding atmosphere
- Isolation
  - Purged or Pressurized
    - Preventing entry of a surrounding atmosphere into the enclosure by maintaining a positive pressurized inert gas inside the enclosure

- Oil Immersion
  - Arcing equipment is immersed in oil to isolate contacts from the surrounding atmosphere
- Sealing
  - Prevents the casual entrance of the external flammable atmosphere. Sealing may be accomplished from simple gasketing to hermetic sealing.
- Other methods
  - Encapsulation, sand or powder filling

- Energy Release Limitation
  - Non-Incendive
    - Use of electrical circuits that, under normal conditions, do not release sufficient energy to ignite the surrounding atmosphere
  - Intrinsically Safe System
    - Apparatus incapable of igniting combustible material in the air due to the limitation of electrical energy in the circuit

Documents

- NFPA 70 - National Electrical Code - Article 504

- UL 913 - “Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous Locations”

- ISA S12.1 - “Definitions and Information Pertaining to Electrical Instruments in Hazardous (Classified) Locations”

- ISA RP12.6 - “Wiring Practices for Hazardous (Classified) Locations, Instrumentation, Part I: Intrinsic Safety”

Manufacturers' Literature

- MTL (Measurement Technology Limited) - Application Note AN9003 - "A User's Guide to Intrinsic Safety".

- MTL - Application Note AN9007 - "A User's Guide to Shunt-Diode Safety Barriers".

- MTL - 1998/1999 Intrinsic Safety Catalog

  - 127 Technical Papers
  - 21 Application notes
  - 3 Text books
  - 3 Videos

Definitions

- Associated Apparatus: Apparatus in which the circuits are not necessarily intrinsically safe themselves, but that affect the energy in the intrinsically safe circuits and are relied upon to maintain intrinsic safety.

- Control Drawing: A drawing or other document provided by the manufacturer of the intrinsically safe or associated apparatus that details the allowed interconnections between the intrinsically safe and associated apparatus.

- Different Intrinsically Safe Circuits: Different intrinsically safe circuits are intrinsically safe circuits in which the possible interconnections have not been evaluated and approved as intriniscally safe.

- Intrinsically Safe Apparatus: Apparatus in which all the circuits are intrinsically safe.

- Intrinsically Safe Circuit: A circuit in which any spark or thermal effect is incapable of causing ignition of a mixture of flammable or combustible material in air under prescribed test conditions.

  - (FPN): Test conditions are described in Standard for Safety, Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous (Classified) Locations, ANSI/UL 913-1988.

- Intrinsically Safe System: An assembly of interconnected intrinsically safe apparatus, associated apparatus, and interconnecting cables in that those parts of the system that may be used in hazardous (classified) locations are intrinsically safe circuits.

  - (FPN): An intrinsically safe system may include more than one

intrinsically safe circuit.

- Simple Apparatus: A device that will neither generate nor store more than 1.2 volts, 0.1 ampere, 25 milliwatts, or 20 microjoules.

  - (FPN): Examples are switches, thermocouples, light-emitting diodes (LEDs), connectors, and resistance temperature devices (RTDs).

504-1. Scope.

- This article covers the installation of intrinsically safe (I.S.) apparatus, wiring, and systems for Class I, II, and III locations.

  - (FPN): For further information, see Installation of Intrinsically Safe Instrument Systems in Class I Hazardous Locations, ANSI/ISA RP 12.6-1987.

Comment: Prior to the 1990 NEC, ISA 12.6, was the recommended practice for the installation of IS systems. Article 504 was proposed to provide a

more enforceable set of requirements for enforcement authorities.

504-3. Application of Other Articles.

- Except as modified by this article, all applicable articles of this Code shall apply.

Comment: Although IS circuits are inherently low energy circuits, there still may be a shock hazards because of the operating voltage.

504-4. Equipment Approval.

- All intrinsically safe apparatus and associated apparatus shall be approved.
    - Exception: Simple apparatus, as described on the control drawing,

shall not be required to be approved.

504-10. Equipment Installation.

- (a) Control Drawing. Intrinsically safe apparatus, associated apparatus, and other equipment shall be installed in accordance with the control drawing(s).

  - Exception: A simple apparatus that does not interconnect intrinsically safe circuits.

  - (FPN): The control drawing identification is marked on the apparatus.

Comment: To ensure that a given interconnection forms an IS system, it is necessary to obtain the control drawings that specify each IS apparatus and

associated apparatus to be interconnected.

- (b) Location. Intrinsically safe and associated apparatus shall be permitted to be installed in any hazardous (classified) location for which it has been approved.

- General-purpose enclosures shall be permitted for intrinsically safe apparatus.

504-20. Wiring Methods.

- Intrinsically safe apparatus and wiring shall be permitted to be installed using any of the wiring methods suitable for unclassified locations,

including Chapter 7 and Chapter 8. Sealing shall be as provided in Section 504-70, and separation shall be as provided in Section 504-30.

504-30. Separation of Intrinsically Safe Conductors.

- (a) From Nonintrinsically Safe Circuit Conductors.
  - (1) Open Wiring. Conductors and cables of intrinsically safe circuits not in raceways or cable trays shall be separated at least 50 mm and secured from conductors and cables of any nonintrinsically safe circuits.
  - (FPN): 50 mm is approximately equal to 2 in.
  - Exception: Where either (1) all of the intrinsically safe circuit

conductors are in Type MI or MC cables or (2) all of the nonintrinsically safe circuit conductors are in raceways or Type MI or MC cables where the sheathing or cladding is capable of carrying fault current to ground.

- (2) In Raceways, Cable Trays, and Cables. Conductors of intrinsically safe circuits shall not be placed in any raceway, cable tray, or cable with conductors of any nonintrinsically safe circuit.

- Exception No. 1: Where conductors of intrinsically safe circuits are separated from conductors of nonintrinsically safe circuits by a distance of at least 50 mm and secured, or by a grounded metal partition or an approved insulating partition.

- (FPN No. 1): 50 mm is approximately equal to 2 in.

- (FPN No. 2): No. 20 gauge sheet metal partitions 0.0359 in. (912 micrometers) or thicker are generally considered acceptable.

- Exception No. 2: Where either (1) all of the intrinsically safe circuit conductors or (2) all of the nonintrinsically safe circuit conductors are in grounded metal-sheathed or metal-clad cables where the sheathing or cladding is capable of carrying fault current to ground.

  - (FPN): Cables meeting the requirements of Articles 330 (MI cable) and 334 (MC cable) are typical of those considered acceptable.

(3) Within Enclosures.

- a. Conductors of intrinsically safe circuits shall be separated at least 50 mm from conductors of any nonintrinsically safe circuits, or as specified in Section 504-30(a)(2).
- (FPN): 50 mm is approximately equal to 2 in.

- b. All conductors shall be secured so that any conductor that might come loose from a terminal cannot come in contact with another terminal.

- (FPN No. 1): The use of separate wiring compartments for the intrinsically safe and nonintrinsically safe terminals is the preferred method of complying with this requirement.

- (FPN No. 2): Physical barriers such as grounded metal partitions or approved insulating partitions or approved restricted access wiring ducts separated from other such ducts by at least 3/4 in. (19 mm) can be used to help ensure the required separation of the wiring.

- (b) From Different Intrinsically Safe Circuit Conductors. Different intrinsically safe circuits shall be in separate cables or shall be separated from each other by one of the following means:

- (1) The conductors of each circuit are within a grounded metal shield;

- (2) The conductors of each circuit have insulation with a minimum thickness of 0.01 in. (254 micrometers).

- Exception: Unless otherwise approved.

504-50. Grounding.

- (a) Intrinsically Safe Apparatus, Associated Apparatus, and Raceways. Intrinsically safe apparatus, associated apparatus, cable shields, enclosures, and raceways, if of metal, shall be grounded.

- (FPN): Supplementary bonding to the grounding electrode may be needed for some associated apparatus, e.g., zener diode barriers, if

specified in the control drawing. See Installation of Intrinsically Safe Instrument Systems in Class I Hazardous Locations, ANSI/ISA RP 12.6-1987.

- (b) Connection to Grounding Electrodes. Where connection to a grounding electrode is required, the grounding electrode shall be as specified in Sections 250-81(a), (b), (c), and (d) and shall comply with Section 250-26(c). Section 250-83 shall not be used if electrodes specified in Section 250-81 are available.

- (c) Shields. Where shielded conductors or cables are used, shields shall be grounded.

- Exception: Where a shield is part of an intrinsically safe circuit.

504-60. Bonding.

- (a) Hazardous Locations. In hazardous (classified) locations, intrinsically safe apparatus shall be bonded in the hazardous (classified) location in accordance with Section 250-78.

- (b) Nonhazardous Locations. In nonhazardous locations, where metal raceways are used for intrinsically safe system wiring in hazardous locations, associated apparatus shall be bonded in accordance with Sections 501-16(a), 502-16(a), or 503-16(a), as applicable.

504-70. Sealing.

- Conduits and cables that are required to be sealed by Sections 501-5 and 502-5 shall be sealed to minimize the passage of gases, vapors, or dust. Such seals shall not be required to be explosionproof.

- Exception: Seals shall not be required for enclosures that contain only intrinsically safe apparatus, except as required by Section 501-5(f)(3).

504-80. Identification.

- Labels required by this section shall be suitable for the environment where they are installed with consideration given to exposure to chemicals and sunlight.

- (a) Terminals. Intrinsically safe circuits shall be identified at terminal and junction locations in a manner that will prevent unintentional interference with the circuits during testing and servicing.

- (b) Wiring. Raceways, cable trays, and open wiring for intrinsically safe system wiring shall be identified with permanently affixed labels with the wording "Intrinsic Safety Wiring" or equivalent. The labels shall be so located as to be visible after installation and placed so that they may be readily traced through the entire length of the installation. Spacing between labels shall not be more than 25 ft (7.62 m).

- Exception: Circuits run underground shall be permitted to be identified where they become accessible after emergence from the ground.

- (FPN No. 1): Wiring methods permitted in unclassified locations may be used for intrinsically safe systems in hazardous (classified) locations. Without labels to identify the application of the wiring, enforcement authorities cannot determine that an installation is in compliance with the Code.

- (FPN No. 2): In unclassified locations, the identification is necessary to ensure that nonintrinsically safe wire will not be inadvertently added to existing raceways at a later date.

- (c) Color Coding. Color coding shall be permitted to identify

intrinsically safe conductors where they are colored light blue and where no other conductors colored light blue are used. Likewise, color coding shall be permitted to identify raceways, cable trays, and junction boxes where they are colored light blue and contain only intrinsically safe wiring.

R&D Is It Really Different (Lloyd Gordon)

R&D Electrical Safety

Lloyd B. Gordon
Los Alamos National Laboratory
Principal Engineer - R&D Safety

DOE Electrical Safety Meeting
June 23, 1999

R&D Electrical Hazards and Training

- Are they different from other electrical hazards?
- What exactly does OSHA, NESC, and NEC cover?
- What training does OSHA require?
- R&D Electrical Safety Training at LANL.
- Training effectiveness.

Objectives

- to understand the unique differences in the R&D lab that affect
  - code application
  - safe work practices
  - training
- to review the hazards in the lab
- to present training requirements driven by these differences
- to consider the methods of delivery that best address these training requirements

Electrical Safety in the Codes

- NESC - power and communications (utility)
- NEC - power and communications (premises)
- NRTL - utilization equipment (e.g., UL)
- OSHA - everything
- ac and dc, frequency
- low voltage, high voltage

What are the electrical hazards in the R&D environment ?

- ac power
- high voltage, high current, high power
- low voltage and high current
- high voltage and low current
- radiofrequency and microwave
- stored energy
- x-rays

How do R&D requirements differ from these safety codes?

- over regulation - e.g., high voltage, low energy/current
- under-regulation - e.g., low voltage, high current
- stored energy (batteries, capacitors, inductors)
- radiofrequency
- must have additional standards and guidelines
  - IEEE/ANSI
  - DOE

What is different about work in the R&D environment?

- less standardization of design and procedures
- fewer routine procedures
- more knowledge of theory, but less experience
- lower reliability requirements
- more testing, troubleshooting, modification
- less safe/higher risk

What must be done differently to compensate?

- more customized procedures (e.g., SEWPs)
- different training
- less energized electrical work
- more oversight by qualified personnel

Unique training requirements for R&D at LANL

Designing training that

- **is based on education and knowledge and emphasizes work analysis, hazard identification, and work planning rather than individual procedures**
- **engages an audience with diverse backgrounds**
- **covers a wide range of exposure/responsibilities**
- **limits information, detail, possibilities**
- **fits into LANL's safety program (Integrated Safety Management)—this bullet addresses your topic as specific to LANL, add "at LANL" to title?**

What are the goals of an R&D training program

- to clarify AHJ, requirements, safe work practices, etc.
- to teach work analysis, hazard identification, mitigation planning
- to promote safe attitude
- to emphasize on-the-job training requirements
- to provide some details/tools

Electrical Safety Training at LANL Includes

Includes

- **R&D electrical workers (scientists, engineers, technicians)**
- **utility and facility electrical workers (electricians/linemen)**
- **non-electrical workers**
- **general office workers**

Course Areas

- NEC
  - Analysis of the 1999 changes
  - Understanding the R&D/NEC interface
- Utility
  - NESC
  - OSHA
- R&D
  - LANL Electrical Safety Program
  - Electrical Injury Mechanisms
  - Optional Modules

Training vs retraining

Initial training

- must impress upon the worker the severity of the hazard
- must provide the worker with the tools to work safely
  - familiarity with Lab requirements
  - knowledge of safe work practices
  - design approaches for safety

Retraining

- provides review
- allows updates and lessons learned

Methods of delivery

- classroom
- self-study
- web-based
- test-out
- on-the-job training (OJT)

How do we measure effectiveness?

- Number of accidents and incidents
- Testing
- Fewer observed unsafe practices

Have we done our job?

- student evaluations
- increased enrollment
- requests for additional class topics
- increased classroom participation
- increase in safety awareness

Summary

R&D Work is:

- **Unique**
- **Cutting edge**
- **Requires adaptable rules**
- **Higher hazards**

Safety Ground Hooks

Lloyd B. Gordon
Los Alamos National Laboratory
Principal Engineer - R&D Safety

DOE Electrical Safety Meeting
June 23, 1999

Outline

- Background
- Requirements
- Design
- Safe Use
- Common Mistakes
- Testing, Documentation
- Examples

What is a ground hook?

Ground hook - A device for making a temporary connection to discharge and ground the internal energy sources in hazardous electrical equipment. It consists of a bare copper rod shaped like a shepherd's hook at one end, an insulation handle, and a suitable bare flexible copper cable securely connected at the other end, and can be securely connected to an equipment or building ground. (DOE manual)

Other terms used around the lab

stick - a slang term for hook. Sometimes a ground hook may not have a “hook” at the end, but merely a point; thus, it is sometimes called a stick.

to crowbar - the process of abruptly removing stored energy from an electrical system. (sometimes a ground hook is known as a “crowbar hook”)

shorting hook/bar - a variation of a ground hook, but the purpose is to short between the terminals of a capacitor. This is not a sufficient condition for safety, because it does not bring the component to zero potential, thus it is only an intermediate step to safety.

to safe - the process of assuring that an electrical system is de-energized. This involves steps of disconnection (lockout/tagout), removal of stored energy, and placement of safety devices (e.g., ground hooks).

More terms

- **Soft ground/crowbar (high Z ground)** - a ground hook with a series resistor to limit the discharge current. Is especially important if significant energy (>1 kJ) is being removed by the manual safing process.
- **Hard ground/crowbar (low Z ground)** - a ground hook with a low resistance path to ground, typically 0.1 ohm or less. A hard ground hook must be applied even if a high Z ground was used to discharge the system.

$$t = RC \qquad E = \frac{1}{2}CV^2 \qquad P_{av} = \frac{E}{t}$$

What must a ground hook do?

- The purpose of a ground hook is to assure that the system is at zero potential, and stays there during all work.
- The hook also prevents capacitor recharging and protects the employee in the unlikely event of re-energization or fault from some other portion of the system.
- The ground hook may be used to remove any residual energy in the system.
- The design of the ground hook, and the procedure to use it must PROTECT the employee at all stages.

Design requirements

- bare metallic hook or point of strength to withstand any deformation forces of application or current discharge. (typically, at least 0.5 cm diameter, hardened copper)
- insulating handle of length sufficient to protect against the voltage, i.e., surface flashover (may range from 0.5 to 3 m). A flash guard may be used.
- cable firmly attached at the base of the hook. Preferably soldered. (#0000 copper-braided welding-type cable is typical)
- cable insulation - if insulation is used, it should be transparent so that the integrity of the ground path can be visually assured.

System design requirements

- provide sufficient numbers of ground hooks to adequately ground all designated points
- access points for grounding must be easily identifiable and safely accessible
- permanently installed ground hooks must be permanently grounded and stored in manner to ensure that they are used
- connection point of the grounding cable to system ground should be provided that to minimize tripping hazards
- ground hooks must be visible while work is being performed

Safe use of a ground hook

- always wear eye protection during application of the ground hooks
- if a flash guard is not built into the ground hook, consider wearing dielectric gloves
- never hold or step on the hook grounding cable during application of the ground hook
- keep proper clearance of all body parts from all potentially energized electrical components
- calculate the energy stored, the discharge rate, and the power dissipated in the discharge resistor. Limit the discharge current to 500 A for hard or soft ground hooks.

Some common mistakes made with a ground hook

- failure to wear eye protection
- holding onto the ground cable
- insufficient length of handle
- too rapid of a discharge
- failure to leave ground hooks in place
- insufficient ground hooks, especially in series capacitor configurations

Testing a ground hook

There are three tests that can be performed on a ground hook:

- handle flashover voltage
- power dissipation for soft ground
- fault current

Voltage withstand rating test

- This must be done without the person attached!
- Use a hi-pot tester, which limits the current (5 mA), while providing high voltage
- Firmly attach a well-grounded simulation of the hand (e.g., a hose clamp with cable)
- Apply the hi-pot tester to the end of the ground hook
- Properly suspend the ground hook to prevent other discharge paths
- Raise the voltage until flashover occurs, repeat 3 to 5 times

IMPORTANT - high current flashover testing will damage the dielectric material by leaving carbonized tracking paths.

Power dissipation test

- Used to test the power rating of the resistor in soft ground hooks.
- Calculations should be done to determine that the resistor is rated properly for the energy to be dissipated.
- Discharge the capacitor(s) from a fully charged condition.
- Watch for arcing at the resistor connections.
- The resistor can be warm, but should not be dangerously hot. Continual use of the resistor should not result in discoloration, blistering, or cracking.

Fault current test

A ground hook should be designed to take possible fault currents. However, repeated application of this test may damage the ground hook. It is best to test a design prototype, and then build to that standard.

Summary

GROUND HOOKS

- are a critical part of safe work procedures in energy-storage systems
- must be purchased or designed to exacting standards
- are not listed and must be approved by the local AHJ
- must consider both design and safe use

Interactive Electrical Safety Course for Researchers (Marcia Jacobs)

Web-based R&D Electrical Safety Awareness Training

Combustion & Physical Sciences Center

Sandia National Laboratories
Livermore, CA.

Marcia Jacobs

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

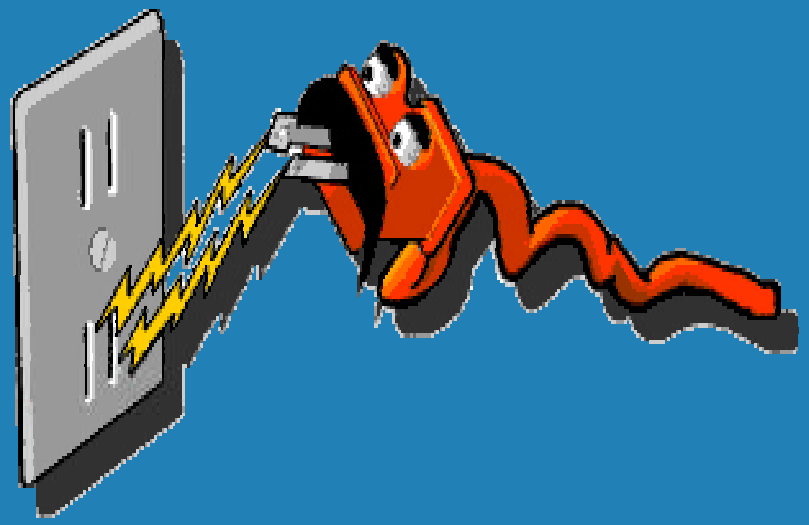
Sandia National Laboratories

Objectives

- Training issues
- Course development
- Modules
- Module structure
- Providing feedback
- Course material

Training Issues

- Available & convenient
- Site-specific hazard information
- Site/corporate policies and procedures
- Resources



Course Development

8300 management

ES&H coordinator

Electrical safety SMEs

Researcher development teams

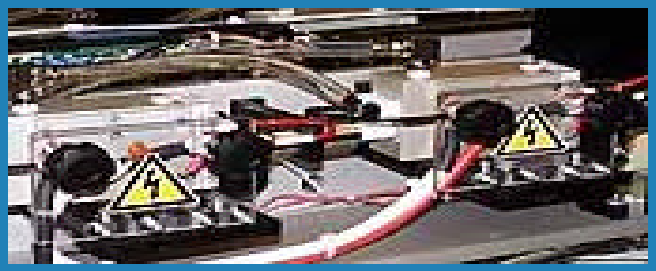
Multimedia and web designers

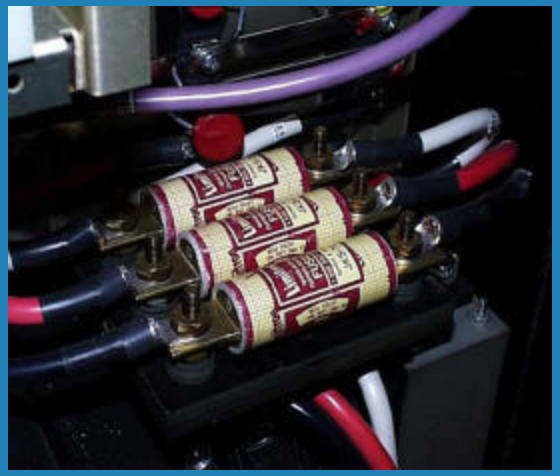
Available & Convenient

- Web-based medium
  - being “out of compliance” is not an issue
  - eliminates enrollment process
  - completion in office
  - personnel select time
  - ability to up-date material as needed
  - course becomes reference material

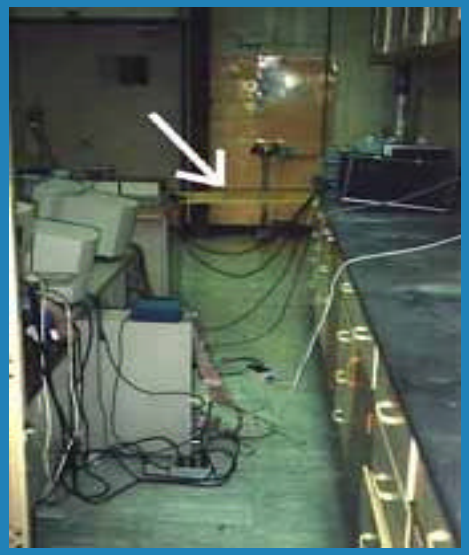
- Module structure
  - personnel choose completion rate
  - ability to “start and stop”

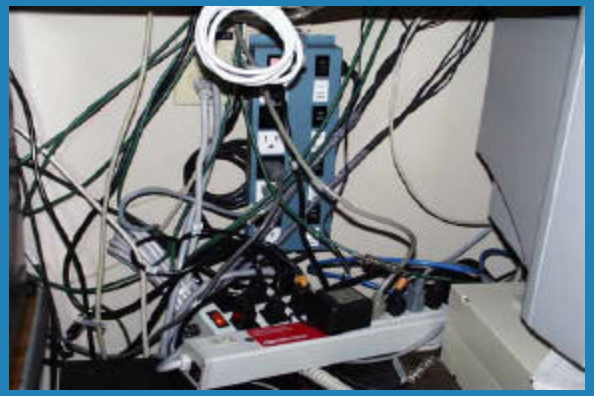
Site-specific hazards





Site-specific hazards



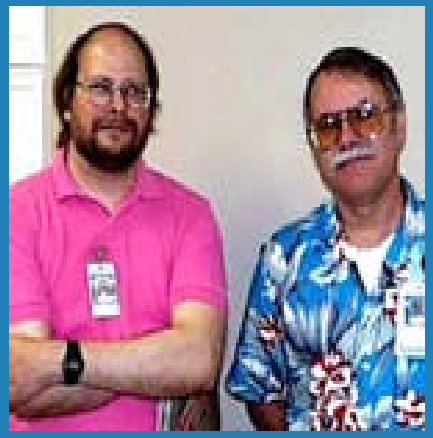


Policies

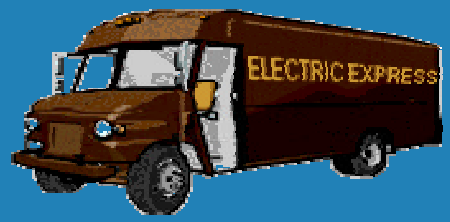
- ☆ Integrated Safety Management System-ISMS
- ☆ Circuit breakers
- ☆ Extension cords and temporary power taps
- ☆ Specific troubleshooting techniques
- ☆ SOP requirements for energized work
- ☆ Shock event

Resources

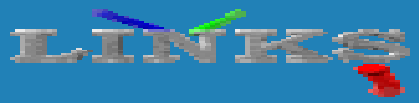
Committee representatives



Supplier information



Hyperlinks



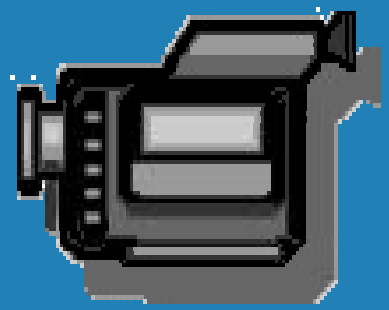
Resources

R&D case histories

Committee bulletins/alerts

Resources

- Video clips
  - basics of electricity
  - electrical incidents
  - hazard identification



  - help fill the instructor “void”
  - always accessible
  - retention rates (50% of what we see and hear)

Modules

ISMS-Integrated Safety Management System
Basic Electrical Safety Principles
Lockout Tagout Awareness
Components
Electrical Distribution Equipment
Water
PPE
Stored Energy
Troubleshooting
Accident Response

Introduction-Resources-Credits

Module Structure

safe work practices

lessons learned/case histories

committee bulletins/alerts

video clips

where to go for help

feedback form

quiz

Providing Feedback

- Feedback email form in each module.

- Evaluation form must be completed to receive course credit.
- Completion certificate will be sent upon receipt of evaluation form.

Electrical Inspection Program (Terry Fogle)

LANL Electrical Safety Program

Terry Fogle
Chief Electrical Safety Officer
Los Alamos National Laboratory

DOE Electrical Safety Meeting
June 22 - 24, 1999

LANL Electrical Safety Program

- History
- Purpose
- Workers affected
- Authority Having Jurisdiction
- Implementation

Recent history of the LANL Electrical Safety Program

- **Electrical Safety Laboratory Implementation Requirements LIR402-600-01.1**
  - **Issued December 24, 1996**
  - **Revised December 18, 1998**
- **Electrical Safety Implementation Guide LIG402-600-01.0**
  - **Issued December 24, 1996**
  - **major revision expected, summer 1999**

Purpose of the Program

- Promote an electrically safe workplace, free from unauthorized exposure to electrical hazards.
- Reduce or eliminate the dangers associated with the use of electrical energy.
- Provide implementation requirements for electrical safety consistent with the Integrated Safety Management five-step process.
- Establish requirements and controls for implementation.
- During all phases of activities:
  - design and construction
  - modification
  - maintenance
  - utilization, including research and development (R&D) activities
  - decontamination and decommissioning of Laboratory facilities and equipment

PURPOSE - cont.

- Complies with applicable OSHA, NFPA, NEC, NESC, ANSI and other established safety standards.
- Establishes the AHJ and AHJ hierarchy of authorities for
  - interpreting these codes
  - approving equipment, assemblies, and materials
  - determining the acceptability of electrical installations.
- Develops responsibilities, and clear lines of authority for the performance of electrical work

WHO does the program affect?

- These electrical safety requirements apply to any individual performing electrical work at the Laboratory
- Including those involved in:
  - design
  - construction
  - maintenance
  - operation
- Of facilities and R&D electrical and electronic systems
- Including expectations for:
  - managers
  - supervisors
  - staff
  - technicians
  - contractors
  - visitors
  - off-site employees

AHJ - The Electrical Safety Committee (ESC)

- **The LANL Electrical Safety Program establishes the Electrical Safety Committee for**
  - **evaluating, updating, and improving electrical safety requirements**
  - **evaluating each Laboratory organization against the stated implementation requirements**
  - **serving as the site-wide AHJ**
  - **providing assistance when there are disputes over electrical safety decisions, clarifications, and interpretations.**

Clear Lines of Authority

LANL AHJ - What does it do?

- Enforce all electrical code requirements
- Clarify electrical code requirements
- Provide advice and consultations on how to meet electrical requirements
- Manage the electrical inspection program
- Issue formal interpretations
- Final technical arbiter on electrical safety issues
- Assure that employees work freely from unmitigated exposure to electrical hazards

LANL Electrical Safety Program - Implementation

- Important terms
- Responsibilities
- Integrated Safety Management
- Unknown electrical hazards
- Training (see Gordon, this meeting)
- Equipment approval process (see Grant, this meeting)
- Safe work practices and documentation
- Electrical hazard classification

Definitions - electrical work

- **electrical work**
  - (1) working on or near energized electrical parts
  - (2) assembly or fabrication of potentially hazardous electrical equipment
  - (3) working with unlisted or unapproved electrical equipment, and/or
  - (4) using listed or approved equipment in a manner not consistent with the listing, or approval.
- **hazardous electrical work** - All electrical operations in which workers may be exposed to an electrical hazard.

Definitions - on/near

- **working on** - Coming in contact with exposed energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment a person is wearing.
- **working near** - Any activity inside the limited approach boundary or the flash protection boundary (see NFPA 70E) of exposed energized electrical conductors or circuit parts that are not put into an electrically safe work condition.

Definitions - two-person rule

- **two-person rule** - The requirement for two qualified electrical workers to be present in the workplace and to be aware of the other worker's task while performing electrically hazardous work. Each worker must:
  - be a qualified electrical worker
  - remain in visual and audible contact with the workers performing the work;
  - be able to disengage an injured worker from the hazard;
  - be trained in cardiopulmonary resuscitation;
  - have a thorough knowledge of the location of shut-down controls and disconnects; and
  - be able to de-energize equipment and alert emergency-rescue personnel

Definitions - safety watch

- **safety watch** - A safety watch is *more stringent* hazard control measure than the two-person rule and shall be implemented when there are grave consequences from a failure to follow safe-work procedures. The safety watch shall be a qualified electrical worker who must be responsible for monitoring qualified worker(s) performing high-hazard electrical work. A safety watch must:
  - have no other duties that preclude continually observing, coaching, and monitoring for potential mistakes;
  - be less than 50 feet from the worker performing the work (where practicable);
  - have a thorough knowledge of the specific working procedures to be followed and the work to be done; and
  - ensure that access to barricaded areas is controlled

Definitions

- **100% Rule**—Work on or near energized parts must be performed only after all participating qualified electrical workers are in 100% agreement on the work to be completed, on the sequence in which it should be performed, and that the hazards are fully controlled or mitigated.
- **compelling reason**—The reason for authorizing workers to perform work on or near hazardous energized electrical circuit parts. The reasons include two types:
  - increased or additional hazards of de-energizing critical systems; and
  - infeasibility due to equipment design or operational limitations (e.g., testing of electric circuits that can only be performed with the circuit energized).

Definitions - state of system

- **energized**—Electrically connected to a source of potential difference, or electrically charged to have a potential significantly different from that of earth in the vicinity. NOTE: "De-energized" parts that have not been verified and locked out and tagged in accordance with established standards are considered energized.
- **de-energized**—Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth. A state in which the conductor or circuit part to be worked on or near has been disconnected from energized parts, locked out and tagged in accordance with established standards, tested/verified to ensure the absence of voltage, and grounded if determined necessary.

Responsibilities of Qualified Electrical and Electronic Workers

- Maintaining qualification
- Participating in the scope of work, hazard analysis, and hazard mitigation techniques
- Participating in the generation, review, and verification of SOPs, SEWPs, and HCPs
- Being aware of and warn others of electrical hazards
- Implementing safe work procedures
- Using PPE

Responsibilities of Qualified Electrical and Electronic Workers - cont.

- Stopping work .....hazardous operation
- Excusing themselves, if lacking competency
- Informing supervisor of any deficiency
- Maintaining copies of documents
- Participating in electrical safety assessments
- Immediately reporting unanticipated incidents
- Reporting electrical injury

Responsibilities of Group Electrical Safety Officers

- Assist in the development and maintenance of up-to-date SOPs, SEWPs, and HCPs
- Review and approve SEWPs
- Provide oversight for electrical safety within their group by conducting periodic and random walk-throughs of their electrical work areas to validate application of safety related work practices;
- Facilitate corrective action and report findings, including stopping work or activity if it does not meet the Laboratory's electrical safety requirements;
- Clarify codes, standards, and regulations, and request interpretations through the Division ESO from the Chief ESO;

Responsibilities of Group Electrical Safety Officers - cont.

- Assist in identifying NRTL listed equipment for purchase, if available;
- Review and approve unlisted equipment;
- Verify that current SOPs, SEWPs, and HCPs are posted at work sites and are provided to the Division ESO;
- Participate in investigations of electrical incidents;
- Coordinate and facilitate safe electrical work at the group level; and
- Maintain an electrically safe workplace by ensuring that electrical reviews are conducted before proceeding with work or experimentation on newly designed or modified equipment and apparatus.
- Disseminate electrical safety information and incident reports to electrical workers.

Integrated Safety Management for Electrical Hazards -

Step 1 - Scope of Electrical Work

Step 2 - Electrical Hazard Assessment

Step 3 - Hazard Mitigation

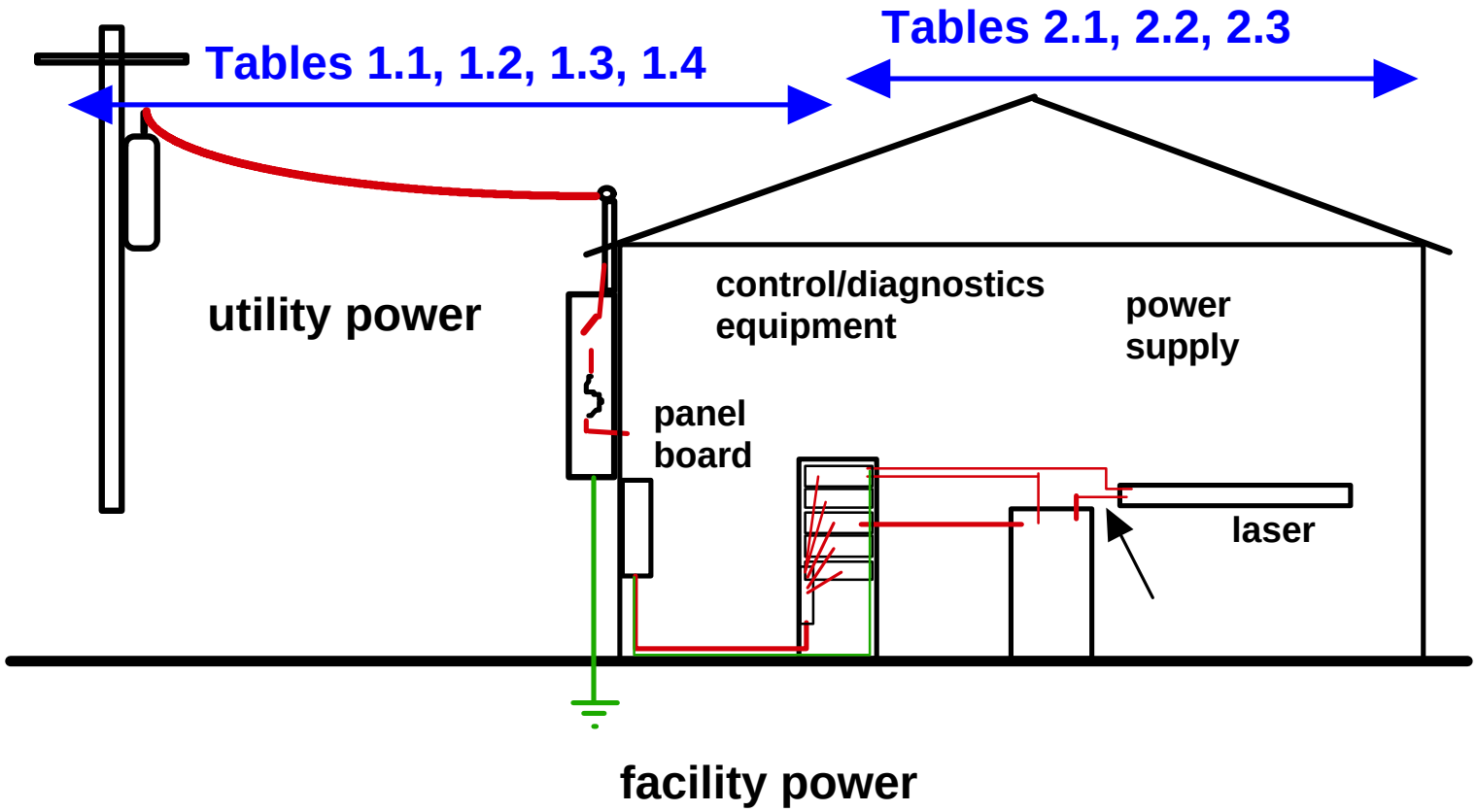
Step 4 - Safe Electrical Work, General Requirements

Step 5 - Electrical Safety Improvement Process

ISM Step 2 - Electrical Hazard Assessment

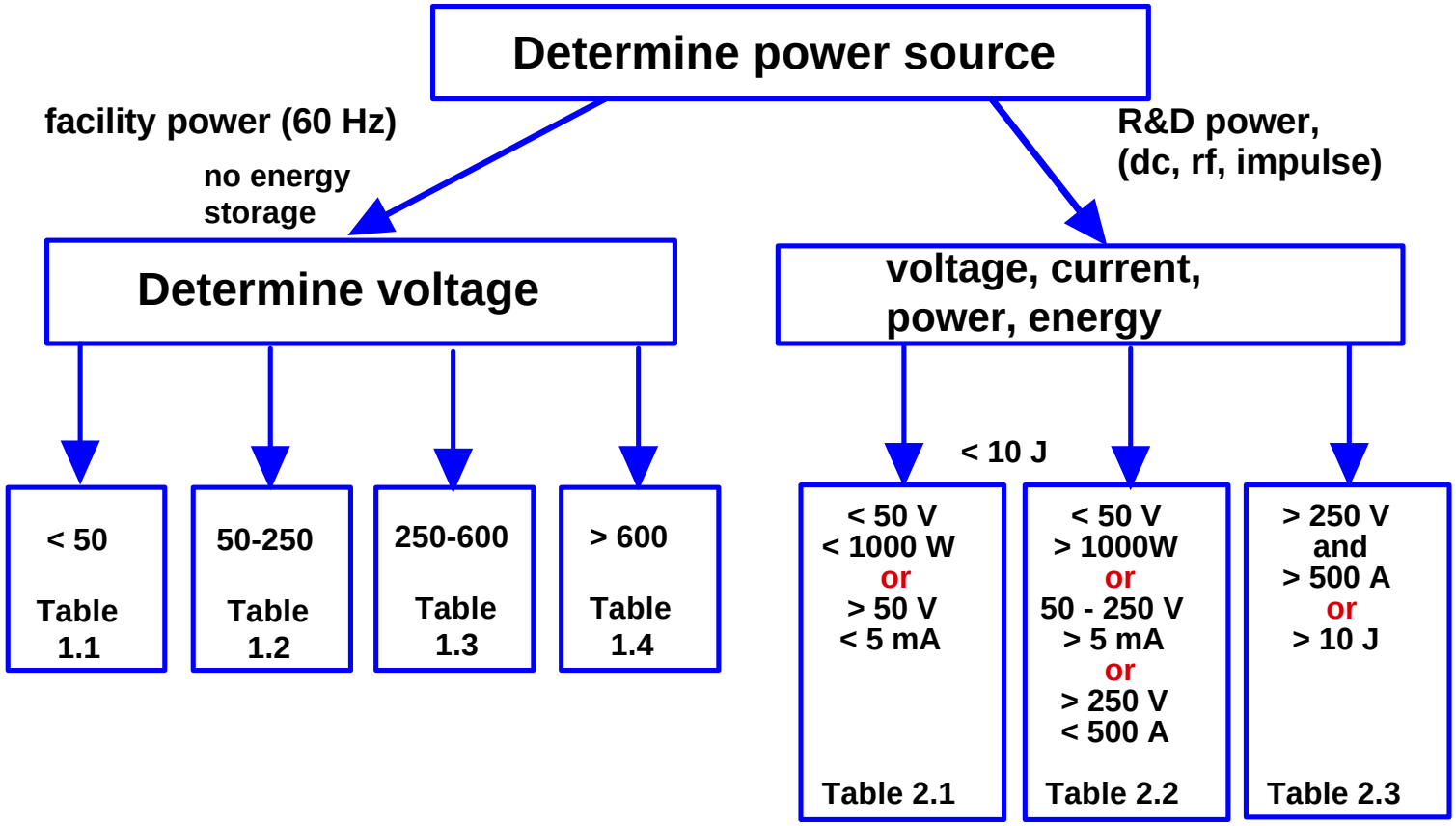
- Classify the hazard based on the potential for injury, use the Hazard Identification Tables in the LIR. There are seven Tables for use:
  - 4 for Facility and Utility Sources
  - 3 for R&D and Electronic Work
- Determine the Mode of Operation
  - Mode 1 - De-energized
  - Mode 2 - Diagnostics and Testing
  - Mode 3 - Energized
- Determine the safe work practices needed, including
  - qualification requirements
  - PPE
  - procedures
  - documentation
  - alone, 2nd person, or safety watch

Electrical Hazard Classification



Approach to Electrical Hazard Classification

see LANL Hazard Classification Tables



Modes of Operation

- **Mode 1 - De-energized**
  - external sources of electrical energy disconnected by some positive action (e.g., lockout/tagout)
  - all internal energy sources rendered safe
- **Mode 2 - Diagnostics and Testing**
  - some or all of the normal protective barriers removed
  - interlocks bypassed
  - measurements, diagnostics, testing, observation
  - no physical moving of conductors and parts near energized conductors
- **Mode 3 - Energized**
  - The physical movement of energized conductors and parts, or
  - moving parts that are near energized conductors
  - some or all of the normal protective barriers removed

ISM Step 3 - Hazard Mitigation

- Hierarchy of Controls
  - 1 - De-energize the circuit, and verify
  - 2 - Engineering controls
    - barriers, insulation, interlocks
  - 3 - Administrative controls
    - work control, warning signs, access control
    - training, SOPs, SEWPs, HCPs, design reviews
  - 4 - Personal Protective Equipment (PPE)
    - safety glasses, protective gloves
- Safe-process and documentation approval
- Work authorization

ISM Step 4 - Safe Electrical Work, General Requirements

- Qualified workers
- The 100% rule
- De-energized electrical work
- Working on or near energized electrical equipment
- Two person rule
- Safety watch
- Personal protective equipment

Unknown electrical hazards (e.g., penetrations).

When an unknown electrical hazard may exist (for example, during penetrations into walls, ceilings, floors, or excavations into masonry surfaces, slabs, ground surfaces, or other structures), the hazard evaluation must include the following steps (appropriate to the job) to determine the presence of energized electrical conductors or circuits:

1. Review historical records, engineering plans, and as-built drawings.
2. Perform a walk-down of the job-site, which must include visually identifying electrical installations and their locations.
3. Confer with the facility or building manager.
4. For excavations as described in AR 1-12, Excavation or Fill Permit Review, obtain a utility location from the Support Services Subcontractor (SSS).
5. Penetrations into walls, floors, and ceilings require a branch circuit locate by the requestor or the SSS if the location of the circuit is not known.
6. Integrate and validate these sources of information and locate, mark, and de-energize electrical circuits and conductors as accurately as possible.

The following controls must be applied:

1. Engineering controls (e.g. relocations, different work methods) must be applied if the presence and location of electrical conductors and circuits cannot be accurately identified and de-energized.
2. Workers doing blind penetration work must wear appropriate voltage-class dielectric gloves with approved protective outer leather gloves, and dielectric mat, along with nonconductive safety glasses.

Training for R&D Safety

- The original "Electrical Safety in the R&D Laboratory" has been replaced by a series of modules
- Advantages of the new courses are:
  - less redundancy for retraining
  - specifically tailored to the worker's needs
  - more specialized training available
  - short, intense modules

Approval of Unlisted Equipment

- Purpose
- OSHA requirements
- NRTLs
- Approval process
- Design guidelines

Documentation

When to use a written procedure. SOPs, SEWPs or HCPs shall be required for work on or near energized and de-energized electrical equipment and systems based on the level of hazard to which the worker is exposed. See the tables in Attachment D and the following requirements:

- Electrical procedures must be based on a thorough analysis of the job and its hazards.
- Repetitive tasks, such as diagnostics and testing of certain classes of equipment, shall be performed under an SOP or HCP that is based on such analyses.
- Changes in scope, process, or equipment that introduce new hazards shall require an update to the existing SOP, SEWP, or HCP and be re-approved and the work reauthorized.

Special Electrical Work Permit (SEWP)

- An SEWP may be used (1) when an operation covered in an SOP has changed or the work goes beyond the scope of what is covered in that document; (2) when infrequent short-duration or one-time operations are planned.
  - Reasonable effort must be made to notify an ESO before starting SEWP-covered work.
  - A copy of all SEWPs must be provided to the Group and Division ESO.
  - An SEWP must be approved by the qualified worker(s) and a qualified supervisor or an ESO, and an authorizer.
  - HCP's may not be used in place of SEWP's for energized work in Tables 1.2, 1.3, 2.2, 2.3 in Attachment D.

Contents of work procedures

- Location of work;
- General summary of work to be performed to include notification of affected personnel before beginning work;
- Equipment to be worked on, including:
  - ratings and a description of electrical hazards
  - abnormalities of the equipment
  - any other hazards associated with the task
- Special protective equipment to be used
- Identification of test equipment to be used and special instructions for safe use
- Special safety requirements or procedures

Contents of work procedures - cont.

- Identification of personnel authorized
- Documentation of the compelling reason why electrical work must be performed energized
- Description of tasks to include any sequence that affect safety
- Approval, by a minimum of three qualified individuals
  - qualified electrical worker
  - approval (supervisor or Electrical Safety Officer
  - authorizer

LANL Presentations at this Meeting

- LANL Electrical Safety Program - Terry Fogle
- Understanding Grounding of Electrical Systems - Mark Regan
- Alternate Grounding Methods - Ernie Garcia
- Approval of Unlisted Electrical Equipment - Grant Guymon
- Designing Safe Electrical Equipment - Terry Fogle
- R&D Electrical Safety - Lloyd Gordon
- Safety Ground Hooks - Lloyd Gordon
- The Effects of Electrical Shock - Lloyd Gordon
- Pulsed Power Safety - Lloyd Gordon

Electrical Hazard Assessment Tables

Introduction

It is not feasible to develop a single set of safety requirements for electrical work that covers every task. The graded-approach in the tables below must be considered in developing an appropriate hazard mitigation. *It shall be the collective responsibility of the qualified worker and the qualified supervisor or group ESO or group leader to ensure that the safeguards for a specific task effectively protect the worker against electrical hazards.* Electrical work at the Laboratory shall be organized into seven classifications, according to the degree of energy present, and three modes, according to the operational status of the equipment or system.

Tables D-1.1 through D-1.4 apply to work on or near facility and utility power systems. Tables D-2.1 through D-2.3 apply to work on or near electronic equipment and R&D systems.

Modes of Operation

Mode 1 De-energized

Working de-energized shall be the preferred work method. All operations shall be conducted in a positively de-energized state. All external sources of electrical energy shall be disconnected by some positive action, for example, with a locked and tagged-out circuit breaker, and all internal energy sources are rendered safe.

Mode 2 (De-Energized to Energized or Diagnostics and Testing)

In Mode 2, operations that involve physically moving conductors and parts, or moving parts that are near energized conductors, shall be conducted with the equipment in the positively de-energized state. When these operations are suspended, measurements, diagnostics, testing, and observation of equipment functions are conducted with the equipment energized and with some or all of the normal protective barriers removed and interlocks bypassed.

An approved SOP, SEWP, or HCP may be required (see individual tables). Authorization by the worker's safety responsible line manager shall be required. Some examples of Mode 2 operations are the following:

- Making voltage measurements with a multimeter on energized components;
- Performing tests while working in close proximity to exposed energized components;
- Following manufacturer's instructions for diagnostics and troubleshooting of energized circuits; and
- Working on experimental facilities that operate in this mode.

Mode 3 (Energized)

Mode 3 operations involve physically moving energized conductors and parts, or moving parts that are near energized conductors, and are conducted with the equipment fully energized and with some or all of the normal protective barriers removed.

Mode 3 work in excess of 50 volts must be treated as an electrical hazard that shall be permitted only when justified by a compelling reason except for 2.1 Class Work. Tasks performed in this mode must be conducted under close supervision and control.

An approved SEWP shall be required, with exceptions as indicated in Tables 1.1 and 2.1. Authorization by the worker's safety responsible line manager shall be required.

Table D-1.1:
Requirements for Facility and Utility Sources—Less than 50 Volts

NOTE: *Work on or near energized electrical equipment is only performed by qualified electricians or other qualified electrical workers.*

Class 1.1[a]	Voltage [b]and Capacity	Hazard	Remarks
	less than 50 V and less than 1000 W	Burn	Low-voltage control circuits
Mode 1: De-energized and Checked	• A qualified person may work alone if all other work hazards have been assessed and mitigated. • SOP, SEWP, or HCP is optional.		
Mode 2: Diagnostics and Testing	• A qualified person may work alone if all other work hazards have been assessed and mitigated. • SOP, SEWP, or HCP is optional.		
Mode 3: Energized	• A qualified person may work alone if all other work hazards have been assessed and mitigated. • SOP, SEWP, or HCP is optional.		

[a] Class 1.1 does not include stored energy. (See Table D-2.1.)

[b] Voltage is line-to-ground or line-to-line, whichever is higher.

Table D-1.2:
Requirements for Facility and Utility Sources—Less than 250 Volts

NOTE: *Work on or near energized electrical equipment is only performed by qualified electricians or other qualified electrical workers.*

Class 1.2	Voltage [a] and Capacity	Hazard	Remarks
	50 V to 250 V	Shock, burn, and arc blast	Low power utility
	or less than 50 V **and** greater than 1000 W	Burn	Low voltage, high current
Mode 1: De-energized and checked	• A qualified person may work alone if all other work hazards have been assessed and mitigated. • SOP, SEWP, or HCP is optional.		
Mode 2: Diagnostics and Testing	• A qualified person may work alone if all other work hazards have been assessed and mitigated. • Eye protection, insulation gloves, insulated tools, and other insulating personal protective equipment, as appropriate to the task, shall be required. • Worker may move probes to various contact points while energized. • SOP, SEWP, or HCP is required.		
Mode 3: Energized	The two-person rule must be used. • Eye protection, insulated gloves, insulated tools, and other insulating personal protective equipment, as appropriate to the task, shall be required. • An SEWP shall be required for all work, and compelling reasons identified or an SOP with authorization of each individual job. • Access must be restricted by ropes, barriers, or other means to exclude unauthorized personnel.		

[a] Voltage is line-to-ground or line-to-line, whichever is higher.

Table D-1.3:
Requirements for Facility and Utility Sources—250 to 600 Volts

NOTE: *Work on or near energized electrical equipment is only performed by qualified electricians or other qualified electrical workers.*

Class 1.3	Voltage [a]	Hazard	Remarks
	250 V to 600 V	Shock, burn, and arc blast	Medium-power utility (less than 600 V)
Mode 1: De-energized and checked	• The two-person rule shall be used until it has been verified that the equipment has been de-energized. Then, one qualified person may work alone. • SOP, SEWP or HCP is optional.		
Mode 2: Diagnostics and Testing	• While equipment is energized, the two-person rule shall be used throughout the Mode 2 operation. • Eye protection, insulated gloves, insulated tools, and other insulating personal protection equipment, as appropriate to the task, shall be used. • Worker may move probes to various contact points while equipment is energized. • SOP, SEWP, or HCP is required.		
Mode 3: Energized	• At least two qualified workers shall be required. One shall be a safety watch, stationed outside normal protective barriers and in continuous sight and sound communication with the worker(s). • Eye protection, insulated gloves, insulated tools, and other insulating personal protective equipment, as appropriate to the task, shall be used. • An SEWP shall be required for all work, and the compelling reasons shall be identified or an SOP with authorization of each individual job. • Access must be restricted by ropes, barriers, or other means to exclude unauthorized personnel.		

[a] Voltage is line-to-ground or line-to-line, whichever is higher.

Table D-1.4 Requirements for Facility and Utility Sources – Greater Than 600 Volts

NOTE: *Work on or near energized electrical equipment is only performed by qualified linemen.*

Class 1.4	Voltage [a]	Hazard	Remarks
	Greater than 600 V	Shock, burn, and arc blast	High-power utility

Mode 1: De-energized and checked	• The two-person rule shall be used until it has been verified that the equipment has been de-energized. Then, one qualified worker may work alone. • Eye protection, insulated gloves, insulated tools, and other insulating personal protective equipment, as appropriate to the task, shall be used. • SOP or SEWP shall be required to de-energize equipment. • Only support services subcontractor or commercial power utility personnel or their subcontractors shall work on or near Class 1.4 equipment.
Mode 2: Diagnostics and Testing	• At least two qualified persons shall be required. One shall be a safety watch standing clear of the electrical hazard and within continuous sight and sound communication with the worker(s). The safety watch must not be distracted from this assignment at any time. • Eye protection, insulated gloves, insulated tools, and other insulating personal protective equipment, as appropriate to the task, shall be used. • SOP or SEWP shall be required. • Only support services subcontractor or commercial power utility personnel or their subcontractors shall work on or near Class 1.4 equipment.
Mode 3: Energized	• At least two qualified persons are required. One is a safety watch, standing clear of the electrical hazard and within continuous sight and sound communication with the worker(s). The safety watch must not be distracted from this assignment at any time. • Eye protection, insulated gloves, insulated tools, and other insulating personal protective equipment, as appropriate to the task, shall be used. • SOP or SEWP shall be required, and the compelling reason shall be identified. • Only the support services subcontractor or commercial power utility personnel or their subcontractors shall work on or near energized Class 1.4 equipment. • Access must be restricted by ropes, barriers, or other means to exclude unauthorized personnel.
[a] Voltage is line-to-ground or line-to-line, whichever is higher.	

LANL UC personnel must not work on or near Class 1.4 equipment except as specified in Section 7.7.2.

Table D-2.1:
Requirements for R&D and Electronic Work—

NOTE: *Work on or near exposed energized electrical equipment is normally performed by qualified R&D workers or electronic technicians.*

Class 2.1	Voltage [a] and Capacity	Hazard	Remarks
	Voltage less than 50 V and power less than 1000 W	Burn	Low voltage, low power
	or voltage greater than 50 V and current less than 5 mA	Reflex action	High voltage, very low current
	and stored energy less than 10 J[b]	Reflex action	Low stored energy
Mode 1: De-energized and checked	• A qualified person may work alone if all other work hazards have been assessed and mitigated. • SOP, SEWP, or HCP is optional.		
Mode 2: Diagnostics and Testing	• A qualified person may work alone if all other work hazards have been assessed and mitigated. • SOP, SEWP, or HCP is optional. • Care shall be taken to address the secondary hazard (reflex action) and adequate clearances.		
Mode 3: Energized	• A qualified person may work alone if all other work hazards have been assessed and mitigated. • SOP, SEWP, or HCP is optional. • Care shall be taken to address the secondary hazard (reflex action) and adequate clearances.		

[a] Voltage is line-to-ground or line-to-line, whichever is higher.

[b] Where the energy can be delivered to the body in less than one second.

Table D-2.2:
Requirements for R&D and Electronic Work—

NOTE: *Work on or near exposed energized electrical equipment is normally performed by qualified R&D workers or electronic technicians.*

Class 2.2	Voltage [a] and Capacity	Hazard	Remarks
	Voltage less than 50 V and power greater than 1000 W	Burn	Low voltage, high current
	or voltage from 50 V to 250 V and current greater than 5 mA	Shock and burn	Medium-to-high voltage, medium current
	or voltage greater than 250 V and current less than 500 A	Shock and burn	Medium-to-high voltage, medium current
	and stored energy less than 10 J[b]	Reflex action	Low stored energy
Mode 1: De-energized and checked	• A qualified person may work alone if all other work hazards have been assessed and mitigated. • SOP, SEWP, or HCP is optional.		
Mode 2: Diagnostics and Testing	• The two-person rule shall be required. • Eye protection, insulated gloves, insulated tools, and other insulating personal protective equipment shall be used in accordance with the SOP, SEWP, or HCP. • Worker may move probes to various contact points while the equipment is energized. • An SOP, SEWP, or HCP shall be required.		
Mode 3: Energized	• The two-person rule shall be required. • Eye protection, insulated gloves, insulated tools, and other insulating personal protective equipment shall be used in accordance with an SEWP. • An SEWP shall be required for all work, and the compelling reasons shall be identified. • Access must be restricted by ropes, barriers, or other means to exclude unauthorized personnel.		

[a] Voltage is line-to-ground or line-to-line, whichever is higher.

[b] Where the energy can be delivered to the body in less than one second.

Table D-2.3:
Requirements for R&D and Electronic Work—

NOTE: *Work on or near exposed energized electrical equipment is normally performed by qualified R&D workers or electronic technicians.*

Class 2.3	**Voltage [a] and Capacity**	**Hazard[b]**	**Remarks**
	Voltage greater than 250 V and current > 500 A	Shock, burn, and arc blast	High voltage, high current, and high energy
	or stored energy greater than 10 J[c]	Shock and burn	High voltage, high current, and high energy
Mode 1: De-energized and checked	• The two-person rule shall be used until it has been clearly verified that the equipment has been de-energized. Then, one qualified worker may work alone. • Eye protection, insulated gloves, insulated tools, and other insulating personal protective equipment, as appropriate to the task, shall be required. • SOP, SEWP, or HCP shall be used.		
Mode 2: Diagnostics and Testing	• At least two qualified persons shall be required. One shall be a safety watch standing clear of the electrical hazard and within continuous sight and sound communication with the worker(s). The safety watch must not be distracted from this assignment at any time. • Eye protection, insulated gloves, insulated tools, and other insulating personal protective equipment shall be used in accordance with the SOP, SEWP, or HCP. • Workers shall not move probes to various contact points while the equipment is energized above 600V. • SOP, SEWP, or HCP is required.		
Mode 3: Energized	• At least two qualified persons shall be required. One shall be a safety watch standing clear of the electrical hazard and within continuous sight and sound communication with the worker(s). The safety watch must not be distracted from this assignment at any time. • Eye protection, insulated gloves, insulated tools, and other insulating personal protective equipment shall be used in accordance with the SEWP. • An SEWP shall be required for all work, and the compelling reason shall be identified. • Access must be restricted by ropes, barriers, or other means to exclude unauthorized personnel.		

[a] Voltage is line-to-ground or line-to-line, whichever is higher.
[b] Most high-voltage, high-energy, high-power, Class 2.3 circuits and equipment should never be worked on while energized.
[c] Where the energy can be delivered to the body in less than one second.

Idaho Fatality (Jake Jacobson)

A video about the Idaho fatality was shown and more details can be found at:
http://www.tis.eh.doe.gov/oversight/acc_inv/ineelaillntro.pdf

Alternate Methods to Meet NEC Requirements (Ernie Garcia)

Alternate Grounding Methods

Ernest S. Garcia
Lead Electrical Construction Inspector
Los Alamos National Laboratory

DOE Electrical Safety Meeting
June 24, 1999

Code Requirements

- Recognized Codes
  - NEC- National Electrical Code NFPA-70
    - Non-Utility Premises Wiring
    - Specifies Installation Guidelines
  - NESC- National Electrical Safety Code
    - Utility Wiring
    - Specifies Electrical Safety Guidelines

The need for alternate methods

- Unusual situations

  Building with no metal raceways (non-ferrous conduit required because of magnetic research)
- R&D applications

  Numerous types of unique power systems
- Special needs

  Noise limiting grounding

  Isolated grounding

Benefits of allowing alternate methods

- Develop better working relationships-

  R&D, Craft workers, Facility personnel, Code enforcing agency
- Work towards a common goal

  Meet Specific Research Needs

  Satisfy Electrical Safety Requirements
- Results - Safer Workplace and fewer accidents

NEC Requirements - Purpose

- Main purpose - Practical safeguarding of <u>persons</u> and <u>property</u> from hazards arising from the use of electricity
- Adequacy - Compliance results in an installation that is essentially free from hazard but not necessarily efficient, convenient, adequate for future expansion, or adequate to meet specific R&D needs

NEC Requirements - Enforcement

NEC Article 90-4

The authority having jurisdiction may waive specific requirements in the Code, or permit alternate methods where it is assured that equivalent safety objectives can be met.

NESC Requirements

NESC Section 013. Application

- These rules shall apply to all new installations and extensions
- They may be waived or modified by the authority having jurisdiction - AHJ
- When so waived, safety shall be provided in other ways

Los Alamos National Laboratory Requirements

Alternate methods to the NEC & NESC

- Alternate methods provide a level of safety equivalent to the original requirement
- The requesting division, program, or group will initiate the Request for an Alternate Method - Attachment C
- The Chief ESO has been delegated the authority to review and approve Alternate Methods

Achieving equivalent safety

- Important to understand that equivalent safety must be maintained
- Reduces electrical accidents due to inadequate grounding methods
- Complies with all applicable codes
- Standardizes grounding installations by meeting requirements

Requirements for approval contained in Attachment C

- Description of Alternate Method
- Justification/The reason compliance cannot be achieved
- Compensatory Measures/Alternate methods used to reduce risk
- Assessment of residual risk, compared with the risk if full compliance were achieved

Common problems

- Connectors and fittings - not listed or suitable for the type of grounding installation
- Incompatible materials - problems with galvanic action, expansion & contraction
- Sizing for fault conditions - grounding conductor must be capable of carrying available current during fault condition - NEC tables 250-66 & 250-122

Reasons for grounding problems

- Knowledge of acceptable grounding methods - must be <u>qualified installer</u>
- Confusion with different methods of installation - jurisdictional requirements
- Unusual applications requiring special needs - R&D, High frequencies, etc.
- Separate grounding points being established for each system - results in isolated systems

Research & Development Example

- Low Energy Demonstration Accelerator
  Mobile rack assembly on tracks required
  flexible utility connections in tunnel
  Requirement for grounding electrode conductor connection to three transformers satisfied by using a copper plate anchored to the floor. Connections could be relocated easily

LEDA example

Equipotential Grounding

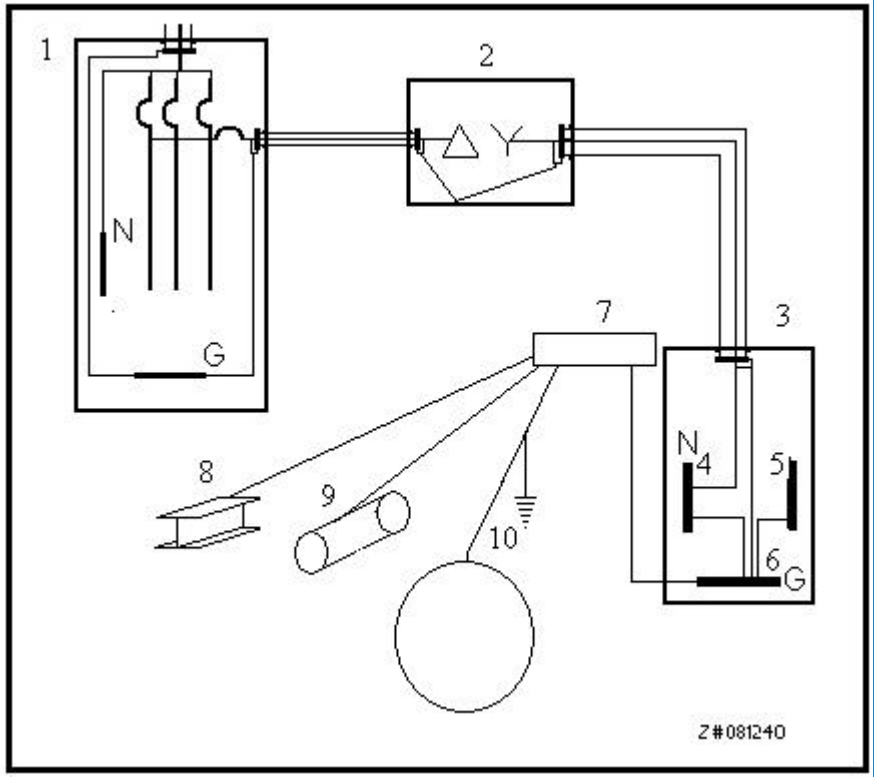
- Purpose - bonding all adjacent conductive equipment, structures, or surfaces to the electrical grounding system to prevent a difference in voltage from developing within the plane
- An example of this would be in the livestock industry. Rebar and wire mesh in the concrete are also bonded to the grounding electrode system

Isolated equipment grounding

- Purpose - to reduce electrical noise (electromagnetic interference)
- Term does not allow for complete isolation between equipment, and the building grounding system
- The isolated grounding conductor may be terminated in the main service disconnecting means

Isolated Grounding Schemes

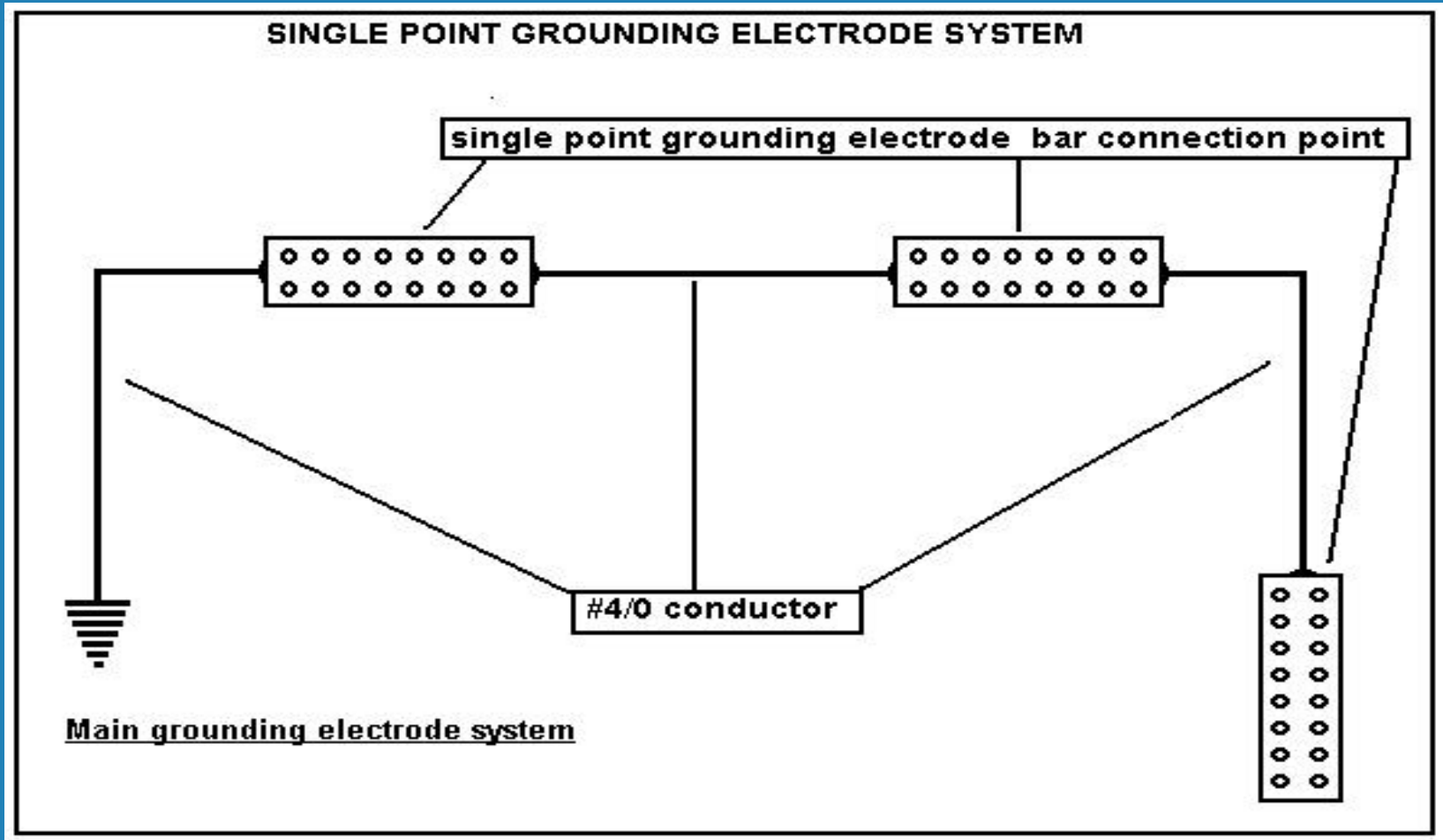
1. 480/277 Volt panel
2. Transformer
3. Computer Panel
4. Neutral Bar
5. Isolated Ground Bar
6. Ground Bar
7. Electrode Ground Bar
8. Building Steel
9. Water Piping System
10. Supplemental Ground



LANL required grounding schemes Single point grounding

- Impedance and ground resistance tests may be performed on the entire grounding electrode system or the individual components during routine maintenance
- Connections to the grounding system can be accomplished without interrupting power to other systems
- Allows for connection to the grounding system for R&D applications

Single Point Grounding Diagram



Just the Start to correcting grounding deficiencies

- Return to facilities, identify and correct grounding problems using alternate methods if needed
- Work together to develop satisfactory solutions
- Maintain contact to provide assistance in determining equivalent safety solutions by comparing similar situations

Address/Phone numbers

- Ernest S. Garcia
- Los Alamos National Laboratory
  P.O. Box 1663 Mail Stop K403
  Los Alamos, N.M. 87545
- garcia_sisto_e@lanl.gov
- Phone number: (505) 667-1069
- Fax number: (505) 665-7384

REQUEST for ALTERNATE METHOD to NEC/NESC

(This form from LANL document LIR 402-600-01, Electrical Safety, 12/18/98)

Date Submitted _____

1. Group, Division or Program requesting the alternate method. _____

2. Group, Division or Program point of contact / telephone / e-mail _____
   _____

3. Alternate Method to NEC and NESC (Number / Page / Paragraph):
   _____

4. Description of Alternate Method:
   _____
   _____
   _____
   _____

5. Justification / The reason compliance cannot be achieved:
   _____
   _____
   _____
   _____

6. Compensatory Measures / Alternate methods used to reduce or control the risk:
   _____
   _____
   _____
   _____

7. Assessment of the Residual Risk, compared with the risk if full compliance were achieved:
   _____
   _____
   _____

8. Alternate Method: ❑ Approved ❑ Denied

9. Signatures (for the Authority Having Jurisdiction):

   _____
   Signature and Date

   _____
   Chief Electrical Safety Officer (printed)

Submit to: Chief ESO
MS K403

Los Alamos, NM 87545

Form 1783, SEWP-1 (10-98) LIR 402-600-01.0 (ESH-5, OIC)

Applied Integration Principles to Electrical Construction Safety (Bryan Drennan)

Applying ISM Principles to Electrical Construction Through Owner Involvement

Sandia National Laboratories
Albuquerque, New Mexico

C. Bryan Drennan

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy under contract DE-AC04-94AL85000.

Owner Involvement in Construction

The Owner:

Sandia Corporation - operates Sandia National Laboratories under an O&M agreement for the Department of Energy

~ $60M in construction annually

- ***Line item projects***
- ***Customer funded***
- ***Operations and Maintenance***
- ***D&D***

Sandia National Laboratories

Owner Involvement in Construction

Why ?

- DOE directives and orders
- Multiple hazards
- Owner involvement in <u>all</u> phases of construction projects yields positive results
  - Zero fatalities, injury rates < 1/2 national average
  - Improved working relationships with contractors, community, and the DOE

Sandia National Laboratories

Owner Involvement in Construction

How are we involved?

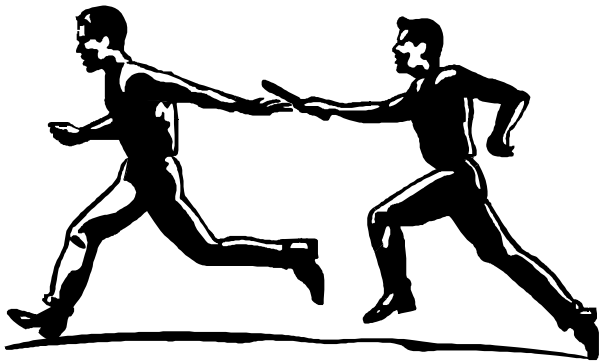
Through Integrated Safety Management using:

- ES&H support teams
- Hazard evaluations
- Contractual requirements
- Construction oversight
- Training / includes contractor staff

Sandia National Laboratories

Owner Involvement in Construction

Integrated Safety Management - a systems approach to safety



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Owner Involvement in Construction

Integrated Safety Management

- ES&H support team has opportunity to review project scope with design engineers
- Risk based approach based on project location and complexity

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Owner Involvement in Construction

Integrated Safety Management

- **Hazard evaluation process**
  - ***Safe work practices***
  - ***PPE Recommendations***
  - ***Restrictions / ES&H support***
- **Communication through contract documents**

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Owner Involvement in Construction

Integrated Safety Management

- Hazards designed out of project
- Engineering controls
- Hazard Abatement
- Administrative controls/ training
- Contract disclosure

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Owner Involvement in Construction

Integrated Safety Management

- Site specific safety plan
- Q/A Inspection
- Contract Requirements
- Permits
  - *digging , hot work, confined space*
- Data collection

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Owner Involvement in Construction

Integrated Safety Management

- Audit findings discussed w/ contractor
- In-house training w/ emphasis on trends
- Contractor performance data used for future contract evaluations

Sandia National Laboratories

Owner Involvement in Construction

Are there benefits ?

- Proactive hazard identification, disclosure, and control improves schedule
- Designers have tools to make informed decisions regarding cost
- Contract workers are better informed and work with greater efficiency
- Overall costs to corporation are reduced, liability reduced - *due diligence*

Sandia National Laboratories

Approval of Unlisted Equipment (Grant Guymon)

APPROVAL of UNLISTED ELECTRICAL EQUIPMENT

Grant Guymon
Electrical Inspector
Los Alamos National Laboratory

DOE Electrical Safety Meeting
June 24, 1999

What Are The Requirements?

"CONDUCTORS AND EQUIPMENT SHALL BE APPROVED".

- Occupational Safety and Health Standards (OSHA) 29CFR 1910.303(b)
- National Electrical Code (NEC) Article 110-2, 3(a)

The Standards Say…

OSHA:

Electrical equipment shall be free from recognized hazards that are likely to cause death or serious physical harm to employees.

NEC:

The conductors and equipment required or permitted by this code shall be acceptable only if approved.

Who Is Required to Approve Equipment?

- If your facility has contract language stipulating conformance with OSHA, or the NEC then your management is required to have unlisted equipment approved prior to use.
- Your facility may have a DOE order covering unlisted equipment approval.

What Type of Approval Program?

- The program should be based on the published requirements,
- You can tailor the program to fit your facility needs,
- Suggestions to improve this program are welcome. This process is new to most of us.

What Subject Matter Expertise Is Needed to Approve Equipment ?

- Nationally recognized testing laboratory training to assist your personnel in learning equipment approval procedures,
- Training in the use and interpretation of the NEC,
- LANL has developed a training program directed primarily toward R&D people.

Who Should Be an Equipment Approver?

Only electrically qualified personnel should be involved in the equipment approval process. Typically these would include electrical engineers, electrical inspectors, electrical technicians, electricians and researchers.

Specific Qualifications Include:

Knowledge, experience and understanding of electrical hazards and the design requirements necessary to mitigate these hazards.

Definitions

- AHJ--authority having jurisdiction
- Approved Equipment-- listed equipment, or equipment that is acceptable to the authority having jurisdiction (AHJ).
- NEC--National Electrical Code
- NRTL--Nationally Recognized Testing Laboratory

Definitions…cont.

- Listed Equipment--equipment that has met NRTL standards.
- OSHA--Occupational Safety and Health Administration
- Unlisted/Unapproved Equipment--electrical equipment that has not been approved by an NRTL <u>or</u> the AHJ.

“Listed” Equipment Is Normally Approved

- Some familiar listing organizations
  - UL--Underwriters Laboratories
  - ITS--Intertek Testing Services NA Inc.
  - FM--Factory Mutual Research Corporation
  - CSA--Canadian Standards Association
  - ETI--Electro-Test, Inc.
  - More symbols follow….

Nationally Recognized Testing Laboratories

NOTE: ALL NRTL's must be OSHA certified!

- Applied Research Laboratories (ARL)
- Canadian Standards Association (CSA)

NRTL's Cont…

- Communication Certification Laboratory (CCL)
- Detroit Testing Laboratory, Inc. (DTL)
- Electro-Test, Inc. (ETI)

NRTL's Cont...

- Entela, Inc. (ENT)
- Factory Mutual Research Corp. (FMRC)
- TUV Rheinland of North America, Inc. (TUV)

NRTL's Cont...

- Intertek Testing Services NA, Inc. (ITS)
- MET Laboratories, Inc. (MET)
- Southwest Research Institute (SWRI)

NRTL's Cont…

- Underwriters Laboratories (UL)
- Wyle Laboratories (WL)

Unlisted Electrical Equipment That is Normally Easy to Approve:

- Most transformers built by a nationally recognized manufacturer,
- Certain reputable test equipment, such as scopes , meters and power supplies,
- The approval process would be primarily focused on making sure the equipment was not damaged in shipment.

What Equipment Requires Approval?

- ALL unlisted, site built, site repaired or site modified electrical equipment that could pose a hazard,
- Any other equipment that the AHJ requires,
- Unlisted purchased equipment.

Older Unlisted Equipment

Your electrical safety AHJ may elect to "grandfather" certain older equipment that has been in continuous service if the equipment has not been involved in any accidents, and has been determined to be safe for use.

How Can You Avoid Approval Problems?

- Require that, when available, only listed equipment be purchased,
- Include listing requirements in specifications,
- Purchasing departments and vendors will need to be notified.

Major Consideration

You will be approving equipment for its intended use. You will not be approving equipment for mass production or public use. You will have a certain latitude in your approval process. You may have approach distances, isolation or other restrictions incorporated in your approval. The goal is safety of persons and property.

Equipment Approval Checklist

- The following eight item checklist, based on OSHA and the NEC, can be used to approve or disapprove unlisted equipment.
- *A copy of the entire checklist is included in your materials.*

#1 Suitability for Installation and Use in Conformity With 29 CFR 1910 And/or the NEC.

- Potential considerations of suitability…
  - Temperature, humidity, altitude, normal and abnormal use, average and peak power, etc,
  - Proper equipment grounding,
  - Properly sized overcurrent protection.

#2 Mechanical Strength and Durability.

- Considerations include enclosure of parts to:
  - Prevent damage,
  - Contain arcing, heating and explosion,
  - Prevent injury to personnel.

#3 Wire Bending and Connection Space.

- Includes consideration of assembly and potential repair, based on:
  - The protection of conductors and their insulation against damage by over bending, over crowding, location near moving parts in equipment and at termination points.

#4 Electrical Insulation.

- Insulation integrity is paramount to assure the system:
  - Is free from short circuits,
  - Uses listed conductors where possible,
  - Is free from grounds other than required,

  (This may require “megger” testing of the conductors).

#5 Heating Effects Under Normal & Abnormal Conditions.

- Conductors must be installed and used in such a manner that normal listed or approved temperature ratings are not exceeded. R&D requirements may necessitate special consideration.

#6 Arcing Effects.

- Appropriate requirements for arcing effects include:
  - If ordinary operation produces arcs, sparks, flames or molten metal, it shall be enclosed, (the enclosure could be an access controlled room).

#7 Classification by Type, Size, Voltage/Current Capacity and Use.

- A permanent label shall be attached that includes the following:
  - Manufacturer or local builders name,
  - Equipment voltage, current, power and any other wording necessary for the safe operation of the equipment.

Sample Tag

LANL electrical safety approval

Division / group _____

ESO _____ date _____

Approved for the intended use only within the

Approving organization.

#8 Other Factors That Contribute to The Safety of Persons…

- Other factors include:
  - Non-electrical hazard review,
  - Live part guarding,
  - Separation of low voltage components,
  - Use of listed components,
  - Proper color coding (grounded and grounding conductors).

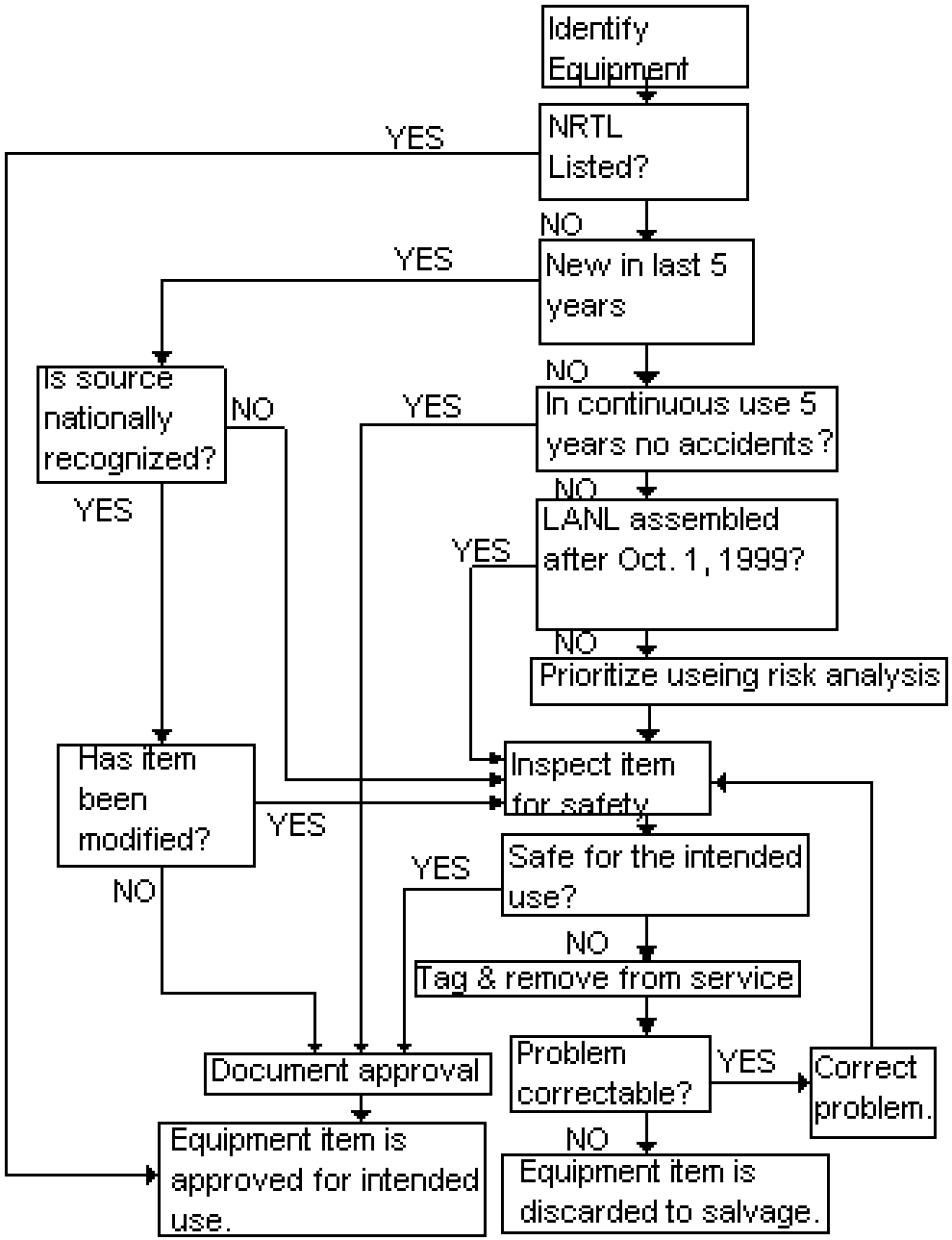
Approval Records

- Documentation of approved equipment should include:
  - Design specifications,
  - Intended use statement,
  - Disposal requirement,
  - Modification statement,
  - Required reevaluation.

Equipment Approval Flow Chart

- A sample flow chart has been included in your handout materials,
- It is not as hard as it looks.

PROCESS FOR APPROVAL OF UNLISTED EQUIPMENT



Suggestions to Approvers

- *An approver is doing the work normally completed by an NRTL, for mass market electrical products,*
- *Most complex approvals will require a "team effort",*
- *Suggest thorough peer review of any site built equipment.*

Impossible Task? NO!

- Equipment approval will require:
  - Management commitment, (In response to ESO concerns senior management has restated the commitment to accomplish equipment approval)
  - Training,
  - Teamwork,
  - A working knowledge of the requirements,
  - A major time investment.

Conclusion

- If you accept the responsibility of approving unlisted electrical equipment please remember:

You are approving equipment that is going to be used by your co-workers.

There are lives at stake!

CHECKLIST for APPROVAL OF UNLISTED EQUIPMENT for INTENDED USE

DRAFT February 17, 1999

SECTION 1: OSHA/NEC Electrical Equipment Approval Checklist

DATE:

LOS ALAMOS NATIONAL LABORATORY	
ELECTRICAL SAFETY APPROVAL	
EQUIPMENT ID. #	
DIVISION:	GROUP:
DATE:	ESO:
APPROVED FOR INTENDED USE WITHIN APPROVING ORGANIZATION ONLY. *REFER TO LIR 402-600-01*	

Electrical equipment shall be free from recognized hazards that are likely to cause death or serious physical harm to employees. (29 CFR 1910.303 (b)) IN JUDGING EQUIPMENT, CONSIDERATIONS SUCH AS THE FOLLOWING SHALL BE EVALUATED. (NEC 110-3 (a)) See Sheets 2 & 3 for instructions to complete items 1 through 8 below.

		Inspected (Check Box)
1	Suitability for installation and use in conformity with 29 CFR 1910 Subpart S and/or the NEC.	
2	Mechanical strength and durability, including for parts designed to enclose and protect other equipment, the adequacy of the protection thus provided.	
3	Wire bending and connection space.	
4	Electrical insulation.	
5	Heating effects under normal conditions of use and also under abnormal conditions likely to arise in service.	
6	Arcing effects.	
7	Classification by type, size, voltage, current capacity, and specific use.	
8	Other factors that contribute to the practical safeguarding of persons using or likely to come in contact with the equipment, including non-electrical considerations and hazards.	

NOTE: APPROVED EQUIPMENT SHALL BE INSTALLED AND USED IN ACCORDANCE WITH THE INSTRUCTIONS PROVIDED BY THE DESIGNER/BUILDER OR ESO.

Comments: (Include all designer/builder instructions, restrictions on use, drawings or information that is relevant to the
safe installation and use of this equipment. Attach additional sheets as necessary.)

This equipment is approved for installation or use at LANL. IF THIS EQUIPMENT IS MODIFIED, RELOCATED, DAMAGED, REPAIRED OR UTILIZED FOR OTHER THAN THE INTENDED USE STATED ABOVE, THIS APPROVAL IS VOID, PENDING RE-EXAMINATION.

Date:	**ESO Printed Name:**	**ESO Signature:**

This equipment is rejected for use at LANL. (See comments above.)

Date:	**ESO Printed Name:**	**ESO Signature:**

SECTION 1: OSHA/NEC Electrical Equipment Approval Checklist

Practical description of approval items 1 through 8.

Item 1: Some potential considerations of suitability for installation and use are:

- Operation, considering the environmental conditions:
  a) Temperature, humidity, air pressure, non ionizing radiation (RF & EMI), ionizing radiation, outdoor/indoor, etc.
  b) Normal and abnormal use, considering duty cycle, average and peak power, etc.
- Properly sized and installed equipment grounding (chassis grounding).
- Equipment design that includes consideration of the available short circuit and ground fault current.
- Properly sized and installed overcurrent protection (fuses or circuit breakers).
- Separation of high and low voltage components, especially where high voltage could escape along a hidden fault path.

See 1999 NEC 250-110, & 110-9.

Item 2: Mechanical strength and durability considerations include:

- Enclosure of parts to:
  a) Prevent damage to internal components during use and transportation.
  b) Contain arcing, heating, and explosion.
  c) Prevent injury to personnel from hazardous energized parts.
  d) Prevent damage to internal components from environmental conditions.
- Workmanship. Unused openings being effectively closed.
- Integrity of electrical equipment and connections.
- Any item that would adversely affect the safe operation or mechanical strength of the equipment, such as damaged, corroded, or overheated parts.

See 1999 NEC 110-12.

Item 3: Wire bending and connection space includes consideration of assembly and potential repair, based on:

- The protection of conductors and their insulation against damage by over bending, over crowding, location near moving parts in equipment and at termination points.

See 1999 NEC 373-6 and tables 373-6(a) & (b).

Item 4: The integrity of insulation is paramount to assure the system:

- Prevents the escape/transfer of electrical energy to other conductors and to personnel.
- Is free from short circuits or potential short circuits.
- Uses listed conductors where possible.
- Is free from grounds other than as required or permitted by Article 250.

As a general rule, the ESO will require visual examination or insulation testing prior to acceptance.
See 1999 NEC 110-7

Item 5: Conductors must be installed and used in such a manner that normal listed or approved temperature ratings are not exceeded, unless a special SME determination is made that the conditions of use in the R&D environment is substantially different and that an appropriate level of safety is maintained. Also, the temperature of exposed parts will not cause burns to personnel or initiate fires.
See 1999 NEC 310-10 including the Fine Print Note.

Item 6: Appropriate requirements for arcing effects include:

- If the equipment's ordinary operation produces arcs, sparks, flames, or molten metal, it shall be enclosed or separated and isolated from all combustible material.
- Potential arc blast/electrical explosion is prevented from injuring personnel and damaging other equipment.

See 1999 NEC 110-18.

Item 7: A permanent label shall be attached to the equipment that includes the following information, prior to approval:

- The manufacturer's (or LANL builder's) name or other descriptive marking by which the assembler, SME, reviewer, ESO and the organization responsible for the equipment can be identified.
- Other markings shall include the equipment voltage, current, wattage, and any additional wording that the ESO deems necessary for the safe operation of the equipment (e.g., type, size, power, stored energy, secondary hazards, specific use, and specific users).

See 1999 NEC 110-21

SECTION 1: OSHA/NEC Electrical Equipment Approval Checklist

Item 8: Other factors contributing to practical safeguarding of personnel include:

- The review of non-electrical hazards by appropriate subject matter experts.
- Preventing electric shock, burn, or reflex hazards by eliminating personnel contact.
- Live parts of equipment operating at 50 volts or more shall be guarded against accidental contact by approved enclosures or by any of the following means:
  a) By location in a box, enclosure, room, or vault that is accessible only to qualified persons.
  b) By suitable permanent, substantial partitions or screens arranged so that only qualified persons will have access to the space within reach of the live parts.
  c) By location on a suitable balcony, gallery, or platform elevated and arranged so as to exclude unqualified persons.
  d) By elevation of 8 ft. or more above the floor or other working surface.
- Procedure of safing and energy removal, e.g., disconnection, LOTO, removal of stored energy, for both normal/emergency shutdown.
- Damage to eyes, skin or other equipment from UV and IR.
- Personnel injury or equipment interference from RF fields.
- Preventing personnel exposure to excessive noise.
- Preventing personnel exposure to X-rays for equipment >15 kV operating especially in a vacuum.
- Standard designs, including failsafe design:
  a) Use listed or recognized components where possible.
  b) Use accepted color coding of wires, especially grounded (white or gray) and grounding conductors (bare or green).
  c) Consider loss of electrical power, pneumatic, etc.
  d) Consider automatic removal of stored energy.
  e) Consider the use of interlocks on enclosures and other systems.

See 1999 NEC 110-27 & 110-31.

With careful planning and preparation, an ESO may be able to approve equipment for use at the laboratory that initially appears to be unsafe. The ESO may suggest or make changes which enable such equipment to be approved.

The NEC articles listed for items 1-8 are only a partial list meant to assist a qualified ESO in the equipment approval process. A working knowledge of the National Electrical Code is a prerequisite to starting the approval process. (Completion of the "Electrical Codes for Electrical Safety Officers" class meets only the minimum standard for ESOs to have a working knowledge of the NEC. Additional training and experience in use of the NEC may be necessary. Contact the Chief ESO if you are not sure.) Technical assistance is available to any ESO that has questions regarding this procedure. With the knowledge that any equipment approved may be in use for an extended period of time, it is strongly advised that the approval process involve as much "subject matter expert" input as the ESO deems necessary. Since the safety of Laboratory personnel, visitors, and the public are of primary importance it should be noted that certain equipment approvals will require guidance by members of the scientific community at the Laboratory.

All ESO's must keep in mind that by approving equipment they are completing work that is normally done for mass-produced commercial electrical equipment by a Nationally Recognized Testing Laboratory (NRTL) such as Underwriters Laboratories (UL). Consequently, they should approach this activity with reasonable and conscientious forethought. It is recognized that this approach will require time, and that experience will be enhanced during a learning period. At least initially more complex approvals will almost certainly require a "team" effort.

NOTES TO ESO's:

1. Maintain this approval document in a permanent "ESO APPROVED EQUIPMENT" file. Provide copies of this file to the Group Office and to the user of the equipment. This may be accomplished by attaching this approval document to the SOP, SEWP or HCP. Other documentation may include:
   a) Approval for specific uses, specific location(s), and specific purposes.
   b) Design specifications.
   c) Operating procedures, including safing procedures; and other SOPs, SEWPs and HCPs.
2. Require the prompt disposal, disassembly, or removal of approval labels of any approved equipment that will no longer be used for its intended purpose. This will require periodic checks of the equipment.
3. Develop a numbering system to track all equipment approvals. (*A suggested numbering system would be the user group acronym, the last two digits of the year, followed by a dash, and a four number assignment. An example would be XYZ98-00001.)*
4. Provide a detailed explanation of the approval to the end user. Explain that unauthorized modifications to the equipment after the approval are not allowed, and will result in the equipment being removed from service immediately, on your authority.
5. It is strongly suggested that equipment approvals involving complex issues be reviewed by the cognizant Division ESO or the laboratory Chief ESO.

AVAILABLE RESOURCES:

1. Electrical Inspectors
2. Chief ESO
3. Scientists and Engineers (Subject Matter Experts)
4. LANL Electrical Safety Committee

Calculations Based on the 1999 NEC (James Stallcup)

James Stallcup from Grayboy and Associates discussed changes in the new 1999 National Electric Code and how they will affect the electrical industry. James then went into great detail to explain how these changes will affect the calculations from the new code.

Electrical Burn Update (Dr. Mary Capelli-Schellpfeffer)

M. Capelli-Schellpfeffer, MD

capschell@earthlink.net

CapSchell, Inc.
Chicago, IL

Worker Safety & Health

The Electrical Trauma Research Program at the University of Chicago directed by Dr. Raphael Lee encompasses a worker safety & health research agenda.

http://http.bsd.uchicago.edu/~btc

History of the Electrical Trauma Research Program

- 1984 Biophysical mechanisms of electrical injury studied under Dr. Lee at the Continuum Electromechanics Laboratory at MIT.
- 1987 Theory that skeletal muscle and nerve cell membranes were directly injured in victims of electric shock reported.

History of the Electrical Trauma Research Program

- 1987 Thermodynamics of Joule heating in the tissues frequently injured by electric shock modeled.
- 1990 Clinical program complements basic research at the University of Chicago. Poloxamer 188 targeted for clinical trials.
- 1997 Clinical trials to begin on high voltage electrical injury survivors.

Program Goals

- To promote the development of effective interventions that prevent or minimize accidental injury from electricity for at-risk populations;
- To support the development of more rapid and accurate acute care injury diagnostic methods; and
- To advance rehabilitation medicine strategies following electrical injury.

Worker Safety & Health

- Safety & Health are an international priorities.
- Safety & Health are core to energy generation, transmission and distribution as well as utility business management.
- Safety & Health research requires resources beyond the funding ability of any single energy business.

Epidemiology of Electrical Injuries

- U. S. BLS statistics: 4000 disabling and 3600 non-disabling injuries each year
- Mortality: 3 to 15% of cases, with 1000 deaths attributable overall to electricall shock in the US annually
- 90% injuries occur in males, with 4 to 8 years job experience

How do electrical injuries occur?

- 75% of electrical injuries occur while the victims are doing a task; the injuries usually involve at least one upper extremity; arc explosions may occur in almost 3/4 of the accidents.
- Lightning related injuries affect 2000 annually, and kill 200-300 in the US each year.

U. S. Electrical Injury Data

- Data collection is fragmented between agencies.
- Nomenclature is inconsistent.
- Injuries are treated in multiple settings besides burn centers.
- Childhood injury data is not routinely available.

California 1993 Cal-OSHA Data

- Survival data for occupational illnesses/ injuries in private industry (CA pop. ~29,800,000)
- Construction, manufacturing and transportation and utilities
- Electric burns-->84 (Work-related burns n=6,103); Multitrauma burns--47 (Multiple Trauma n=1,0852); Electrocutions, electric shock--->327 (Other Injuries n=24,251).

California 1993 Cal-OSHA Data

- Survival data for occupational illnesses/ injuries in state and local agencies reveals 53 electrical burns.
- Private and public employers in 1993 reported over 460 electrical injuries.
- Data on children is not available.

U. S. Construction Injury Experience (1979 data, Business Roundtable)

- Total value of industrial construction in the U. S. was $137 billion.
- Same year accident costs were $8.9 billion
- Direct accident costs were $1.8 billion.
- Electrocution is the second most common cause of death in construction after falls.

U. S. Data

- 1.9 million burn injuries annually (1991 NIHS Survey)
- Cost of burn treatment estimated at $940 million annually (1991 data)
- Projected lifetime costs of annual burn injuries at $3.8 billion (1985 data, Cost of Injury in the US, 1989)
- Electrical burns are 3% US burn center admissions

French (EDF) Data (Cabanes, 1992)

- Ten year data for 120,000 employees
- Accident rate of 125/year electrical injuries
- 1231 Total/10 Year Study
- 2.4% Fatalities
- 77% Electrical Arc Injuries
- 21% Permanent Disability

Accident Scenarios

- Extremely Fast Events
- Multiple Hazards
- Extent of Injury Not Easily Recognized

The pattern of tissue injury after exposure to electrical energy is a consequence of the body's electrical properties.

When a victim comes in contact with a power source, for example a source greater than 200 volts, the epidermal skin is usually destroyed by heat within milliseconds.

All tissues except the epidermis, the outermost layer of the skin, are relatively good electrical conductors.

When the epidermis is lost, currents can pass and produce tissue damage, especially to skeletal muscle and nerve.

Evidence or suspicion of direct electrical contact with more than 25 watts power source capable of operating at more than 100 volts, or exposure to electrical arc suggests need for medical evaluation.

A major obstacle in the care of patients is the difficulty of accurately diagnosing and localizing tissue damage scattered throughout the current path before cellular degeneration occurs.

How does electricity affect the body?

- Historic understanding was that electrical contact caused heating, and the heating resulted in injury or death.
- Tropea and Lee modeled of electrical current's heating effects on extremity.
- Electroporation has been described as direct electrical effect which can result in tissue distruction, even in the absence of heat exposure or heating from current.

For 21st Century Prevention and Treatment of Electrical Injury

- Research and Education
- Enhanced Diagnostic Imaging Techniques
- Therapeutic Strategies Including Non-Ionic Surfactants

Pathophysiology and Management of Burns

CapSchell, Inc and The University of Chicago Electrical Trauma Research Program

Electrical injury is our paradigm for physicochemical injury, commonly referred to as "burns".

How does electricity affect the body?

- Historic understanding was that electrical contact caused heating, and the heating resulted in injury or death.
- Tropea and Lee modeled of electrical current's heating effects on extremity.
- Electroporation has been described as direct electrical effect which can result in tissue distruction, even in the absence of heat exposure or heating from current.

Source of Electrical Current Exposure

- Direct current exposure
- Arc exposure or history of arc blast
- Voltage, current capacity, and power source

Electroporation

Sensory and Neuromuscular Responses to Contact

- Perception
- “No let-go”
- Cardiac effects
- Disruption of skeletal muscle membranes

What kind of injuries result from electricity?

Broader Injury Classification

- Extends beyond voltage exposures
- Estimates electric field strength
- Includes type of affected tissue
- Notes anatomic location of injury

Clinical Spectrum of Electrical Injury

- Low Voltage Injuries
- High Voltage Injuries
- Electrical Arc Injuries
- Lightning

Clinical Update

- Goal:

  To enhance provider, community and industrial awareness of the complexity of electrical injuries.

Clinical Update

- Teaching Objectives
  - » To discuss the spectrum of injury
  - » To emphasize that the extent of injury can not be judged at the scene
  - » To illustrate the use of diagnostic imaging

Overview

- Thermal Injury Dynamics
- Tissue Injury and Manifestations
- Wound Management
- Physiologic Support and Resusitation
- Horizons in Management

Multiple Hazards

- Electrical Forces
- Thermal Exposure
- Blast Effects
- Falls, Crush, Confined Spaces and others

The pattern of tissue injury after exposure to electrical energy is a consequence of the body's electrical properties.

All tissues except the epidermis, the outermost layer of the skin, are relatively good electrical conductors.

Pathologic Mechanisms Underlying Electrical Trauma

- Joule heating
- Direct electrical effects

Electrical Conduction

- Surface contact impedances
- Conversion of electrons to ions in tissue

Tissue Characteristics Influencing Conductivity

- Cell density
- Cell size
- Cell orientation

Dielectric Breakdown

- Body’s resistive load
- Arc flash
- Arc temperatures

When a victim comes in contact with a power source, for example a source greater than 200 volts, the epidermal skin is usually destroyed by heat within milliseconds.

When the epidermis is lost, currents can pass and produce tissue damage, especially to skeletal muscle and nerve.

Electrical Trauma Patient Management

- Acutely injured patients are usually seen within hours to days of their accident.
- Post-acute patients may be seen weeks,months, to years following their accident.

Electrical Trauma Patient Management

- Acutely injured patients require medical transport to a Burn Center.
- On arrival, patients are assessed to determine the extent of their injuries.
- Assessment of injuries includes visual inspection and cleansing of wounds, xrays, magnetic resonance imaging, and technetium-99 scanning.

Electrical Trauma Patient Management

- Resuscitation started in the field is continued, including fluids, respiratory support, and cardiac monitoring.
- Early operative intervention can occur within hours of admission.

Electrical Trauma Patient Management

- Neurophysiologic spectral refractory nerve conduction studies are done to assess nerve fiber performance in upper extremity testing.

Electrical Trauma Patient Management

- Diagnostic imaging with 0.1 Tesla magnetic resonance imager allows critically ill patient's life support needs to be managed during scanning.

- Exploratory use of SPECT (Single Photon Emission Computerized Tomography) in electrical trauma may indicate cerebral flow changes.

Admission Guidelines

- History of loss of consciousness
- Abnormal neurologic examination
- Abnormal EKG or history of CPR following event
- Suspicion of developing muscle compartment pressure

Admission Guidelines

- Thermal injury (arc or flash) >15% TBSA
- Injury to hands, feet, face or perineum
- Suspicion of inhalation injury or upper airway swelling
- History of fall or being thrown by explosion forces

Evidence or suspicion of direct electrical contact with more than 25 watts power source capable of operating at more than 100 volts, or exposure to electrical arc.

Acute Management

- 1. Disconnect and de-energize.
- 2. Stabilize cervical spine.
- 3. Initiate CPR.
- 4. Continue resuscitation:
- a. Intubate;
- b. Manage arrythmias;
- c. Vascular access;
- d. Foley.
- 5. Assess wounds.

Diagnostic Evaluation

- Evaluate tissue damage
- Rule out fractures
- Establish neurologic status
- Auditory studies
- Ophthalmology examination

A major obstacle in the care of patients is the difficulty of accurately diagnosing and localizing tissue damage scattered throughout the current path before cellular degeneration occurs.

Advances in Diagnostics

Tools to Help the Surgeon's Eye

"See" Electrical Injury Damage

CapSchell, Inc and The University of Chicago Electrical Trauma Research Program

Initial Management

- Cooling
- Resusitation
- Pain and anxiety
- Tetanus
- Wound care
- Antimicrobials
- Antioxidants
- Physiologic Support

Clinical Management

- Support vital organ function.
- Control cardiac arrythmias.
- Restore perfusion.
- De-bride non-viable tissue.
- Effect wound closure.
- Rehabilitate aggressively.

Summary on Clinical Management

- Electricity causes damage via several mechanisms.
- Membrane injury is an important common path to cell necrosis.
- Continued research is needed to find enhanced therapeutic strategies.
- Evaluation, treatment, and rehabilitation considerations in electrical injury require a multidisciplinary team approach.

Accident Scenarios

- Extremely Fast Events
- Multiple Hazards
- Extent of Injury Not Easily Recognized

Case Study

- Electrician: In his 40's with over 15 yrs. experience and no previous accident history
- Electrical installation: A 2300V circuit breaker on a 20,000 amp service in a large open area with ceiling >20 ft
- Activities: Circuit was being tested with voltmeter ; electrician was in crouched kneeling position

Case Study, continued

- Witnesses present
- Electrical, thermal and blast hazards
- Medical evacuation within 1 hour to burn center
- First hospitalization: 70 days with five surgeries and multiple diagnostic treatments
- Direct costs first hospitalization: >$600,000

16 Questions To Assist Care

- 1. Where and when?
- 2. What was the victim doing?
- 3. Direct electrical contact?
- 4. What was exposure duration?
- 5. Did the victim fall?
- 6. What was worn (PPE)?
- 7. Were others involved?
- 8. Voltage, current capacity & source?

16 Questions To Assist Care

- 9. Was hazard recognized?
- 10. LOC, confusion or disorientation?
- 11. CPR done?
- 12. Cervical collar or splints used?
- 13. Explosion?
- 14. Closed space?
- 15. Other hazards?
- 16. Who has more info?

Implications for Health and Safety

Why do injury scenarios result in different levels of trauma severity?

Blast Effects

Electrical Arc Blast

- Goal:

  To heighten awareness for provider, community and industrial responders of the complexity,speed and magnitude of blast events.

Electrical Arc Blast

- Teaching Objectives
  - » To give visual information of electrical arc events which may occur at sub-second speed
  - » To present the magnitude of forces which may result in harmful effects

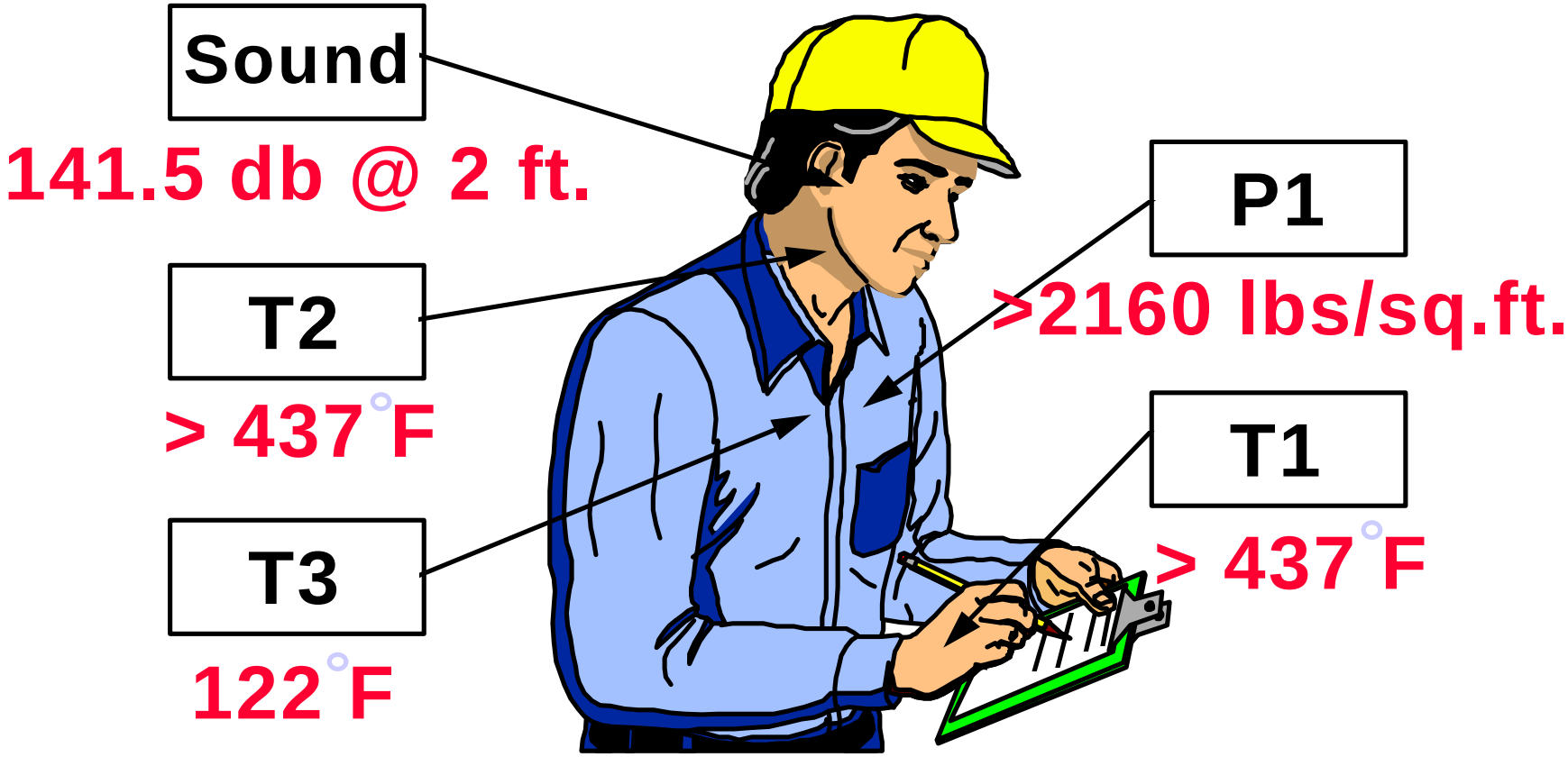
Brain Injury Indicators

- Hearing loss
- Irritability
- Confusion
- Gait unsteadiness
- Concentration problems
- Memory changes
- Depression
- Task inefficiency
- Unexpected family difficulties

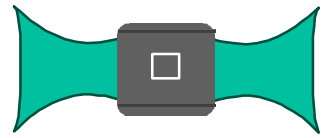
Ad Hoc Group

- Mary Capelli-Schellfeffer, MD, Member
- Robert E. Downey, PE, Member
- Shahid Jamil, PE, Senior Member
- Ray A. Jones, PE, Senior Member
- Danny P. Liggett, Associate Member
- Terry Macalady, PE, Senior Member
- L. Bruce McClung, PE, Fellow
- Vincent Saporita, PE, Member
- Lynn F. Saunders, PE, Senior Member
- Arthur Smith, PE , Member
- Acknowlegments of Contributors including Mike Chosek, Bruce Coburn,

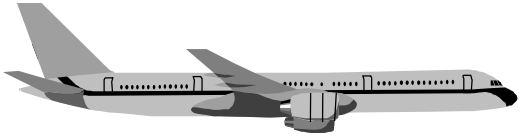
Results: Test No.4



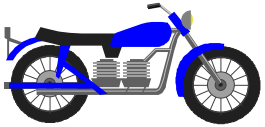
Common Sound Intensity Levels



Siren @ 100 ft.
(135 db)



Jet Plane Takeoff
(125 db)



Accelerating Motorcycle
(110 db)

Lightning Strike Consequences

- Goal:

  To enhance provider, community and industrial recognition of lightning-related electrical injury occurence patterns and consequences.

Lightning Strike Consequences

- Teaching Objectives
  - » To outline locations and activities which are associated with lightning injuries
  - » To review prevention strategies
  - » To review the spectrum of lightning related health consequences

Lightning (Cherington, 1995**)**

- Direct strike
- Side flash
- Ground or stride current (step current)
- Indoor conduction

Lightning Neurologic Sequelae

- Immediate and transient
- Immediate and prolonged or permanent
- Delayed and progressive
- Lightning linked (secondary)

Immediate and Transient Neurologic Loss

- Loss of consciousness
- Retrograde amnesia
- Confusion
- Paresthesias
- Limb weakness

Keraunoparalysis

- Fleeting condition
- Charcot's paralysis, especially lower extremities: a transient limb weakness
- Vasomotor symptoms: pale skin, diminished pulses and paresthesias

Immediate and Prolonged or Permanent CNS Effects

- Occur less often
- Diagnostic findings on imaging and/or postmortem examination
- Hemorrhages, neural cell damage
- Anoxic brain injury

Triage Considerations

- Goals:

  To increase provider, community and industry awareness of triage considerations unique in electrical injury first response including site hazards.

Triage Considerations

- Teaching Objectives
  - » To outline need for site survey before responders treat electrical injury victims (Remember: DE-ENERGIZE!)
  - » To illustrate emergency actions which may be required in electrical injury scenarios prior to triage intervention (Remember: STABILIZE!)

REMEMBER: STABILIZE!

- After an electrical accident, the structural facililties may be unstable due to explosion, presence of combustibles, or nearby energized conductors which may lead to induced current.

REMEMBER: DE-ENERGIZE!

Electricity is a silent, invisible, tasteless and deadly hazard. At the injury scene, a power expert should verify conditions.

REMEMBER: DE-ENERGIZE!

Electricity is a silent, invisible, tasteless and deadly hazard. At the injury scene, a power expert should verify conditions.

REMEMBER: DE-ENERGIZE!

The responder must not put their life at risk by approaching an electrical injury victim before learning whether current is live at the scene.

Triage Considerations: CPR

- Assume that electrical injury survivors have neck fractures.
- CPR should be performed as if head and neck injuries are present.
- Cervical collar should be placed as soon as available and not removed until medical clearance at the provider facility.

Depth of Burn

- First Degree Burn
  - » Outer layer of epidermis
  - » Example: Ultraviolet light exposure
  - » Appearance: Erythema, edema, painful
  - » Healing: 3-7 days, generally no scar

Depth of Burn

- Second Degree Burn
  - » Appearance: Blistered, weeping, red, painful, skin pliable
- Superficial Second Degree Burn
  - » Epidermis
  - » Example: Brief hot liquids or flames
  - » Healing: < 21 days, minimal scar and pigment changes

Depth of Burn

- Deep Second Degree Burn
  - » Deep into dermis
  - » Hair follicles, glands , skin appendages sparred
  - » Example: immersion scalds, flame contact
  - » Healing: > 21 days, severe hypertrophic scarring possible

Depth of Burn

- Third Degree
  - » Full thickness burn with thrombosed vessels
  - » Total destruction of epidermis and dermis
  - » Longer exposure to hazard
  - » Appearance: tan, leathery, non-pliable
  - » Healing: requires grafting

Family, Coworker & Employer Considerations

- Goal:

  To heighten community awareness of consequences for families and others following an electrical injury.

Family, Coworker & Employer Considerations

- Teaching Objectives
  - » To discuss the personal, social and economic costs of electrical injury
  - » To discuss neuropsychological issues for patient, family and others
  - » To outline rehabilition issues

Work is an essential factor of health. It balances and gives significance to our lives, enobling them and permitting man to create those material and cutural values without which human existence would be meaningless.

Henry E. Sigerist (1891-1957) in Medicine and Human Welfare

Employment is nature's physician and is essential to human happiness.

Galen, 2nd Century

Return to Work Issues

Psychological Adjustment

- Pre-morbid adjustment
- Psychiatric history
- Pre-existing alcohol or substance use
- Post-traumatic stress disorder
- Adjustment disorder

Community Reintegration

- Patient family education
- Workplace/learning place education
- Home exercise
- Therapy
- Visiting nurse
- Family/community issues

Work

- Factors influencing return to work
  - » Work history
  - » TBSA
  - » Degree of injury
  - » Hand burns
  - » Type of employment
  - » Age

Skin Factors Affecting Work

- Pruritis
- Skin fragility
- Temperature intolerance
- Altered sensation
- Impaired dexterity
- Sensitivity to chemicals/materials

Facilitating Return to Work

- History of employment
- Supportive supervision
- Work hardening
- Vocational counseling
- Education and retraining
- Workplace adjustments
- Peer support

Acknowledgements

Amoco Foundation , Baltimore Gas and Electric, Central and Southwest Services, Commonwealth Edision, Electric Power Research Institute, Empire State Electric Energy Research Co, New York State Electric and Gas Co, Northeast Utilities Services Co, Pacific Gas and Electric, Public Service Co of Oklahoma, Wisconsin Electric Power Company

Ground Problems at the Y-12 Plant (Richard Goins)

AT THE Y-12 PLANT

Note: All National Electrical Code references are from the 1999 edition.

I. Purpose of Grounding and Bonding

A. Systems are solidly grounded to limit the voltage to ground during normal operation.
B. Prevent excessive voltages due to lightning, line surges or unintentional contact with higher voltage lines
C. To stabilize the voltage to ground during normal operation.

II. Scope of Grounding

A. Permanent and electrically continuous
B. Have a capacity to conduct safely any fault current
C. Have sufficiently low impedance to limit voltage to ground
D. Facilitate the operation of the circuit protective device

III. National Electrical Code Grounding Requirements – Systems that Must be Grounded

A. Less than 50 Volt Systems

1. Where supplied by transformers if the supply voltage to the transformer exceeds 150 volts to ground
2. Where supplied by transformers if the transformer supply system is ungrounded
3. Where installed as overhead conductors outside of buildings

B. 50 to 1000 Volt systems supplying premises wiring or premises wiring systems

1. Where the system can be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 Volts. Ex. 120 volt, 1-phase; 120/240 volt, 1-phase; 208Y/120 volt, 3-phase, 4-wire
2. When the system is 3-phase, 4-wire wye connected where the neutral is used as a circuit conductor. Ex. 208Y/120 volt, 3-phase, 4-wire; 480Y/277 volt, 3-phase, 4-wire
3. When the system is 3-phase, 4-wire delta connected in which the midpoint of one phase winding is used as a circuit conductor. Ex. 120/240 volt, 3-phase, 4-wire; 240/480 volt, 3-phase, 4-wire
4. When the grounded service conductor is uninsulated as follows;
   a. The grounded conductor of a multiconductor service drop cable, Section 230-22
   b. The grounded conductor of an underground service lateral, Section 230-30
   c. The grounded service entrance conductor, Section 230-41

C. NEC also has grounding requirements for AC systems of 1kV and over

IV. Definition of Separately Derived System and Requirements for Grounding

A. Electrical systems derived from a generator, transformer, or converter windings that have no direct electrical connection to the supply conductor originating in another system.
B. Must be grounded if the system that is derived complies with the conditions in III. A, B, and C above
C. The separately derived system then must be grounded as specified in Section 250-20 (d)

V. Grounding Separately Derived Alternating Current Systems

A. Where to bond.
B. Bonding jumper in transformer
C. Bonding jumper in panelboard

VI. Use of Derived Neutral for Bonding

A. Section 250-142 (a) (3) permits the grounded circuit conductor to be used for grounding equipment on the supply side of the disconnecting means or overcurrent devices of a separately derived system
B. As used in Section 250-142 (a), the term, “on the supply side of” means up to or within the enclosure for the disconnecting means or overcurrent devices
C. It is widely accepted to make bonding connections of the neutral or grounded circuit conductor within the disconnecting means enclosure for the service, building and separately derived system

VII. Grounded Circuit Conductor Serves Two Purposes

A. Allows line-to-neutral or grounded conductor loads to be supplied, and the conductor carries the unbalanced loads from ungrounded conductors
B. Serves as the equipment grounding conductor and will carry line-to-ground fault current back to the service

VIII. Scope of Problem at the Y-12 Plant and Possible Existence of Problem at Other Facilities

Extra Presentations

ASTM UPDATE

JUNE 1999

DOE ELECTRICAL SAFETY CONFERENCE

ORLANDO, FLA.

Fire Resistant Clothing

- F1958 (PS 57 - Mannequin ignition test) and F1959 (PS 58 -FR fabric panel test) have been balloted and approved as permanent ASTM Standards.

F1506 - Vertical Flame Test

This standard is now being modified to include F1959. Other possible modifications to F1506 are:

- Inclusion of a definition for arc rating - This rating will be reported on the apparel label. This rating is either the ATPV (Arc Thermal Performance Value) or the Breakopen Threshold Energy [E(bt)] when the ATPV can not be determined.

- A standard reporting format for all required test results including arc rating, arc afterflame time, vertical flame char length, etc.

F1506 - Vertical Flame Test (cont.)

- Require the arc afterflame time be provided at the arc rating exposure level.

- Provide guidance on design considerations such as sewing thread, covering of conductive snaps and zippers, use of flammable logos, etc.

ASTM F-1891 - FR Rainwear

This standard is being modified to possibly include:

- Report and include on the label of the garment the arc rating.
- Move the Breakopen Threshold Above Stoll [E(btas)] information to an Appendix.
    - [E(btas)] is an important value when discussing rainwear as there are types on the market that provide excellent electrical arc energy protection until they breakopen.
    - This breakopen value is above the ATPV, but due to the construction of the garment, may ignite or melt when breakopen occurs.

ASTM F-1891 - FR Rainwear (cont.)

- It was decided that this concept could be confusing and lead to misuse but the information needed to be retained in the document in a non-mandatory manner.

- Require a standard reporting method.

- Address the garment washing issue as outlined in F1959.

Eye and Face Protection

- There will be a draft document out for ballot before the Fall 1999 meeting covering the test method to determine the electrical arc hazard to an employees face and eyes.

- The test method will be based on using a test face/head mounted on a mannequin body. There will be sensors to detect the energy received to the eyes, mouth and chin.

- This will allow testing to be performed to determine the protective value of safety glasses, faceshields, and full hoods.

- There was a discussion on new materials/dyes being tested to come up with a faceshield that has some protective value and also transmit visible light.

Dielectric Overshoes

- ASTM F1117 is being reviewed. There was discussion on adding a requirement to show the actual dielectric area of these shoes.

- Also, as manufacturing methods are changing, there may be information included to cover dielectric overshoes made by a seamless method.

Grounding Assemblies

- There was a task team formed at the Fall 1998 meeting to include grounding assemblies not now covered by F855.

- These include such things as traveling grounds, elbow grounds, equipotential grounding systems, underground distribution, network grounding, etc.

- There was a elbow ground shown that had been received from a vendor that had a hot line clamp on the grounding end.

  - Although , the continuous current rating of the hot line clamp was stamped on the device, these devices are not rated for fault current.

OSHA Update

- The proposal for Subpart V is now scheduled to be out by the end of the year 2000.

Maximum Use Voltage

- There was a discussion of the verbiage that is in a number of ASTM documents.

- There is a change proposal for the next edition of the National Electrical Safety Code that also will address this topic as well as the pertinent work rules.

- There are some that think the verbiage in the ASTM documents amount to work rules. That is not the purpose of these ASTM documents.

Gloves/Sleeves

- F496 was sent out for ballot to address some wording changes concerning glove and sleeve testing issues and to add DC maximum use voltage for gloves and sleeves.

- These items resulted in extensive discussion. The changes in the testing wording was approved but the inclusion of DC maximum use voltages was defeated.

- There will be a review of F496 and F1236 to define the term "minor surface cutting" and to determine the possibility of removing the portion of the F496 standard that allows patching of gloves and sleeves.

Matting

- D178 will be sent out for ballot to address the reference of a flammability standard (D1692) that is now obsolete.

Non-PVC Sheeting

- The task team formed to address the negatives on this draft standard are still working on the changes to this document. The document may be ready to send out for ballot before the Fall 1999 meeting.

Line Hose

- Survey data was reviewed to address the issue of whether to include a periodic in-service testing requirement for line hose.

- The data did not show the need to include this periodic in-service testing requirement.

In-Service Testing of Portable Protective Grounds

- The task team addressing this issue have performed more testing and have addressed other issues resulting from the balloting of Draft 7. There may be a ballot on this standard before the Fall 1999 meeting.

Live Line Tools

- The F711 standards is being reviewed. This is a periodic requirement of all ASTM standards and F1825 is being modified to include all types of clampsticks.

- The existing F1825 only addresses fixed length clampsticks.

- Draft 3 of a proposed new standard "In-Service Care of Live Line Tools" was reviewed.

Designing Safe Electrical Equipment

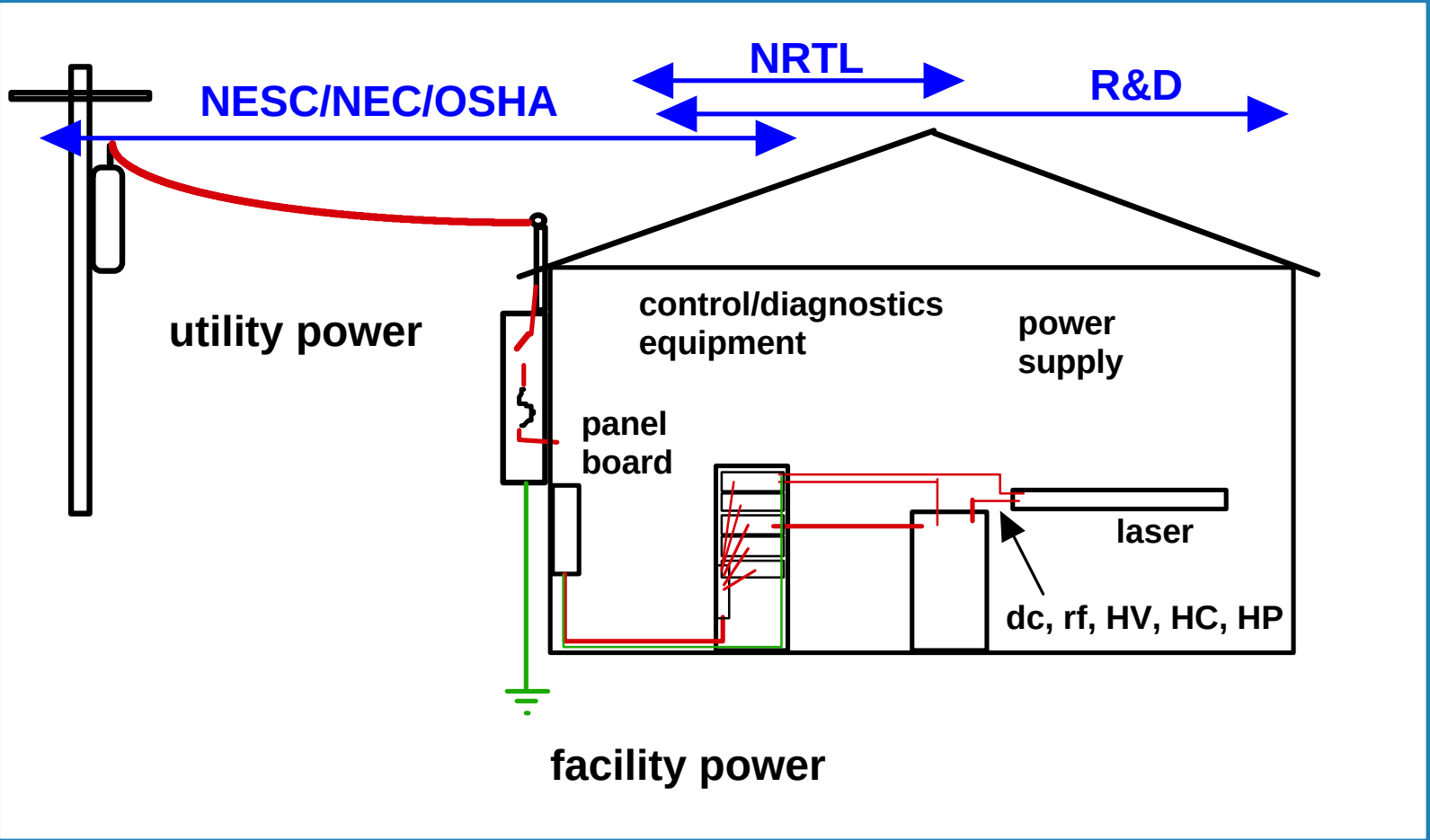
Lloyd B. Gordon
Los Alamos National Laboratory
Principal Engineer - R&D Safety

DOE Electrical Safety Meeting
June 23, 1999

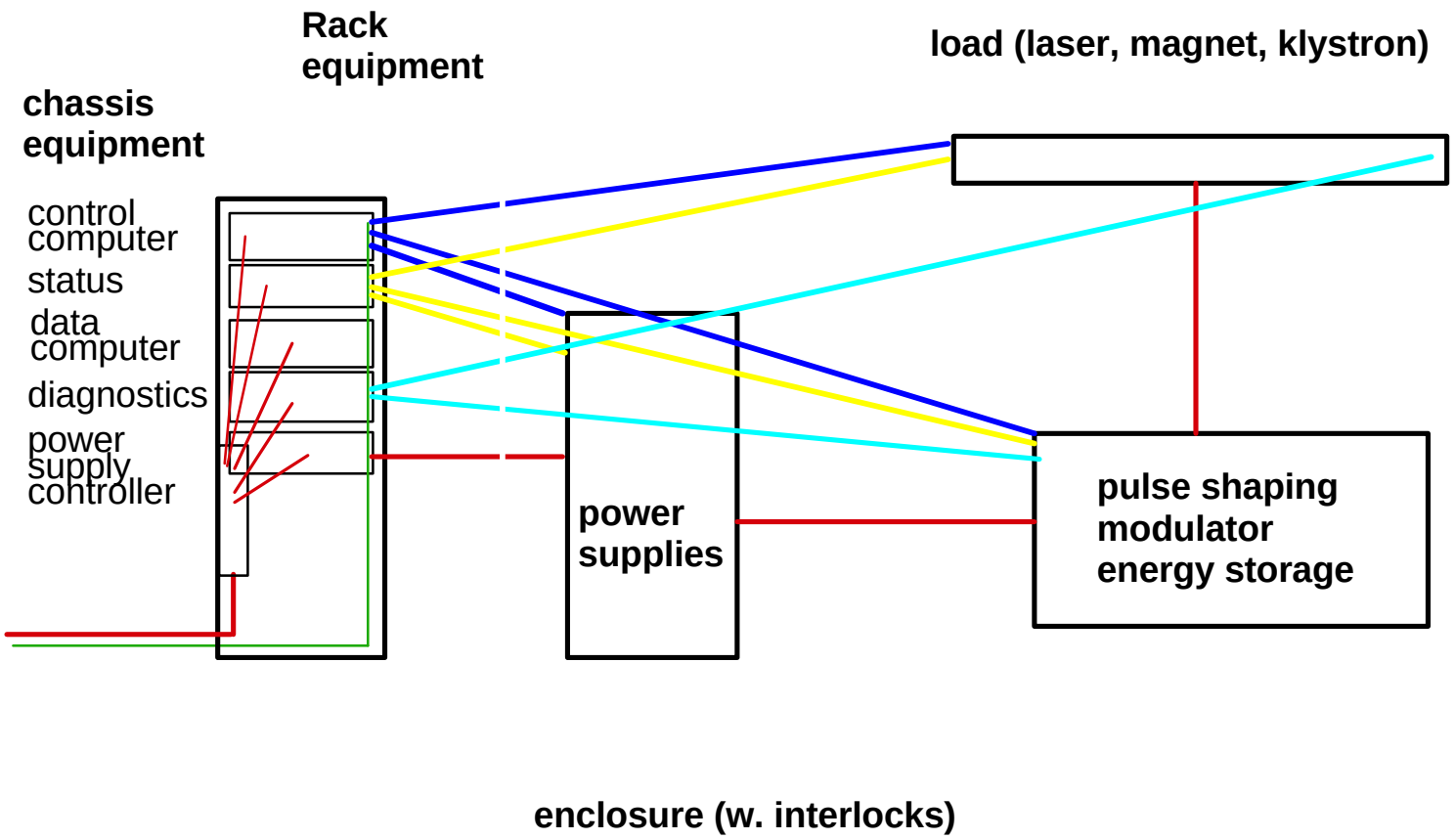
Objectives

- To review types of equipment that might be designed/built in-house
- To understand your responsiblities as an equipment designer/fabricator
- To review the electrical safety standards that can affect your design
- To present some resources that are useful for design
- To consider the principle goals in equipment design
- To look at design issues that affect safety
- To review the equipment approval process
- To get you to THINK about safety when designing and building electrical equipment

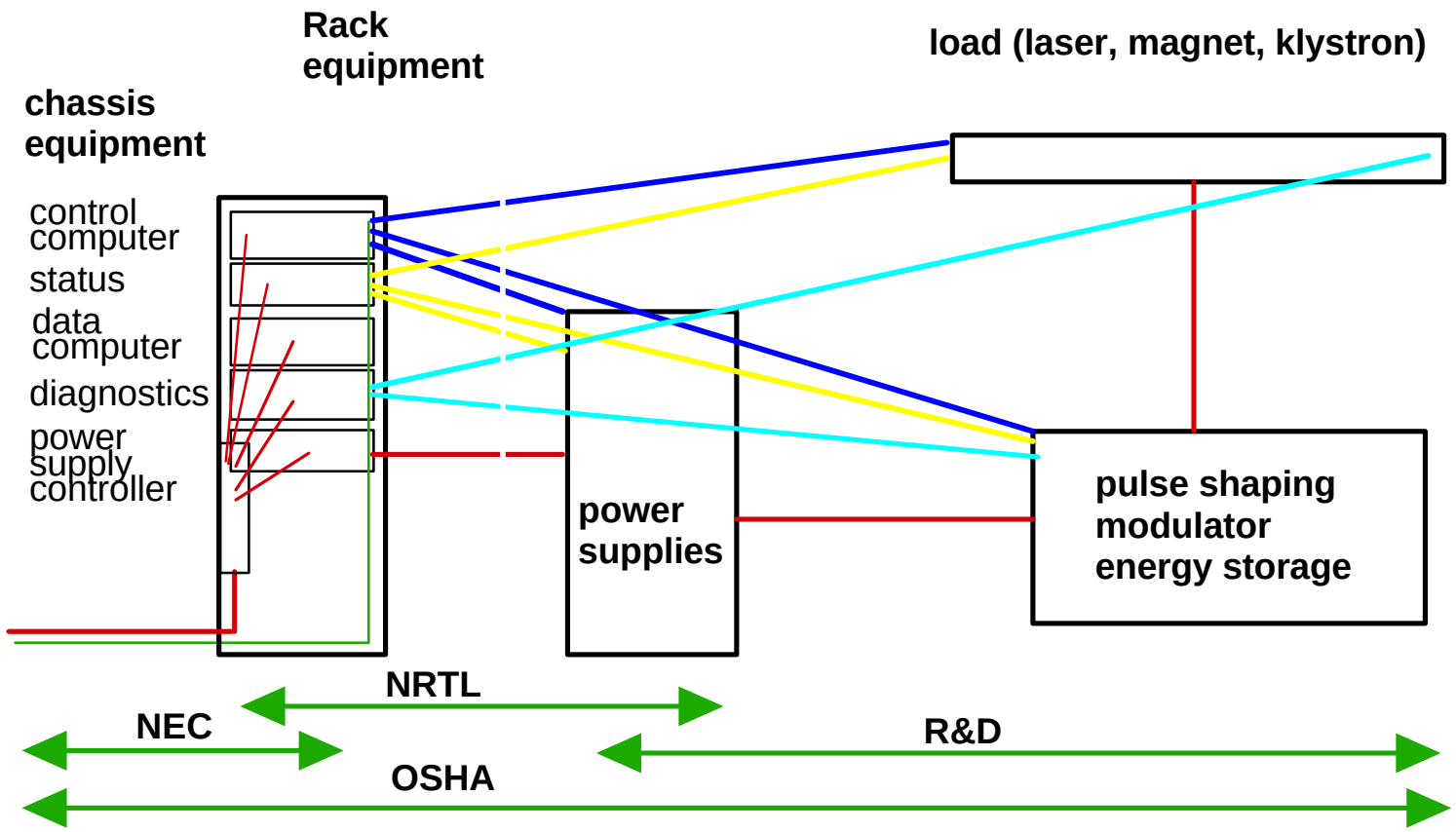
Standards affecting equipment design



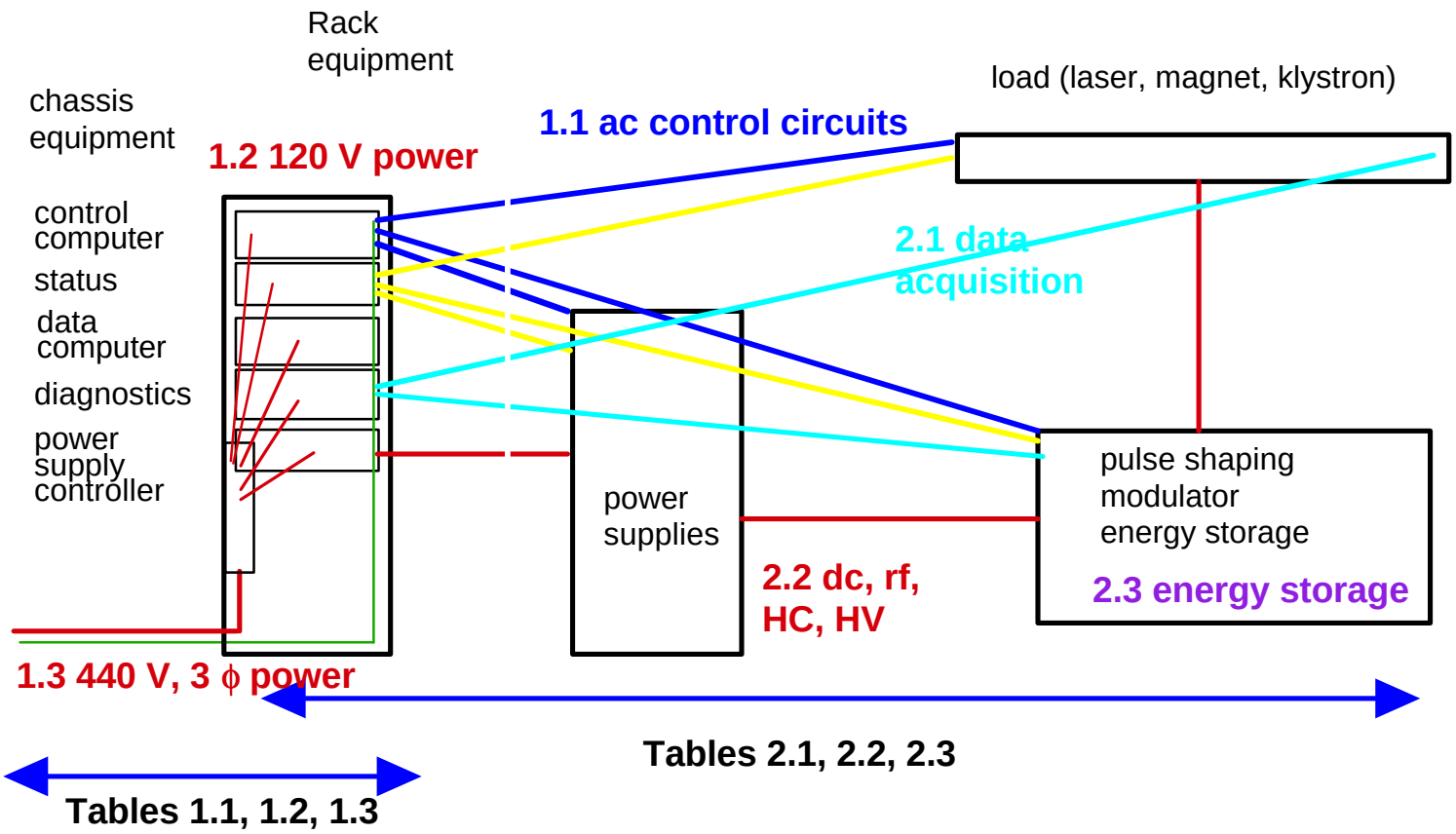
Typical Laboratory System



Typical Laboratory System



Typical Laboratory System



Examples of in-house built equipment

- rack equipment
  - can be mobile or permanent
  - can have overcurrent protection, branch circuits, etc.
  - usually in-house fabricated
- chassis equipment
  - control cicuits
  - computers
  - monitoring, safety, status circuits
  - data acquisition
  - can be NRTL or in-house built
  - power supply controllers
  - in a rack, or separate
- power supplies
  - high voltage
  - high current
  - rf
  - dc

Important Equipment Design Issues

- Safety
- Meeting Standards
- Application requirements
- Cost, resources, expertise required
- Design review
- Documentation

Important Safety Issues

- Will the equipment contain electrical hazards?
- Will the equipment control other hazards?
- What is its intended use?
- Where will the equipment be used?
- Will it be moved from site to site?
- Who will operate/use this equipment?
- What will be the training/qualification requirements?
- Does the equipment require approval?
- Design review, Documentation

More Design Considerations

- Will the equipment be accessible?
- Will the equipment enclosure contain all possible hazards?
  - electric shock
  - electric explosion
  - radiofrequency and microwave radiation
  - infrared, optical and ultraviolet emissions
  - x-rays
  - fire
- How will the equipment be grounded?
- EMI/EMC issues
  - will the equipment interfere with other equipment?
  - is the equipment susceptible to noise from other equipment?

Failure Mode Considerations

- What are the consequences of loss of
  - supply power
  - control power
  - air pressure, water pressure
- What are the consequences of load failure
  - overload
  - fault
  - short circuit
- Can someone open up, enter, or otherwise access the interior of the enclosure?
- Does the equipment interface with any other electrical hazards, especially HV, HC, rf, or stored energy?
- Are there possible ways for the energy to get into the equipment, endangering the user/operator?
- What are the consequences of such energy escape?

Environmental Considerations

- altitude
- high/low temperature
- radiation environment
- electromagnetic noise
- mobile
- shock, transportation
- humidity
- special attention to
  - dielectric materials (electric insulation)
  - wiring methods
  - connections
  - fasteners
  - optical elements

Checklist for Approval of Unlisted Equipment for Intended Use

1 - Suitability for installation and use in conformity with 29 CFR 1910 Subpart S and/or the NEC.

2 - Mechanical strength and durability, including for parts designed to enclose and protect other equipment, the adequacy of the protection thus provided.

3 - Wire bending and connection space.

4 - Electrical insulation.

5 - Heating effects under normal conditions of use and also under abnormal conditions likely to arise in service.

6 - Arcing effects.

7 - Classification by type, size, voltage, current capacity, and specific use.

8 - Other factors that contribute to the practical safeguarding of persons using or likely to come in contact with the equipment, including non-electrical considerations and hazards.

DOE Chapter 9 - Equipment Enclosures in the R&D Laboratory

- An enclosure is designed to protect the user from exposure to electrical hazards
- An oversimplified classification was historically used
  - greater than 50 V
  - any high current greater than 10 A, regardless of voltage
  - any energy storage in excess of 10 J
  - any circuit with RF radiation emissions
- Refer to the LIG hazard classification chart for a more comprehensive classification - still not perfect

General Equipment Enclosure Design Techniques

- - interlocks
- - low voltage and high voltage sections
- - mechanical strength
- - grounding and ground fault detection
- - warning systems and/or "crash" stations

Enclosure Grounding and Bonding

- enclosure houses utilization equipment
- techniques
  - have a common grounding or bonding bus
  - bond the grounding or bonding busses for several bays together
  - each piece of utilization equipment (chassis) installed shall have a grounding conductor attached unless it is properly grounded through the power cord
  - grounding or bonding conductor permanent and continuous
  - subassemblies properly grounded
  - if chassis moveable, grounding should be braided or stranded
- isolation transformers, must
  - continue the equipment grounding conductor, OR
  - the equipment must be guarded and labeled

Objectionable Current and Noise

- Results from proximity of power, signal, and control circuits
- NEC 250-6 allows some freedom to solve these problems
- Does NOT, however, give blanket authority to do any and everything. Must still meet safety requirements
- Voltage differences exist due to impedances in grounds
- NEC 250-6
  - Discontinue one or more but not all of grounding connections
  - Change the location of the grounding connections
  - Interrupt the continuity of the conductor or conductor path interconnecting the grounding connections
  - Take other suitable remedial action satisfactory to AHJ

Rack Power Distribution

- may contain a power distribution unit
  - a main overcurrent protection device
  - multiple branch circuits, individually overcurrent protected
- otherwise is a part of one branch circuit
- branch circuit loading should meet all NEC requirement
- external convenience outlets should be connected to a separate circuit breaker
- distribute phase loads, properly size neutral (e.g., for harmonics)
- components listed by NRTL

Rack Power Distribution - cont.

- **Conductors and Connectors**
  - wires rated per voltage and temperature (ANSI standards)
  - insulating tubing, sleeving, and tape similarly rated
  - power and signal wires should be routed separately within a chassis
  - good workmanship (mechanical considerations)
    - no sharp edges, burrs, screw threads, moving parts
    - holes smooth or use bushings
    - proper use of clamps
    - no damage to wires, cables and cords
- **Flexible cables**
  - may be used:
    - when a part of utilization equipment furnished by manufacturer
    - to facilitate frequent interchange of stationary equipment
    - to prevent transmission of mechanical vibration
    - for data processing cables approved
    - for temporary wiring
- **Strain relief**
- **Separation of Voltages**

Other Rack Considerations

- provide interlocks where exposed conductors over 50 V exist and access is not controlled
- circuit breakers properly rated for switching under load
- provide provisions for Lockout/Tagout requirements

Chassis Power Distribution

- AC Power Distribution
  - chassis bonding and grounding
  - connections, connectors, and couplings
  - terminals/live parts
- DC Power Distribution
  - metal chassis or cabinet should not be used as a return path
  - high current analog or switching dc power supplies should use separate return paths from digital circuits
  - all of the guidelines pertaining to ac power such as grounding, proper wire size, high voltage, etc., should apply to dc circuits as well
  - all accessible terminals charged by an internal capacitor should be below 50 V within 10 seconds after interruption of the supply
- reference NEC, ANSI, and ISA standards

Protective Devices

- surge arrestors
  - MOV
  - avalanche diodes
  - spark gap arrestors
- fuses
- circuit breakers
- power interlock devices

Disconnecting Means

- must have a means
- interlock systems not recommended for disconnecting means
- permanently connected equipment use a switch or circuit breaker as means
- cord-connected use
  - switch or circuit breaker
  - plug that can be disconnected without tools
  - separable plug, without a locking device
- within 50 ft and visible to operator
- emergency shutdown
  - within arm's reach of operator
  - easily identifiable
  - deenergize all power to all equipment
  - be separate from routine on/off switch
  - located to protect employee from moving parts

Special considerations for R&D Equipment

- interface with hazardous electricity
  - propers insulating barriers
  - overcurrent protection (MOV, surge arrestors)
  - overvoltage protection (gaps)
- control of hazardous systems
  - explosives
  - toxic and hazardous materials
- environmental stresses
  - high voltage, corona
  - ionizing radiation
  - temperature extremes
- ground potentials during operation
- flashover

Pulsed Power Safety

Lloyd B. Gordon
Los Alamos National Laboratory
Principal Engineer - R&D Safety

DOE Electrical Safety Meeting
June 23, 1999

Outline

- Introduction
- Objectives
- Energy Storage
- Other hazards
- Summary and Discussion

What is Pulsed Power?

- energy compression (in time)
- electrical energy storage over a period of time, released quickly
- a huge increase in power
- magnification of current and/or voltage

What do we do with Pulsed Power?

- high power pulsed lasers
- compress and heat plasmas
- accelerate projectiles
- accelerate particles
- intense magnetic fields
- generate intense fluxes of energy

Why is Pulsed Power dangerous?

- unique parameters
- transient electromagnetic phenomena
- large forces on components
- intense material stresses
- stored energy
- unique, experimental systems
- intense fields (rf, magnetic)

Other electrical safety problems

- Batteries and Battery Banks
- RF and Microwave Safety
- Grounding and Shielding
- Equipment Design

Today we will discuss

- Energy storage
  - Capacitive
  - Inductive
- Electrical transients
- Forces
  - Electric
  - Magnetic

Important Parameters

voltage	V	V, kV, MV
current	A	A, kA, MA
power	W	kW, MW, GW, TW
energy	J	J, kJ, MJ
time	s	ns, µs, ms, s, min
capacitance	F	µF, mF
inductance	H	mH, H
resistance	W	mW, W, kW, MW
magnetic field	T	mT, T

Electrical Energy Storage

- Capacitors - in the electric field (can store a long time)
- Inductors - in the magnetic field (must have current flow)
- Batteries - as chemical energy (always on)

Capacitors and Capacitor Banks

- often used for energy storage
- voltage multipliers
- filters
- isolation
- high voltage cables

Terminology

- capacitor
- capacitor bank
- header, bushing
- terminals
- dump, crowbar, discharge
- to safe
- ground/crowbar/shorting hook/stick
- shorting vs grounding
- fuse
- switch (spark gap, rail gap, ignitron, thyratron, etc.)
- Marx bank, erection
- voltage doubler, Cockroft-Walton

About Capacitors

- purpose - energy storage, pulse shaping, filtering
- terminal design - case
- dielectric - oil, synthetic fluid, solid, water
- conductor - foils, plates, films
- parameters - capacitance, voltage, energy, inductance

Some useful Principles for Capacitors

- energy stored in a capacitor
- time constant for discharge of a capacitor through a resistor
- current of a capacitor/resistor discharge
  - R very small, pulsed power through a resistive load (µs)
  - R larger, "dumping" a capacitor (s)

Hazards of Capacitors - #1

- Capacitors can maintain a dangerous residual charge after the equipment has been de-energized, even after lockout/tagout of the power source.
- Stored energy from capacitors and capacitor banks can be hazardous and lethal with energy levels greater than 10 Joules.
- After the capacitor has been discharged there is possibility of the capacitor being partially recharged by dielectric absorption. The capacitor will remain a hazard until it has a short circuit between the terminals.

Hazards of Capacitors - #2

- If a capacitor contains a large amount of stored energy when it is discharged, there is a chance that the shorting device could be damaged by the large current flow. This could result in molten metal being ejected.
- Capacitors can explode throwing high velocity metal fragments.
- When a capacitor is discharge rapidly (into a low impedance load) high currents can cause internal heating, shock forces, and explosion.
- Grounding capacitors in series may transfer rather than discharge the stored energy.

Hazards of Capacitors - #3

- Capacitors have been known to start fires under failure modes, due to case rupture.
- When capacitors are used to store large amounts of energy, internal failure of one capacitor in a bank fault can result in explosion when all other capacitors in the bank discharge into the fault.
- Some older capacitors contained carcinogenic compounds known as PCBs and must be properly handled and disposed of.
- The liquid dielectric and combustion products of the liquid dielectric in capacitors may be toxic.

Hazards of Capacitors - #4

- A dangerously high voltage can exist across the impedance of a few feet of grounding cable at the moment of contact with a charged capacitor.
- Discharging a capacitor by means of a grounding hook can cause an electric arc at the point of contact, expelling hot gas and molten metal.
- Improperly sized fuses may explode.
- Internal connection between plates and header can prevent safing of capacitor
- Improper disposal can endanger others

Capacitor Energy Levels

- Greater than 10 J is considered a serious hazard (Table 2.3)
- Greater than 50 J is potentially lethal.
- Even small capacitors (size of a C-cell battery) can be lethal, especially at higher voltages.
- The energy must be deliverable in a reasonably short time (less than 1 second).
- < 50 V - Table 2.1, low hazard
- 50 - 400 V - Table 2.2, shock hazard
- > 400 V - Table 2.3, energy discharged immediately, serious internal injury

Design and Construction #1

- Isolate capacitor banks by elevation, barriers, or enclosures to preclude accidental contact with charged terminals, conductors, cases, or support structures
- Provide mechanical shields to protect personnel in the event of rupture or explosion
- Interlock the circuit breakers or switches to connect power to capacitors
- Interlock the automatic discharge circuits to "dump" the capacitors in case of unauthorized entry

Design and Construction #2

- Provide adequate safeing methods
  - remotely
  - current limiting
  - safety ground hooks
- Provide power supply disconnects with capability for lockout/tagout
- Design current limiting into bank
- Design interconnection (bus, cable, etc.) to withstand the mechanical forces of normal and fault conditions
- Design safety devices to withstand the mechanical forces
- Provide bleeder resistors on all capacitors not having discharge devices

Design and Construction #3

- Design the discharge-time-constant of current-limited shorting and grounding devices to be as small as possible
- Provide suitable grounding
- Provide suitable manual grounding hooks, and safe access to contact points
- Consider the potentials during charging and discharging phases, for insulation and safety purposes.
- Fully visible, manual grounding devices should be provided to render capacitors safe while work is being performed.
- Grounding points must be clearly marked.

Design and Construction #4 - fusing

- Capacitors connected in parallel should be individually fused, when possible.
- Caution must be used in the placement of automatic discharge safety devices with respect to fuses. If the discharge will flow through the fuses, a prominent warning sign should be placed at each entry indicating that each capacitor must be manually grounded before work can begin. This should also be clearly contained in the system SOP.
- Special knowledge is required for high-voltage and high-energy fusing.

Automatic Discharge Devices

- Use permanently connected bleeder resistors when practical
- Have separate bleeders when capacitors are in series
- Design automatic shorting devices that operate when:
  - the equipment is de-energized
  - the enclosure is opened
  - power, air pressure, control power fails
- Discharges the capacitor (bank) to a safe voltage (< 50 V) in less time than is needed for personnel to gain access to the equipment.
- Automatic discharge time never longer than 5 minutes
- Located within barrier/enclosure
- In plain view of personnel entering the region, for verification purposes

Ground Hooks

- Conductor terminations should be soldered or terminated in an approved crimped lug. All conductor terminations must be strain-relieved withing 15 cm.
- Ground hooks must be grounded and resistance should be less than 0.1 ohms to ground
- The cable conductor must be clearly visible through its insulation
- A cable conductor size of at least #2 AWG should be used, and the conductor shall be capable of carrying the available fault current of the system.
- Ground hooks shall be used in sufficient number to adequately ground all designated points.
- Permanently installed ground hooks must be permanently grounded and stored in a manner to ensure that they are used.

Safe Work Practices #1

- Only qualified electrical workers (those trained in the proper handling and storage of power capacitors and hazard recognition) shall be assigned the task of servicing/installing such equipment.
- Proper PPE shall be used when working with capacitors (see SOP, SEWP)
- Access to capacitor areas shall be restricted until all capacitors have been discharged, shorted, and grounded
- The protective devices (interlocks) shall not be bypassed unless by qualified electrical personnel when inspecting, adjusting, or working on the equipment. Proper procedures covered by an SEWP need to be followed when bypassing interlocks for energized electrical work.

Safe Work Practices #2

- Procedures should be established for tagging the interlock and logging its location and the time when bypassed and restored.
- Any residual charge from capacitors shall be removed by grounding the terminals before servicing or removal
- Automatic discharge and grounding devices should not be relied upon, manual grounds are always used as a last step in "safing"
- Grounding hooks shall be inspected before each use.

Safe Work Practices #3

- Capacitor cases should be considered charged.
- Protective devices should be tested periodically (e.g., interlocks, automatic crowbars, etc.)
- All uninstalled capacitors capable of storing 10 J or greater shall be short circuited with a conductor no smaller than #14 AWG.
- A capacitor that develops an internal open circuit may retain substantial charge internally even though the terminals are short-circuited. Such a capacitor can be hazardous to transport, because the damaged internal wiring may reconnect and discharge the capacitor through the short-circuiting wires. Any capacitor that shows a significant change in capacitance after a fault may have this problem. Action should be taken to minimize this hazard when it is discovered.

Safe Work Practices #4 - Discharging capacitors

- A discharge point with an impedance capable of limiting the current to 500 A or less should be provided.
- The discharge point must be identified and should be labled "HI Z PT" in large legible letters.
- A properly installed ground hook should first be connected to the current-limiting discharge point and then to a low-impedance discharge point (< 0.1 ohm) that is clearly identified, and should be labled "LOW Z PT" in large legible letters.
- The grounding hooks should be left on all of these low-impedance points during the time of personnel access.
- The low-impedance points shall be provided whether or not the HI-Z current-limiting points are needed.
- Indications of the voltage hazard should be provided visible at all entry points .

Safe Work Practices #5 - Discharging capacitors

- Use eye protection during safeing procedures.
- Turn off, lock and tag power source.
- Discharge:
  - the capacitor
  - the power supply capacitor
  - transmission line
  - load capacitance
- Prevent transferring charges to other capacitors
- Maintain a personnel safety ground during all de-energized procedures.
- When not in use provide a drain wire to prevent recharging.

Grounding Hooks

- also known as crowbar hooks, ground sticks, shorting sticks
- hard (direct short) vs soft (current limited with resistor)
- PPE required
- testing, maintenance, and proper design important

Inductors

- rarely inductors are used to store electrical energy.
- more often they serve another purpose:
  - pulsed shaping with capacitors
  - charged particle confinement and/or guiding
  - dc power supplies
  - intense magnetic fields
- transformers are a special case of coupled inductors
- to decrease resistive losses for high currents inductors are often operated at superconducting temperatures

Some useful Principles for Inductors

- energy stored in an inductor
- time constant for discharge of an inductor through a resistor
- voltage developed when trying to interrupt (open) an inductive circuit

Hazards of Inductors - #1

- Damage to inductors could occur due to overheating if the system was excessively loaded, or the cooling system failed.
- Large electromagnets and inductors produce fields that can effect the operation of the protective instrumentation and controls.
- Magnetic fields could attract nearby magnetic material, including tools and surgical implants, causing injury or damage by impact.
- Poor contacts for a magnet or inductor can lead to arcing and heating.

Hazards of Inductors - #2

- Hazardous voltages and high temperatures can be generated in conductive materials near a magnet that has been de-energized suddenly, due to eddy currents. This can also cause large forces on adjacent conductive objects.
- Improper discharging of the energy stored in a inductor can damage equipment or injure personnel.
- If "quenching" occurs in a super conducting magnet large amounts of stored energy can be released.

Hazards of Inductors - #3

- Highly inductive circuits have long time constants and can release energy into a fault; producing equipment failure and possibly a fire.
- Intense magnetic fields can be a health hazard.
- Large voltages can be generated when opening a high current, inductive circuit
- Shock can occur from testing inductors

Design and Construction - #1

- provide sensing devices that are interlocked with the power source (temperature, coolant-flow)
- fabricate protective enclosures from materials not adversely affected by external electromagnetic fields. Build a nonferrous barrier to prevent accidental attraction of iron objects.
- design equipment supports and bracing adequate to withstand forces generated during normal operation and during fault conditions

Design and Construction - #2

- appropriately ground electrical supply circuits and magnetic cores and provide adequate fault protection
- provide means for safely dissipating stored energy when the current is interrupted or a fault occurs
- when a magnet circuit includes switching devices that may not be able to interrupt the magnet current and safely dissipate the stored energy, provide a dump resistor connected directly across the magnet terminals that is sized to limit the voltage to a safe level during the discharge and safely dissipate the stored energy

Safe Work Practices

- avoid exposure to intense magnetic fields (> 0.1 Tesla)
- provide adequate warning signs to prevent persons with pacemakers or similar devices from entering areas with fields greater than 0.001 Tesla
- keep metal tools and other objects away from regions of intense dc or pulsed magnetic fields
- follow cryogenic safety procedures
- do not hold the test lead when measuring resistance of large coils of wire
- do not attempt to disconnect a magnet system, even at low voltage, when it is energized

Electrical Transients

- There are often standards that guide the use of conductor and dielectric design for continuous power (ac or dc).
- Pulsed power signals, however, often result in greatly magnified levels of voltage, current, and power that occur in very short times.
- This allows us to use both conductors and dielectrics at far higher levels than continuous duty.
- Pulsed power signals generate four important problems:
  - coupling into adjacent circuits and components
  - transient impedances
  - electric fields and stresses
  - magnetic forces

Coupling due to electromagnetic fields

- Fast transients cause induced voltages and currents in nearby circuits, structural components, grounds, and equipment
- This is due to:
  - magnetic induction (Faraday's Law, eddy currents)
  - capacitive coupling
  - rf radiation

Some useful Principles for Induction

- area of conductor loop is large (A)
- close to source (small r)
- large time rate of change of current
- good conductor (small R)

Hazards of coupling

- electrical noise and disruption to control and safety circuits
- electrical noise corruption of data, and other systems
- voltages on normally non energized conducting surfaces
- heating of nearby conductive materials
- possible intense rf and magnetic fields, biological hazard

Solutions to coupling problems

- Electromagnetic Interference (EMI) is a huge topic and is dealt with in other courses
- induced voltages and currents that are a personnel hazard are usually dealt with by isolation and enclosure of the system and immediate area during pulsed operation
- proper grounding techniques can reduce induced voltages
- minimizing adjacent conducting structural components can reduce heating and induced voltages

Transient impedances

- **grounds not at zero voltage**

Electric Forces

- the force on the plates of a capacitor can be in the range of 100 kNt
- rapid capacitor discharge can result in tremendous shock waves through the capacitor materials, rupturing dielectrics

Magnetic Forces

- I1and I2 are currents in adjacent conductors
- d is the distance between them
- for a 100 kA current, spaced 1 cm apart, the force between the conductors is 200,000 Nt/m.

Summary and Discussion

- unique parameters
- transient electromagnetic phenomena
- large forces on components
- intense material stresses
- stored energy
- unique, experimental systems
- intense fields (rf, magnetic)

Site Specific Safety Plans for Electrical Construction

April 20, 1999

C. Bryan Drennan
Senior Member of Technical Staff

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy under contract DE-AC04-94AL85000.

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Topics of Discussion

- Program Influence
- Site-Specific
- What's the plan
- Hazard Analysis of the plan
- Controls tied to the Analysis
- Implementation of the Plan
- Maintenance of the Plan
- Review and Improve

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Program Influence

- ***PLAN*** is not a program
- Program is the library that the plan references for controls, policies, procedures
- Program is the ***BIBLE!***
- ***PLAN*** is the ***SERMON!***
- Plan may influence the Program due to new hazards not previously addressed
- Plan is evidence you are implementing your program
- They ***MUST*** dance to the same music

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Site - Specific

- Construction Sites are ***Unique***
- Culture - Who are the employers?
- Owner role
- Oversight role
- Constructability - A/E role in safety
- Multi-employer / Prime Contractor work site
- Identifies who has safety responsibility
- Must be flexible - changes in the project
- Provides employees more defined instruction

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What’s In the Plan?

- Emergency Preparedness
- Identified Hazards
- Controls of those Hazards
- Training requirements
- Who’s What - Competent Person(s); Qualified person(s)
- Identify responsibilities - management, workforce and “**Sub-contractors & Suppliers”**

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Hazard Analysis for the Plan

- Task by Task
- What's the Hazard(s)?
- Can the task be accomplished a "Safer" way?
- When is the job going to occur? - Time of year/day
- How does weather affect the job?
- Where is the job going to occur ?- Remote site
- Who are the employees on this job?
- Lurking "Shadow Hazards"? - time constraints/money
- Who's going to run the job?

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Controls tied to the Analysis

- Project Specific **“Written Plan”**
- For each hazard determined
- What’s the most “**Practical**” control
- Best source often for control selection is - “ **the employee**” charged with performing the task
- Don’t forget what your “**Program**” advises
- Training - “**How, Who, When and… - Did Learning Take Place?”** - then **“Document It”**

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Implementation of the Plan

- Acceptance **“Prior to Work Starting”**
- Identify **“WHO”**owns the plan
- **“ALL”** affected employees know and understand the plan
- Identify process for changing the plan
- Stop and Re-start work procedures / responsibilities
- Daily **“Oversight”** of the plan’s effectiveness
- Integration into contractual documents - **“Sub-contractors & suppliers”**

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Maintenance of the Plan

- Review and **“IMPROVE”**
- Project Progress meetings provide Safety & Health an equal place on all agendas
- Control of new employees (training and awareness of the plan) working on the site - Means of **“Identification”**
- Changes to the Plan based on Daily Oversight of the Plan - **“Means to Communicate the Changes”**
- **“Preventative Vs Continual”** Maintenance

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Final Thoughts and/or Opinions

- Policy statement from American Society of Civil Engineers - " **Safety Issues be Addressed for Each Project on a Project Specific Basis".**
- **"…proactive management of construction safety…project by project basis…integrate Safety and Health with the management of the other primary elements of construction project performance: quality, cost and schedule…"**, *DOE Construction Safety Management Guide*
- **"It's Just the Right thing to do",** *Bryan Drennan, April 20, 1999*

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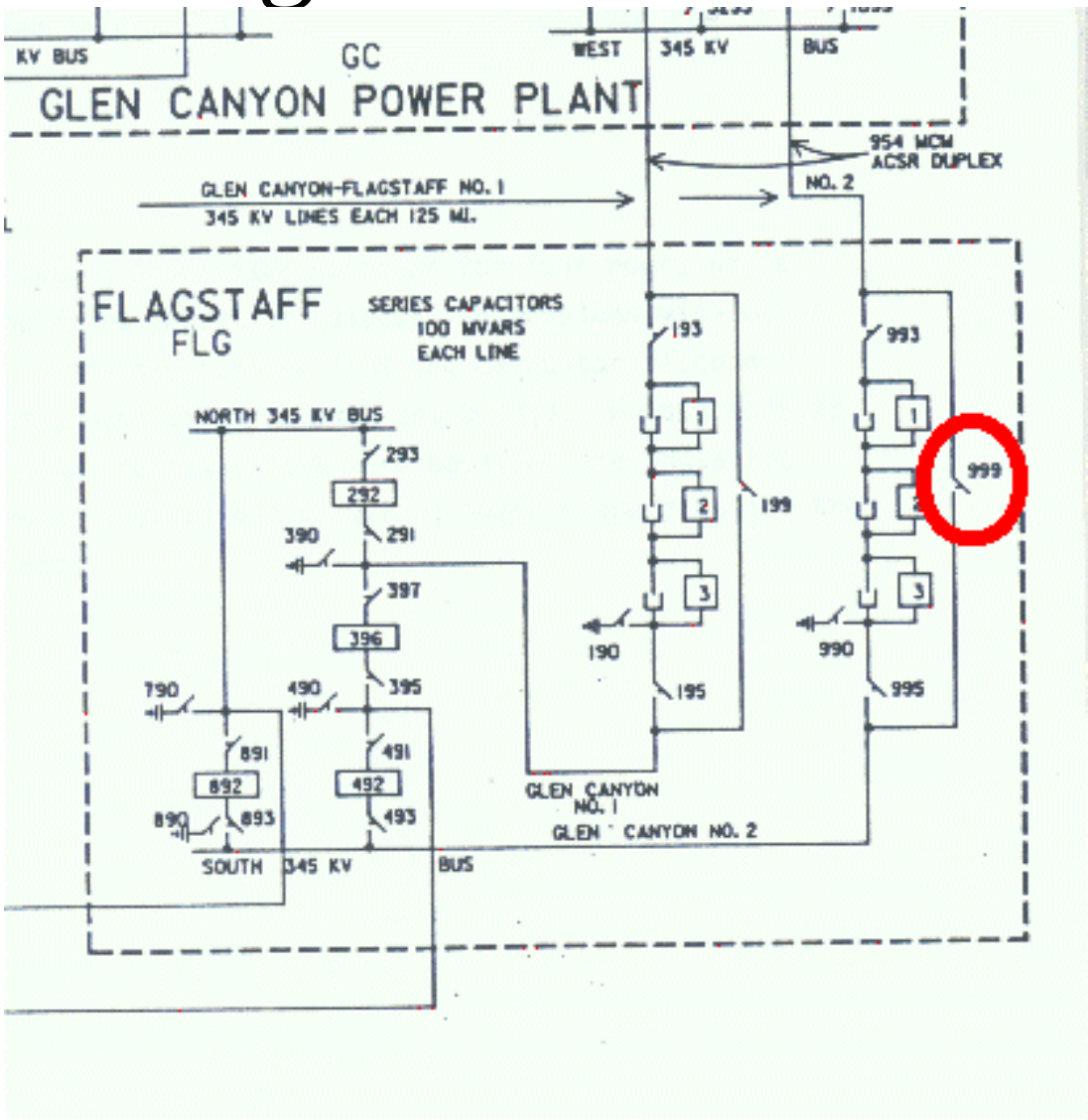
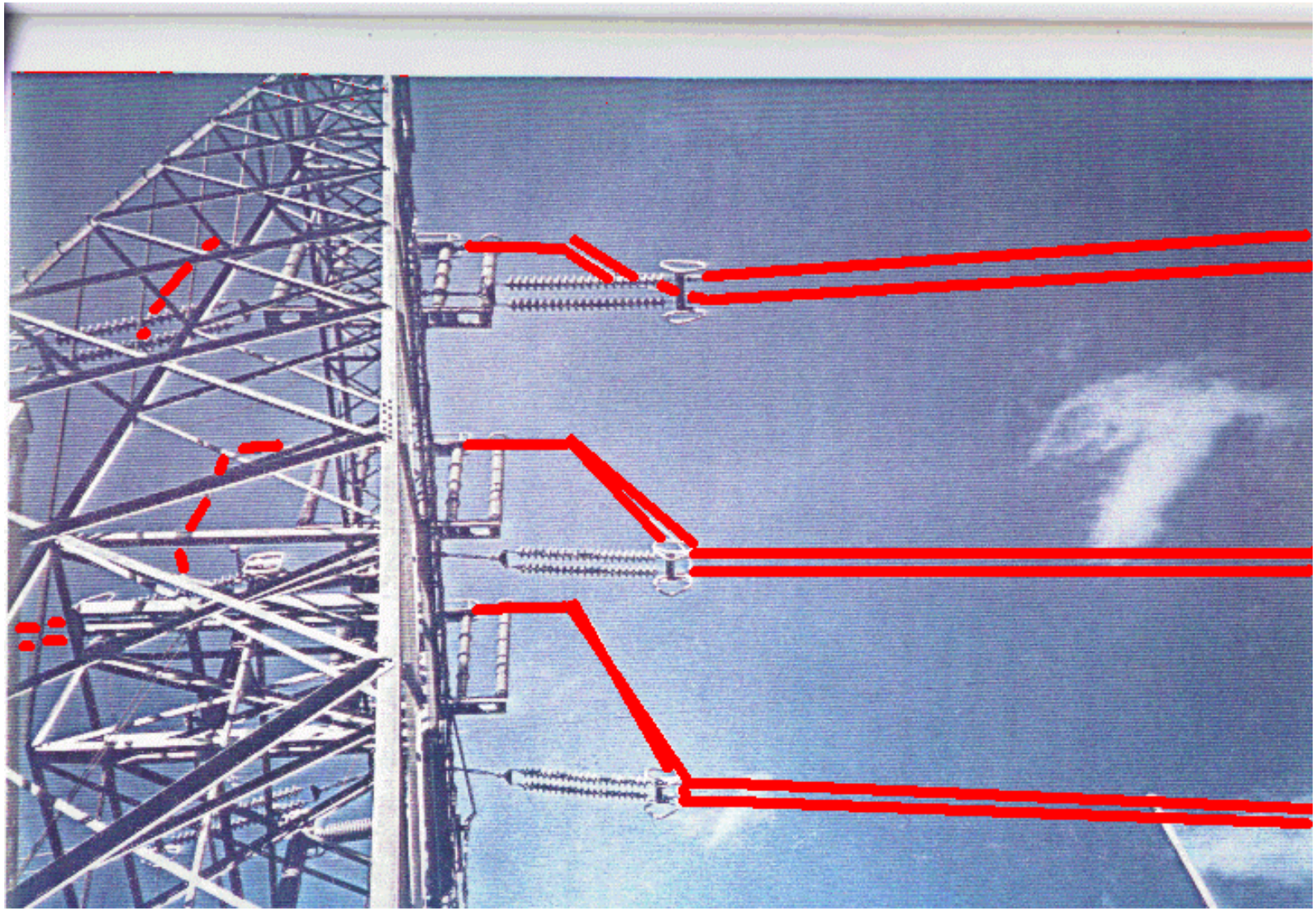
Flagstaff Substation (DSW - 1986) Accident Summary

- Accident occurred while 2 linemen were replacing a series cap bypass switch. Personal grounds were removed from the line side and while working out of an insulated manlift, one employee touched the switch jumper, and another employee touched the grounded substation conductor. This placed both their bodies in series to ground with the induced energy on the line; the energy passed through both employees.

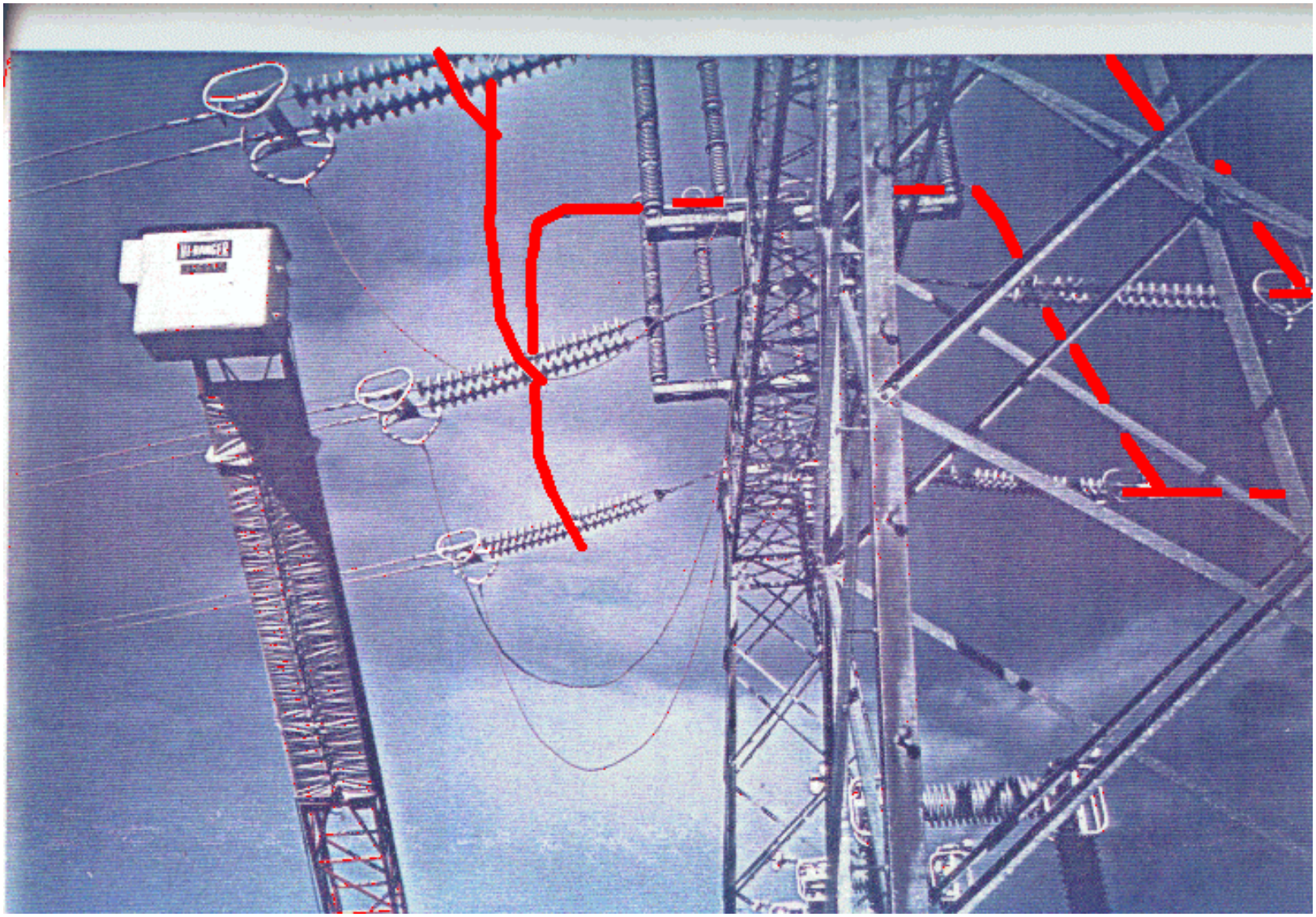
Flagstaff Substation



North end of Bypass Switch



South end of Bypass Switch



Judgements of Need

- Compliance with the PSSM is mandatory and must be enforced.
- A procedure should be developed to allow day to day routine tracking of proper application of grounds. Such tracking should be accomplished by a formal method of listing grounds and their application on each job.
- Mechanical jumpers must not be substituted for personal protective grounds. Such jumpers must be subjected to appropriate fabrication and testing procedures.

Judgements of Need

- The requirements for job hazard analysis and/or other formal job planning must be clarified and strictly enforced.
- Review the adequacy of first aid and cardiopulmonary resuscitation (CPR) for its application to the specific needs of electrical utility workers.

PSSM Rules

- Treat electrical circuits and equipment, normally energized at 600 volts or more, as energized unless they are deenergized, isolated, a clearance is secured, and they are properly grounded (10.1.a.).
- When working in an area of a substation under a clearance where there are one or more physical breaks in the electrical circuit, install personal protective grounds on each section of the circuit if a hazard exists (10.7.g).

Construction Language

- General: In addition to the requirements contained in OSHA 1926, Subpart V, “Power Transmission and Distribution”, and other applicable OSHA requirements, the requirements contained in this paragraph apply.

OSHA 1926 Subpart V

- Standard Number: 1926.954
- Standard Title: Grounding for protection of employees.
- SubPart Number: V
- SubPart Title: Power Transmission and Distribution
- (a)General. All conductors and equipment shall be treated as energized until tested or otherwise determined to be deenergized or until grounded.

Personal Protective Grounding Training

Personal Protective Grounding

- Review of Accident Investigations.
  - Judgements of need.
  - PSSM, OSHA, and Contract Requirements
  - Confusing areas.
  - Areas not addressed?
- Grounding Rules of Thumb/Fault Studies; Discussion.

Grounding Accidents

- New Melones switch yard (SNR - 1980).
- Flagstaff Substation (DSW - 1986).
- Carter Mnt.-Thermop. line (RMR - 1993).
- Carrington Substation (UGPR - 1993).
- Laramie Switchyard (RMR - 1995).
- ED-2 Substation (DSW - 1996).
- Casa Grande Substation (DSW - 1998).

Grounding Rules of Thumb

- Always ground (close as practical) at worksite.
- Personal protective grounding means creating only **<u>one</u>** personal protective grounding path for fault, static, and induced current (worksite-rated).
- “Bonding” means placing yourself and or equipment in “parallel” with the *one* personal protective grounding path (not rated).
- All equipment and hardware within a worker’s possession or reach must be *bonded* to the *one* personal protective grounding path.

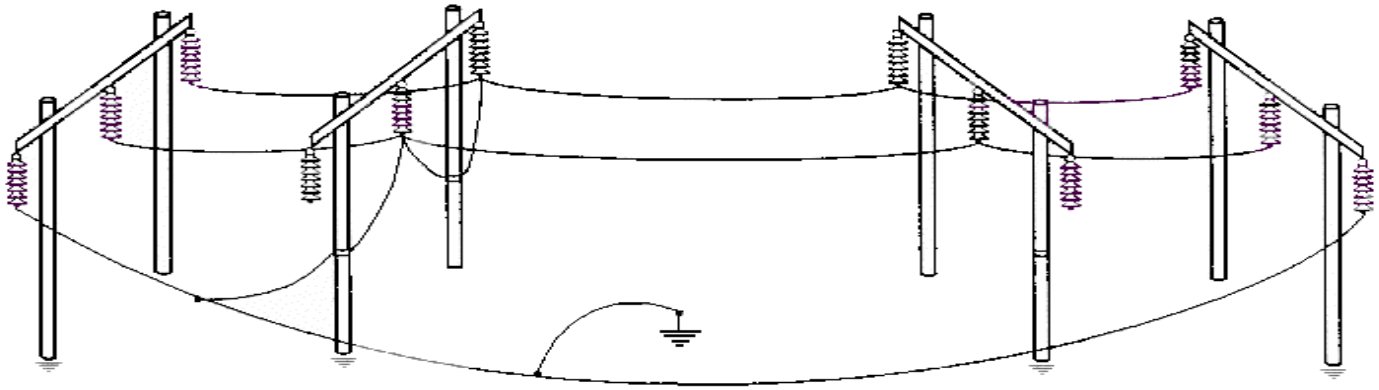
Grounding Rules of Thumb (cont.)

- Properly installed grounds at the worksite DOES NOT MEAN THE **JOB SITE** IS FREE FROM ELECTRICAL HAZARDS. It does remove the electrical hazard from the work **location**, however it creates another electrical hazard (step and touch potential) at the grounded location(s).

Areas of High Frequency of Incidents

- Cutting conductors or removing jumpers changes the circuit. Consider the ***before*** and ***after*** configuration of the circuit prior to performing the splice or removing or connecting the jumper.
- Parallel conditions requires special grounding applications. Why is this considered an issue?

Severing or Splicing



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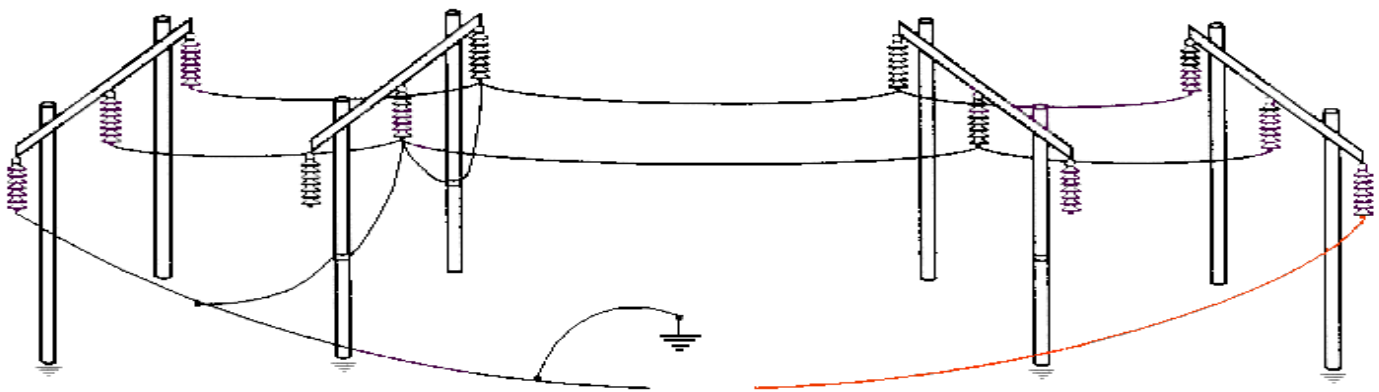
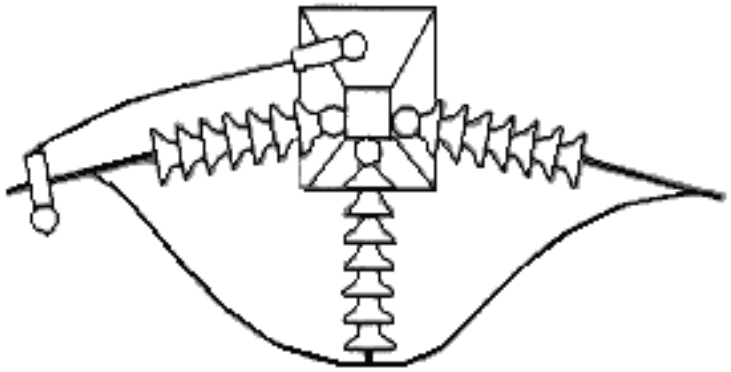


AFTER

Jumpers



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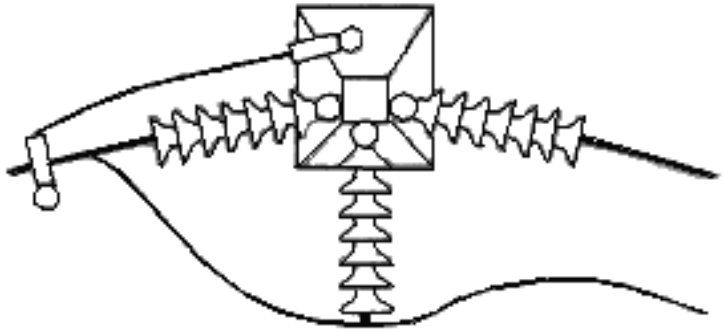


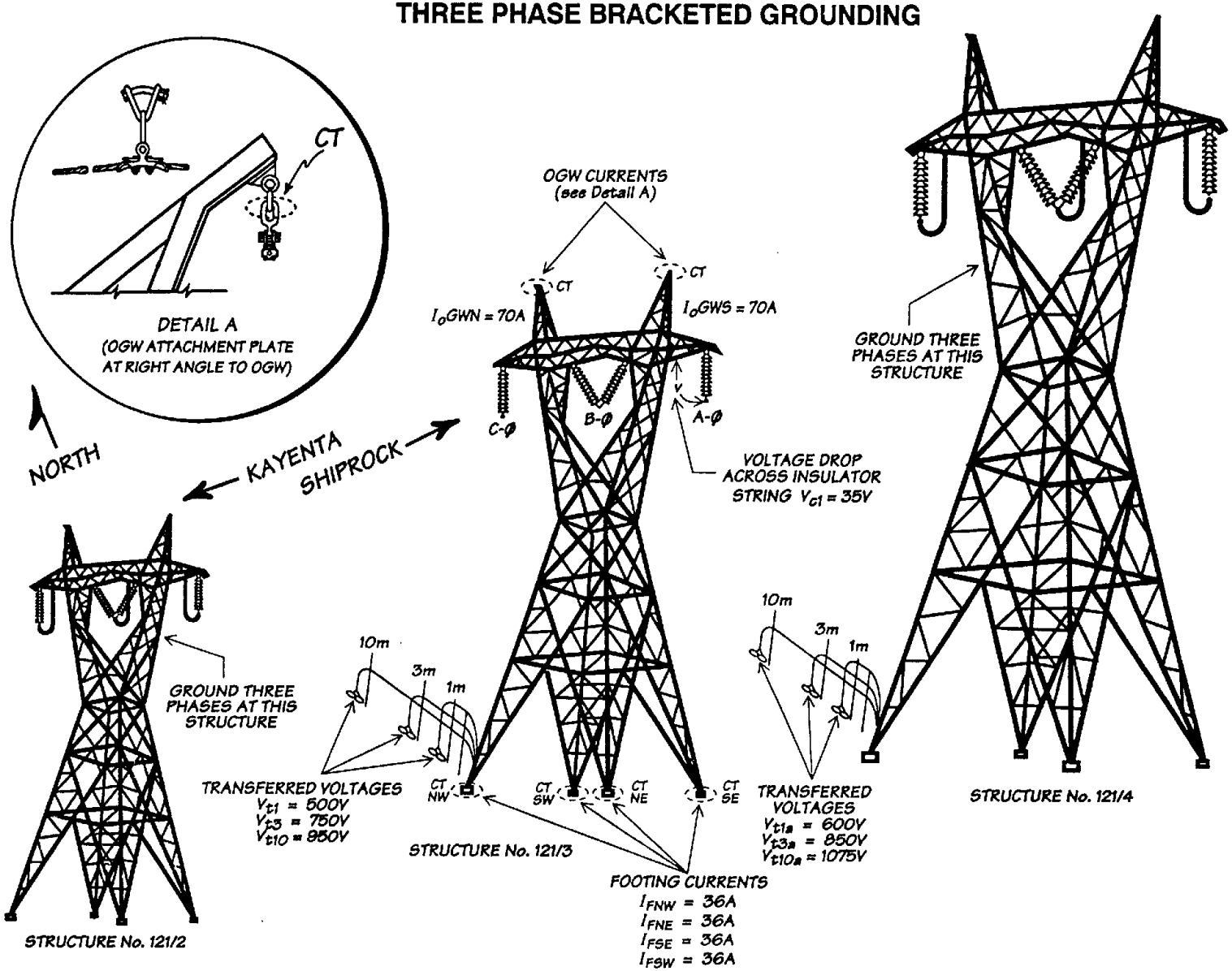
AFTER

Parallel Conditions/Circulating Ground Current

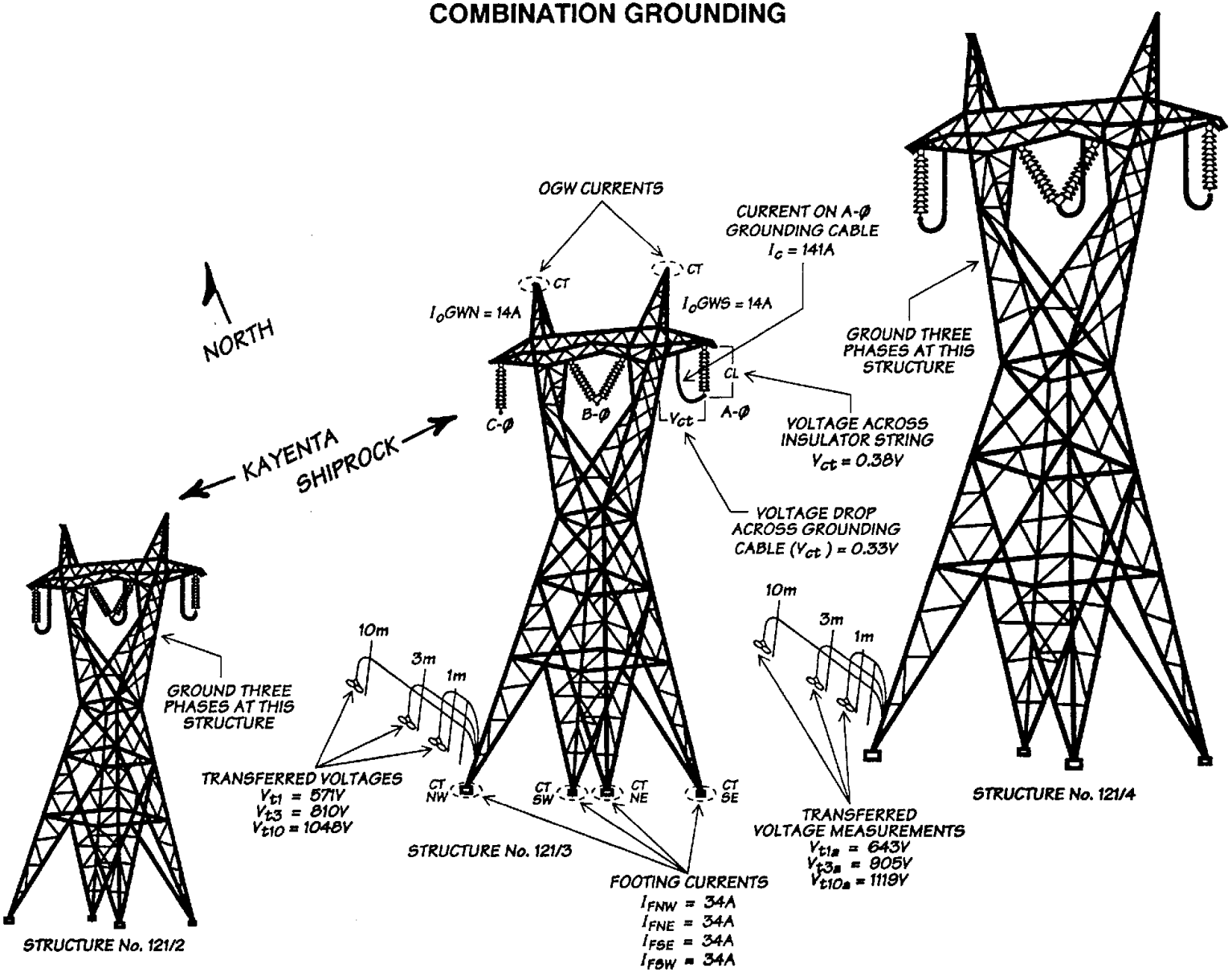
Circulating Ground Current Hazards

- Step potential - Near grounds (structure grounds, grounded equipment and ground rods).
- Touch potential - Between ground and structures and grounded equipment.
- Corrective actions - Keep personnel at least 10 feet away from grounding system (ground rods, structure grounds, down guys, grounded vehicles, etc.).

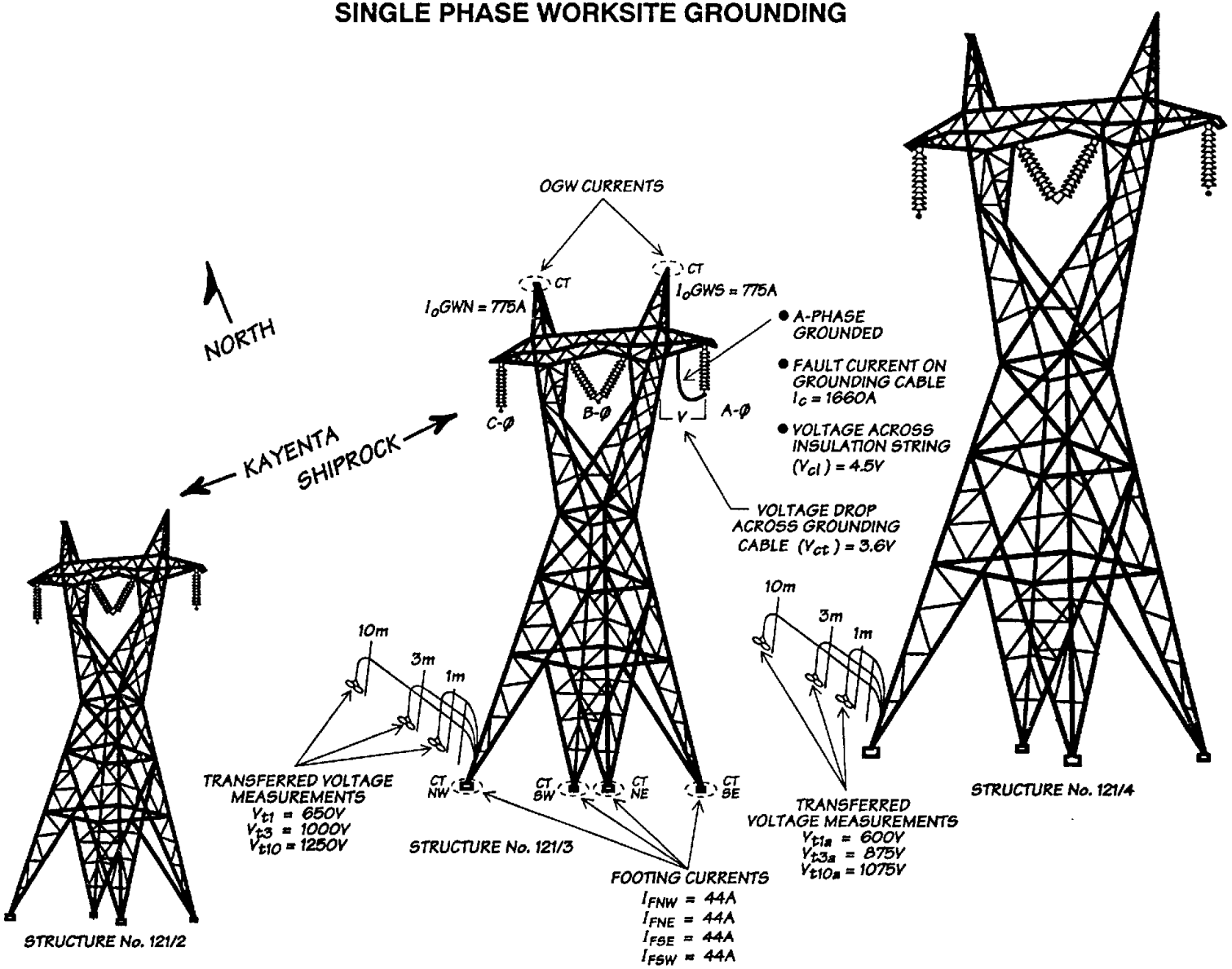
THREE PHASE BRACKETED GROUNDING



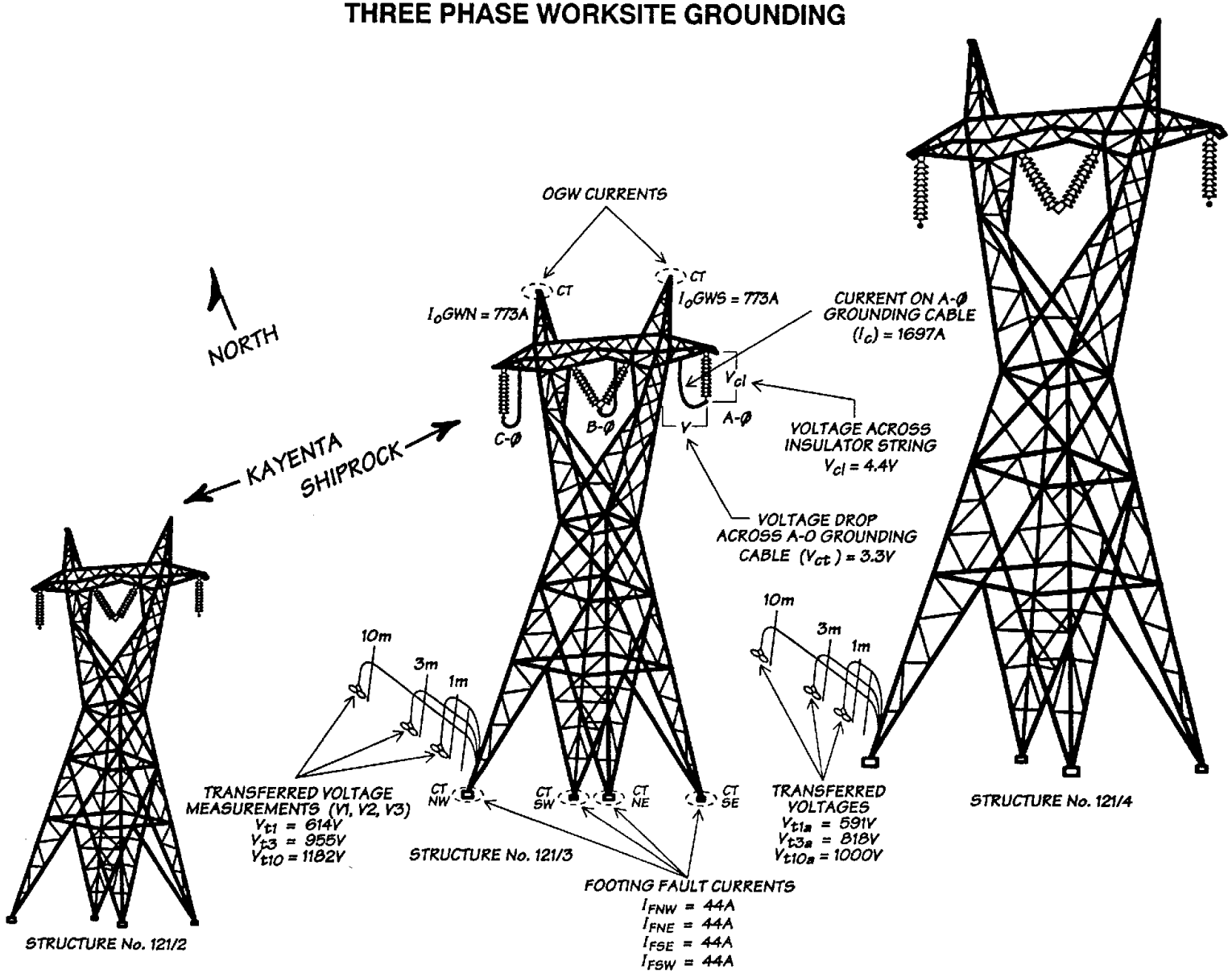
COMBINATION GROUNDING



SINGLE PHASE WORKSITE GROUNDING



THREE PHASE WORKSITE GROUNDING



Removing/Avoiding Circulating Ground Current

- Only one crew on a line at one time.
- Keep disconnects open while worksite grounds are in place.
- When more than one crew is on the line at one time, sectionalize the line with open breaks (for each crew).
- Use live-line hotstick methods in performing maintenance on the deenergized line.

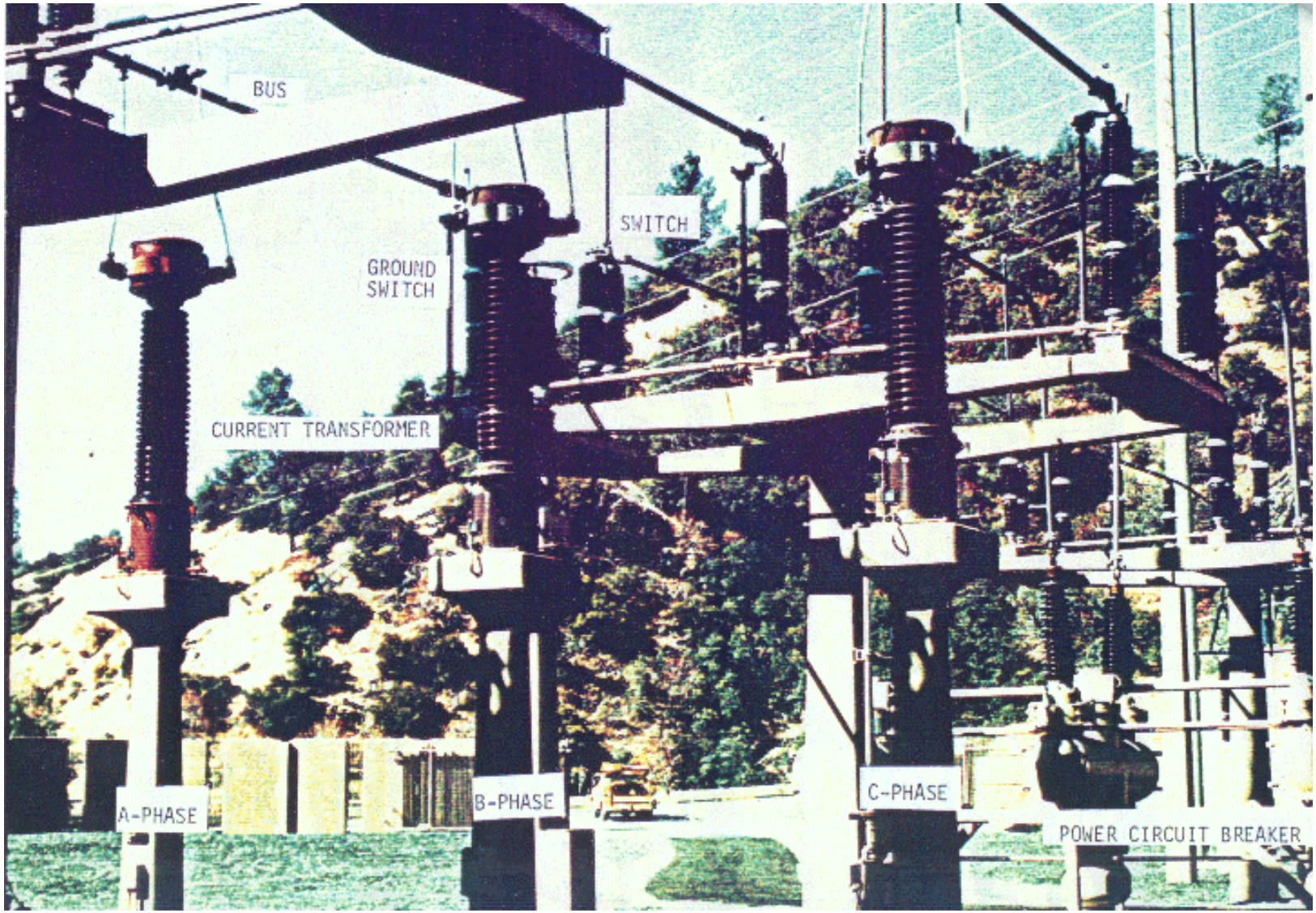
Worksite Grounding Procedures - High Induced Voltage

- Use in-line interrupters.
- Close ground switches while personal grounds are being installed or removed - then re-open after grounds are in place or removed.
- Deenergize parallel line while grounds are being installed or removed - then reenergize after grounds are in place or removed.

New Melones switch yard (SNR - 1980) - Accident Summary

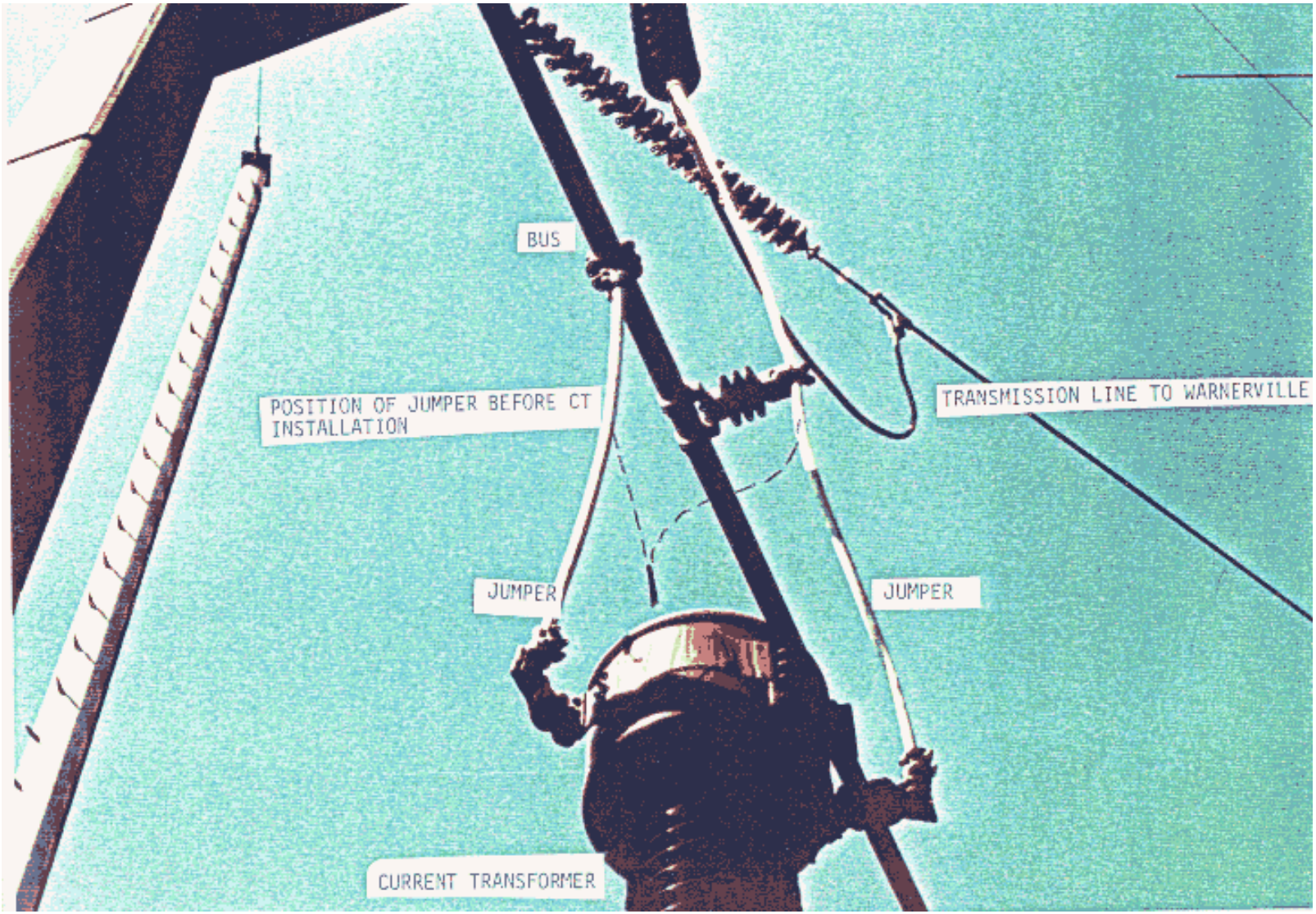
- A Western line crew was installing a current transformer. A personal ground was installed on the interconnecting bus only. The employee was in the process of disconnecting jumper leads from the t-line and the switchyard bus from a bucket truck. When the jumper was separated, the effective protection was negated and received burns due to induced voltage.

New Melones switch yard

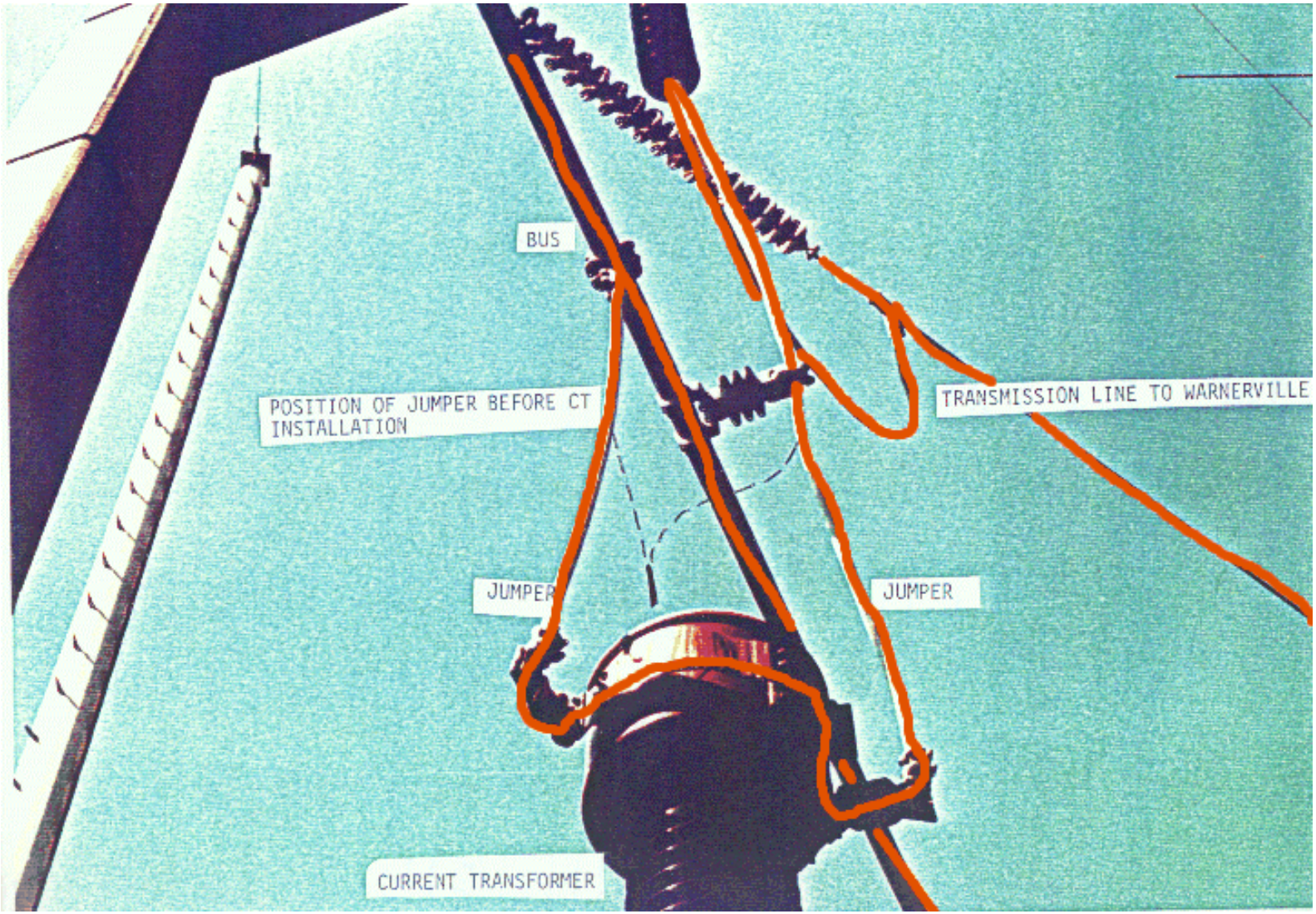


New Melones Switch Yard

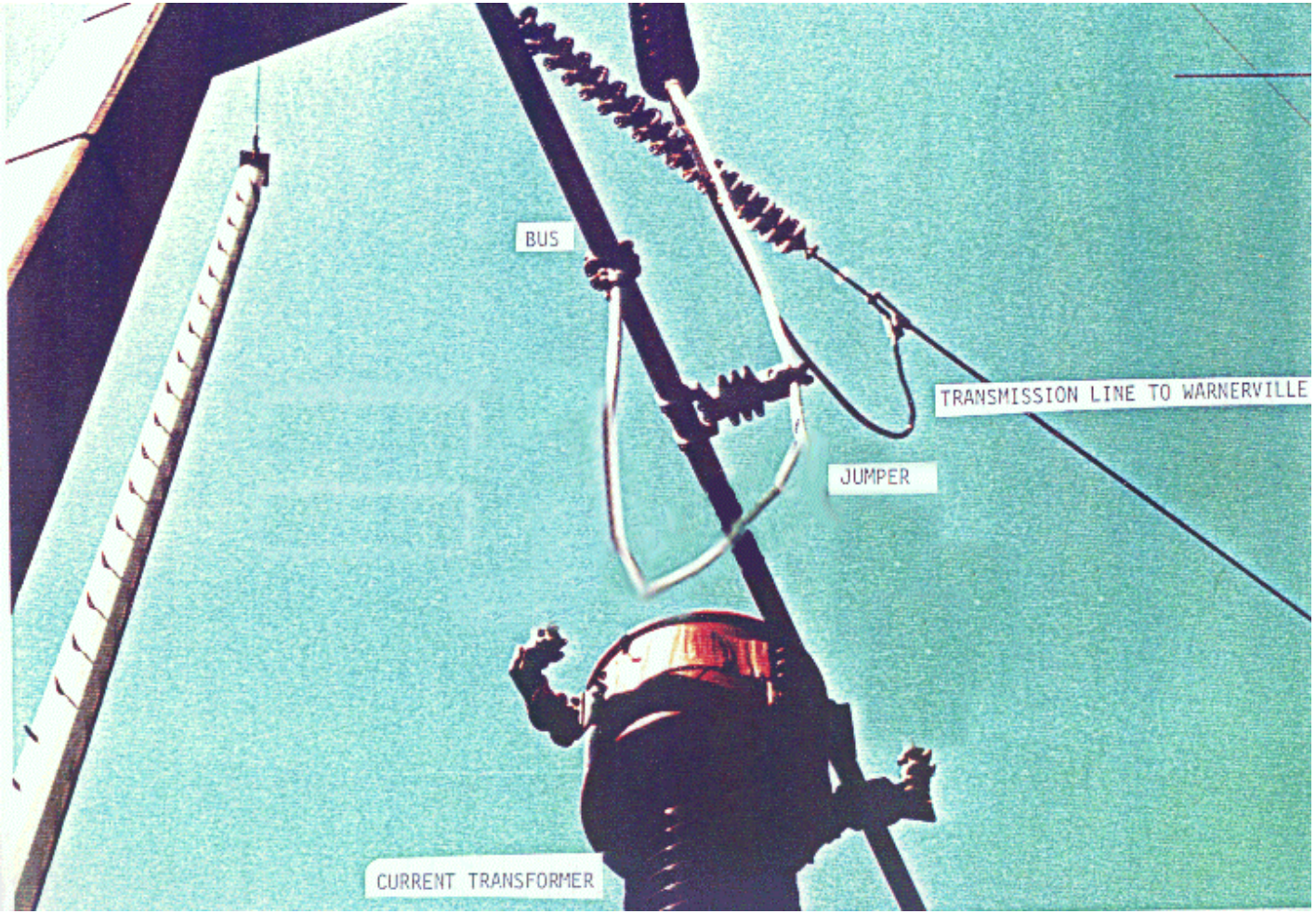
CT With Jumper Assembly



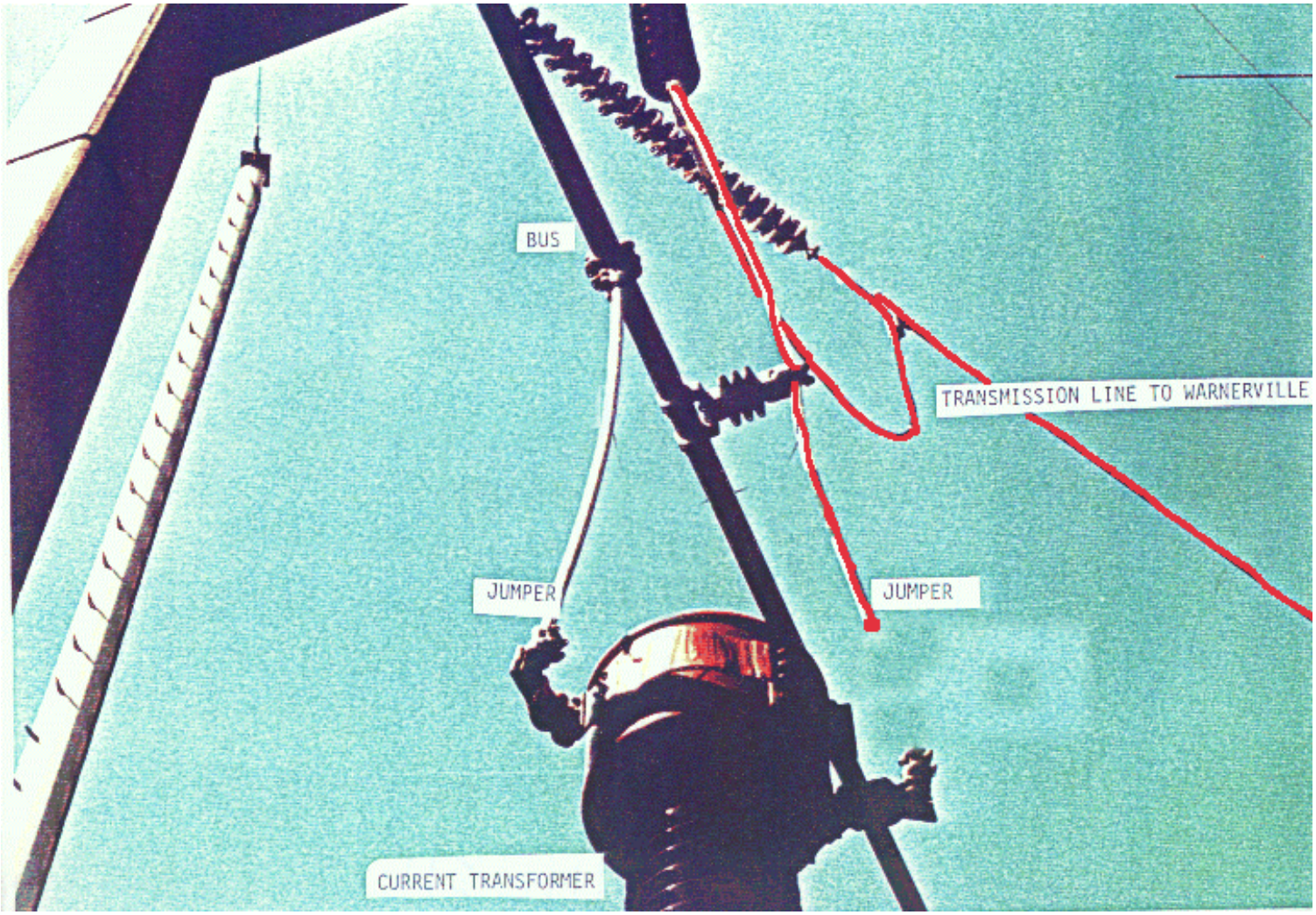
CT in Service



CT Disconnected from Jumper Assembly; Bus or Line Grounded



Bus Side Grounded With Separated Jumper



Judgements of Need

- Supervisory personnel should develop a check list system to use before starting any job even when the job is considered “routine”.
- **Greater care must be exercised by all crew members to assure that all paths of current are isolated from their bodies or shunted to ground.**
- Amelioration should be studied for each job-site and procedures developed and formalized.

PSSM Rules

- When working in an area of a substation under a clearance where there are one or more physical breaks in the electrical circuit, install personal protective grounds on each section of the circuit if a hazard exists (10.7.g).
- Before separating and/or splicing a conductor or OGW at an in-span location above ground level from an insulated or uninsulated aerial device, take the following precautions: Bond all conductors together, including OGW when applicable, and bond them to a ground as near the worksite as practical (10.10.b(1)).

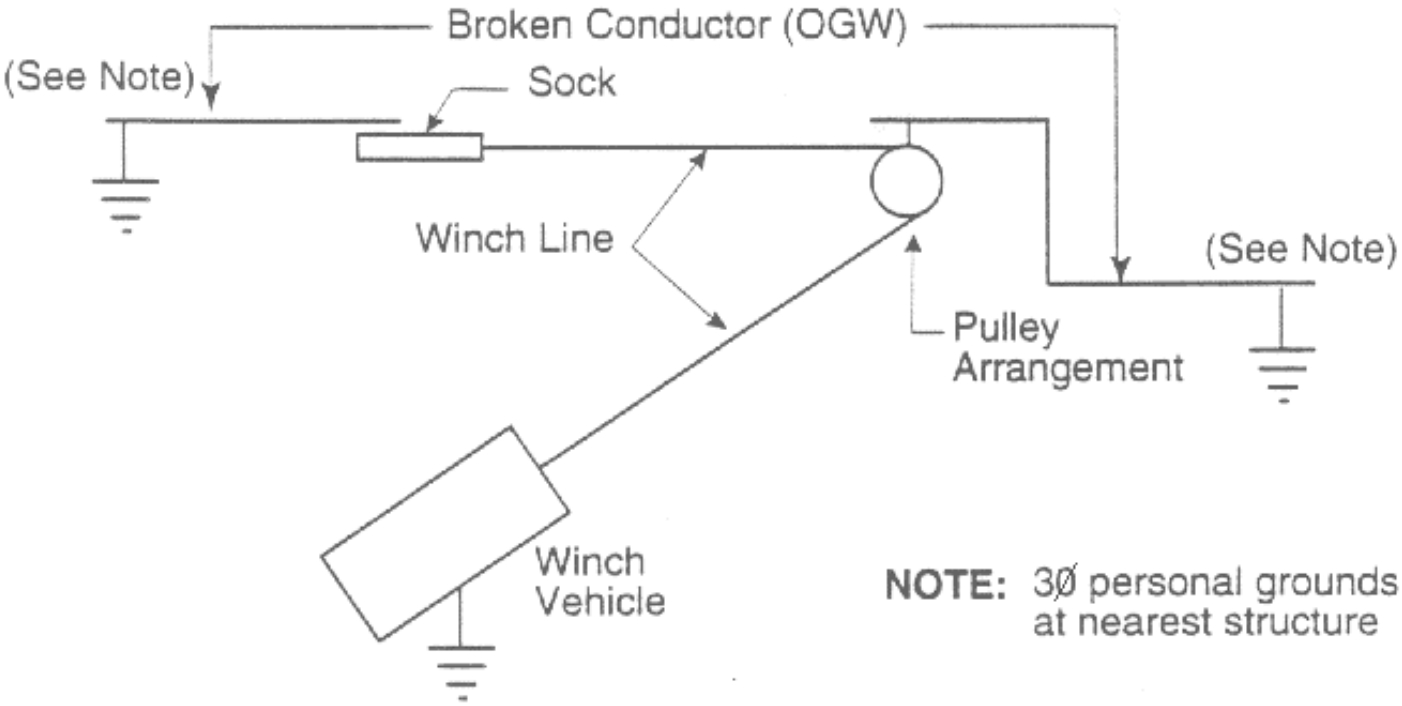
Contract Language

- In addition to the requirements contained in OSHA 1926, Subpart V, “Power Transmission and Distribution”, and other applicable OSHA requirements, the requirements contained in this paragraph apply.

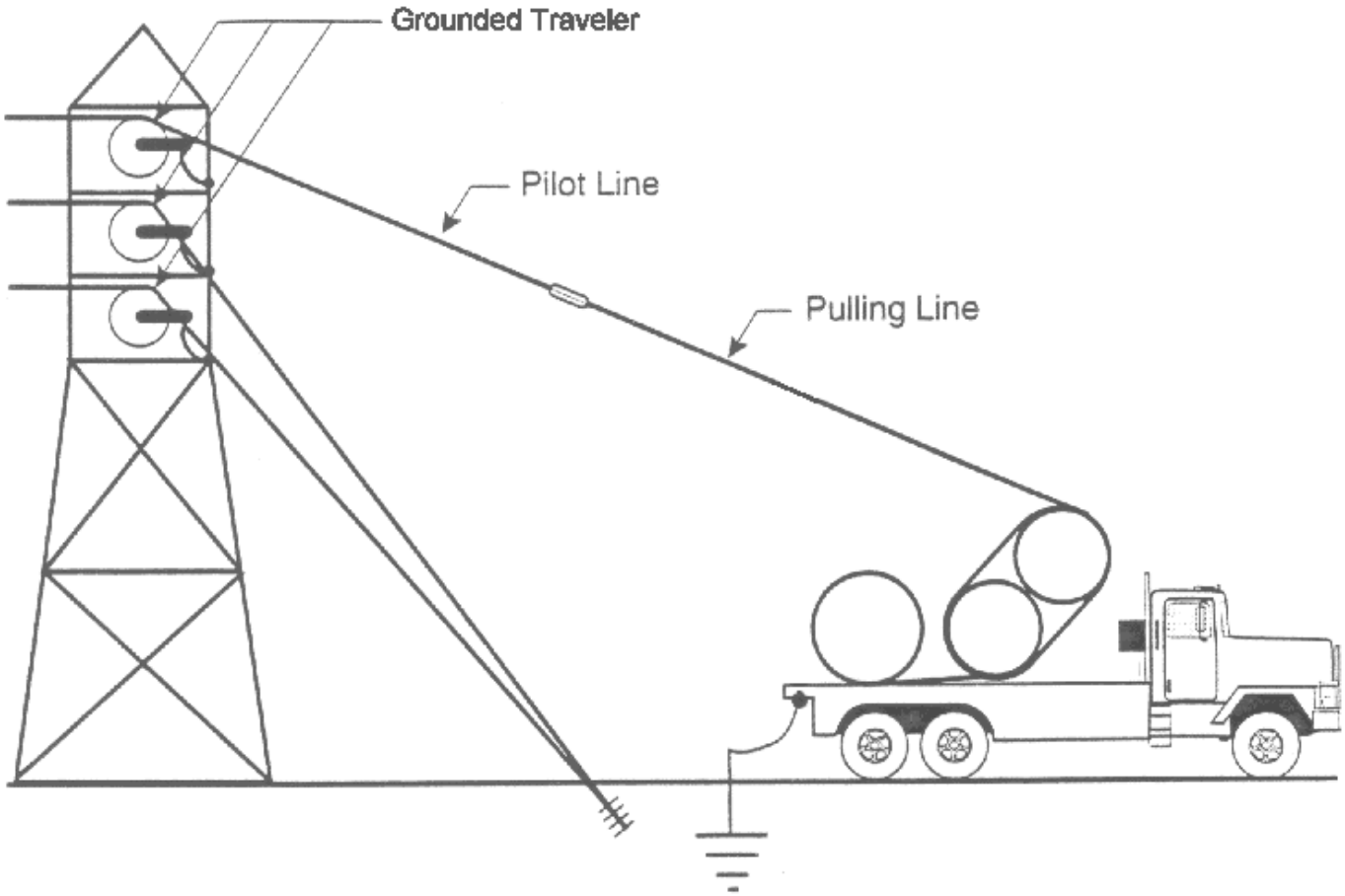
OSHA 1926 Subpart V

- 926.954 (Grounding for protection of employees) (f) Grounds shall be placed between work location and all sources of energy and as close as practicable to the work location, or grounds shall be placed at the work location. The minimum distance shown in Table V-1 shall be maintained from ungrounded conductors at the work location.

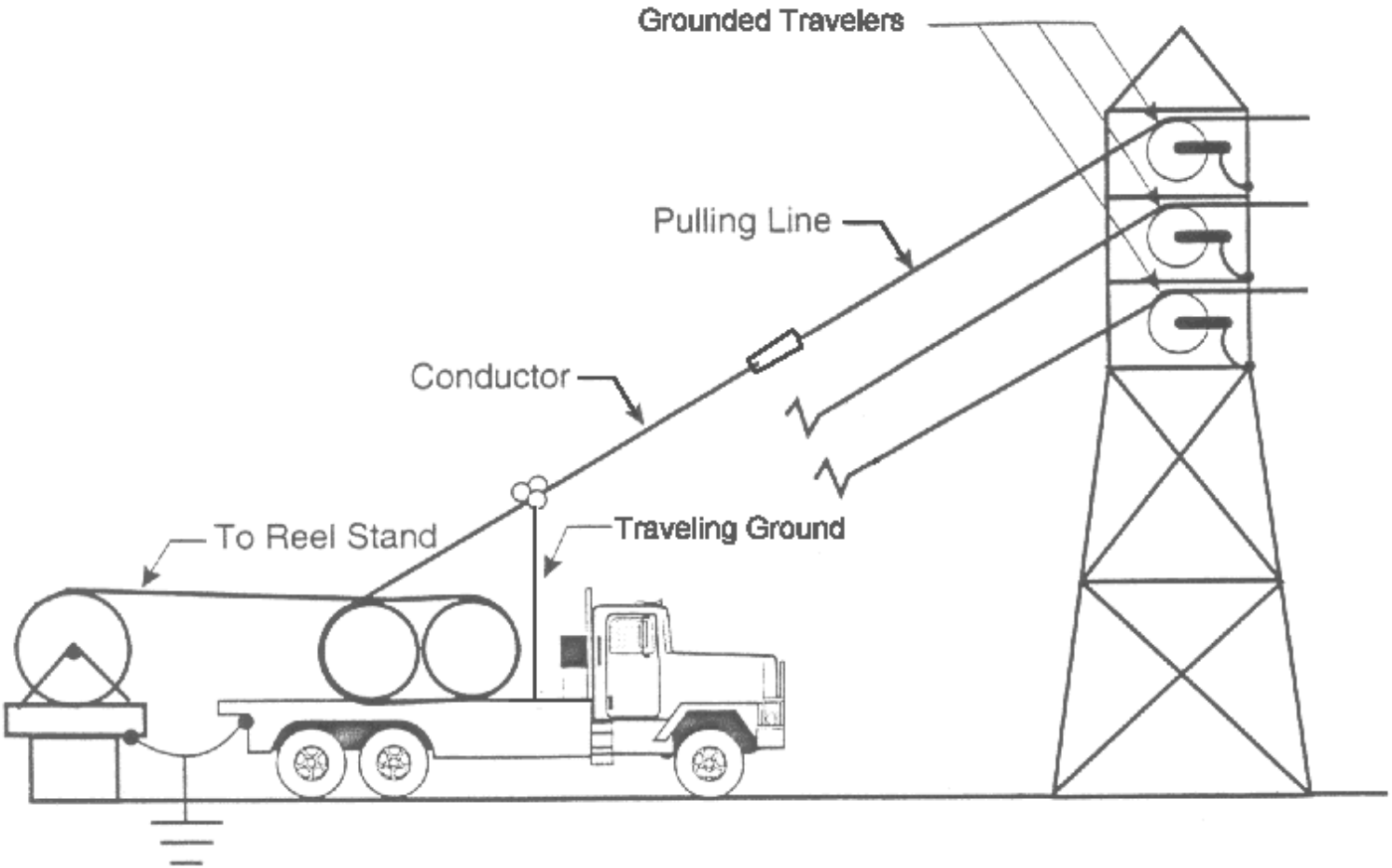
Broken Conductor Splicing



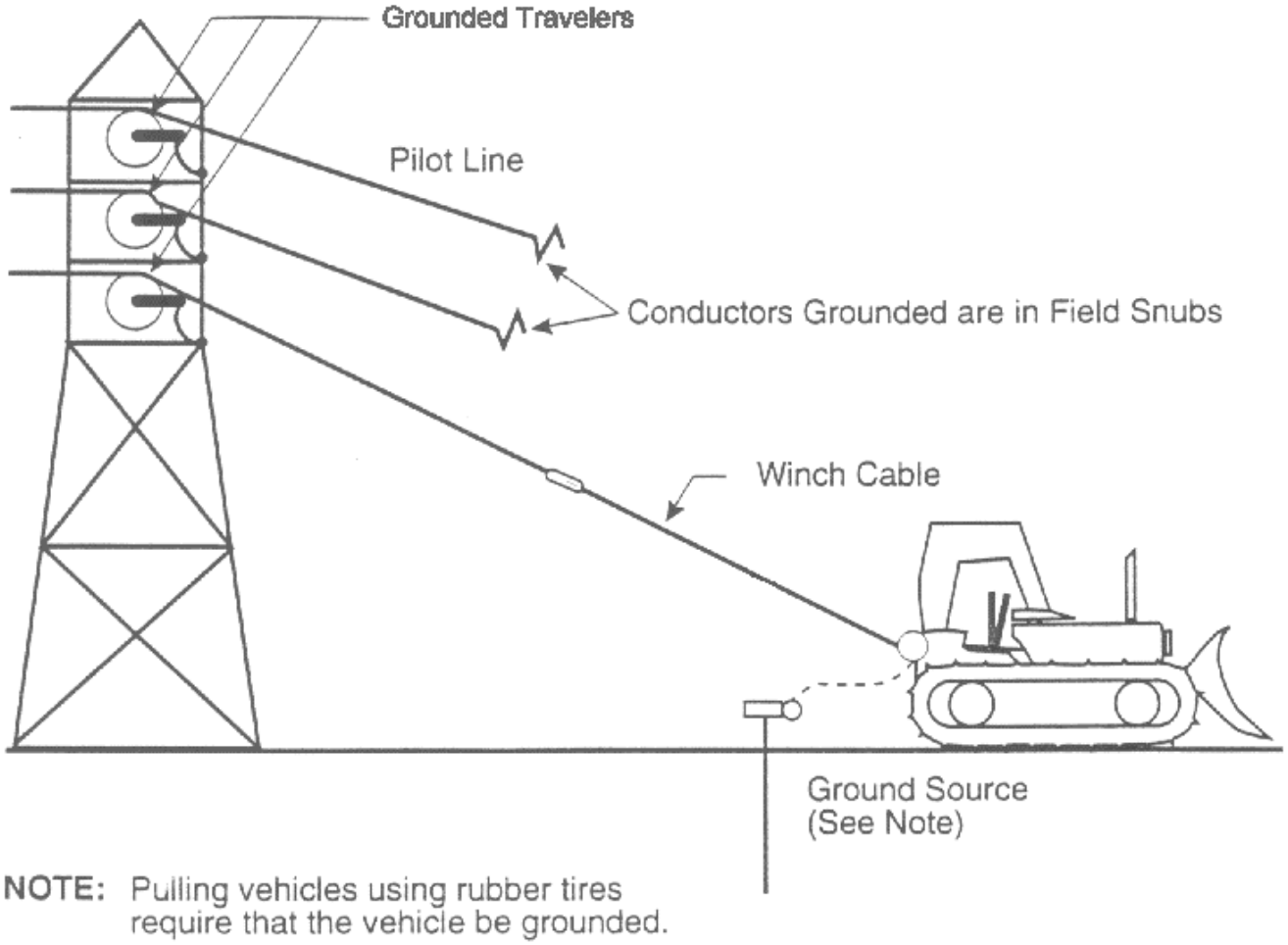
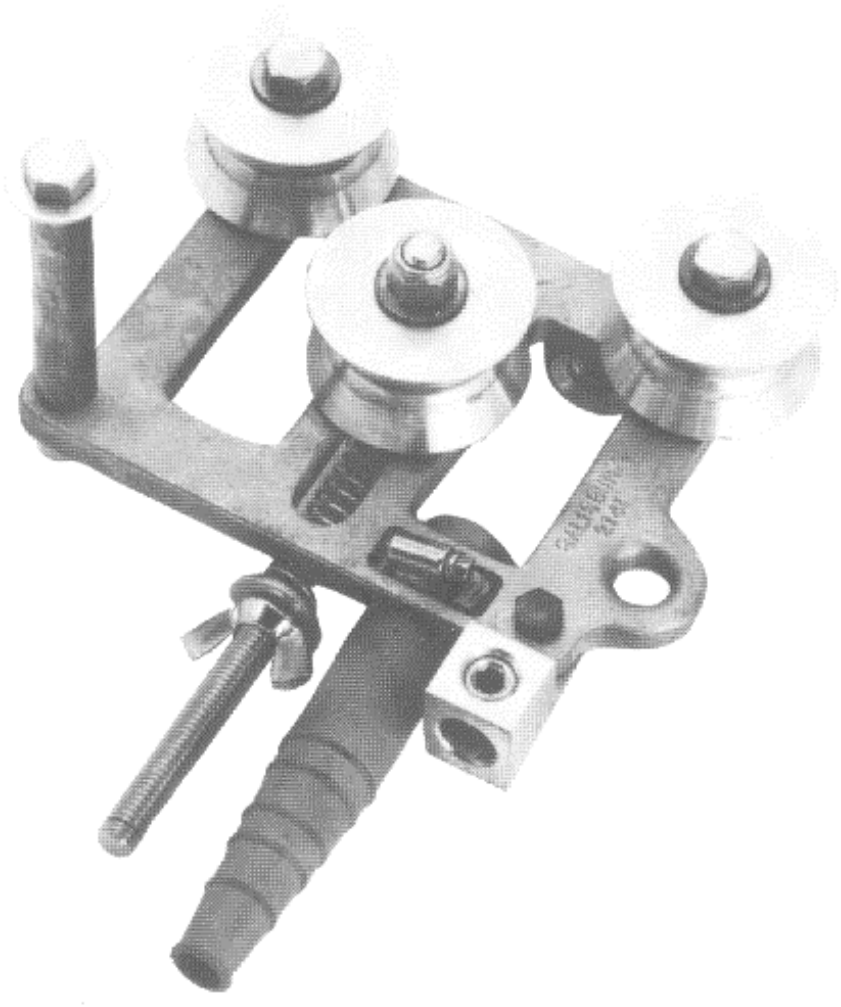
Stringing Pulling End Grounding



Stringing Tensioner End Grounding



Sagging Utilizing a Pulling Vehicle



Traveling Ground