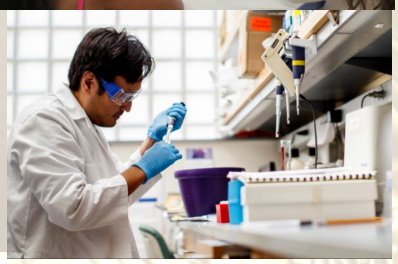
CSHEMA WEBINAR
Electrical Safety for Researchers



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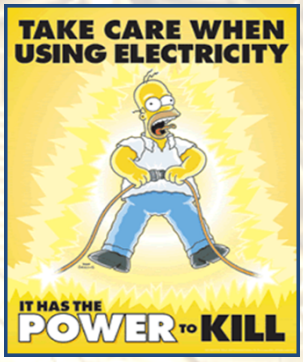
September 28, 2017

Purpose of this training

Familiarize researchers / faculty / staff and students with:

- Electrical hazards
- Electrical hazard controls, safer equipment design and safe work practices
- Lessons learned from previous electrical incidents in research
- Where to get more electrical safety information and help in safe research design.



Electrical Safety – What everyone at UC (and other institutions) should know…..

- All electrical work at UC is restricted to qualified and authorized personnel,
- The "Qualifying" and "Authorizing" process may have different criteria based upon the work and "Owner Department" requirements, and
- Departments are required to determine levels of qualification / authorization to keep personnel safe in their work processes.

Stop and ask for help or training whenever you feel unsafe or unqualified to work safely with electricity.

Electrical Safety –

What's safe for you to do without further training…..?

- ✓ Plug standard 110-120 V-AC equipment into wall outlets.
- ✓ Plug a "3-prong Power Strip" into a wall outlet, and connect low wattage (< 500 Watt) equipment to the power strip.
- ✓ Temporarily connect a tool or appliance with a 3-prong single-plug extension cord of the proper amperage / wattage rating.
- ✓ Use low voltage, small battery operated equipment, instruments and hand-tools.

Electrical Safety –

What's unsafe for you to do without further training…..?

- Work with exposed conductors carrying 50 volts or more
- Make any repairs or alterations to any electrical equipment
- Open up the case, or remove barrier guards, of any equipment that utilizes electricity, even if it's unplugged!
- Use any tools or meters to test for the presence of electricity
- Reset a tripped circuit breaker, or replace a blown fuse.

Get a qualified person to perform these tasks for you!

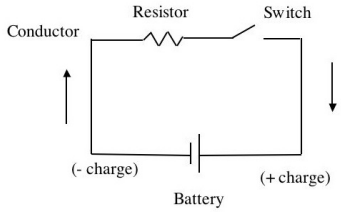
Basic Electrical Theory for Safety

- Electricity is a flow of electrons through an electrically-conductive material (**conductor**)
- Electric flow through any conductor generates **heat** due to resistance
- Electric flow is reduced when materials have higher **resistance**
- Highest resistance materials are called **insulators**
- Electricity "flows" from a high potential electron donor source to a low potential electron sink (**ground**)

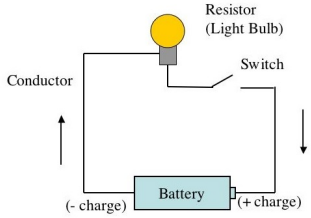
Electricity "flows" through *all pathways* from source to ground, not just the path of least resistance!!

Basic DC Power Distribution

Basic Electrical Circuit (Diagram)

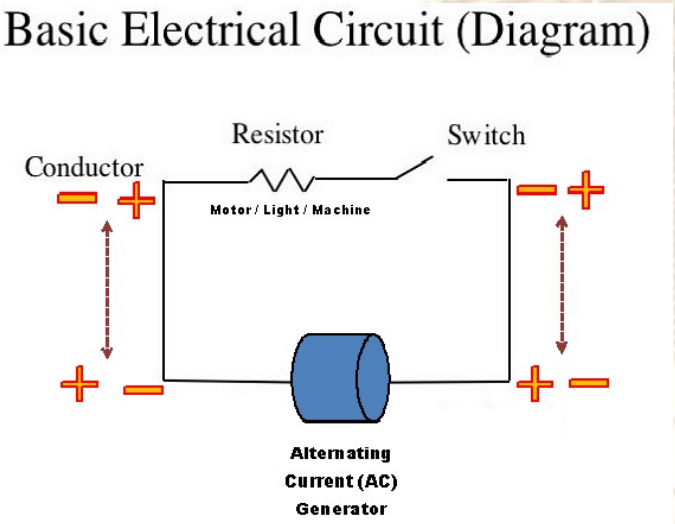


Basic Electrical Circuit (Drawing)

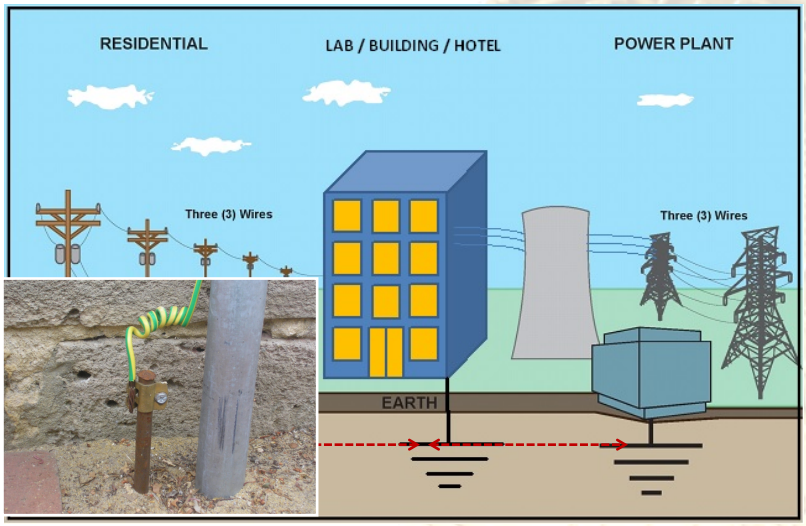


Basic DC Power Distribution

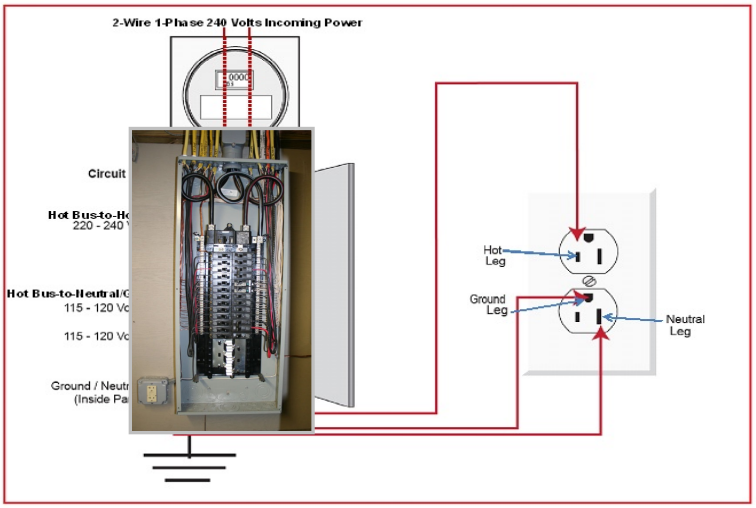
Basic AC Power Distribution



Basic Power Distribution for Safety

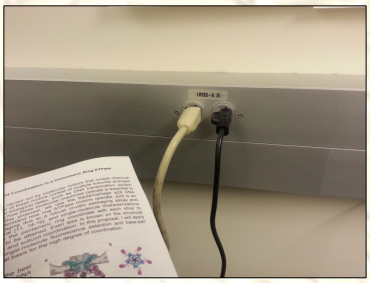


Understanding Basic Power Distribution



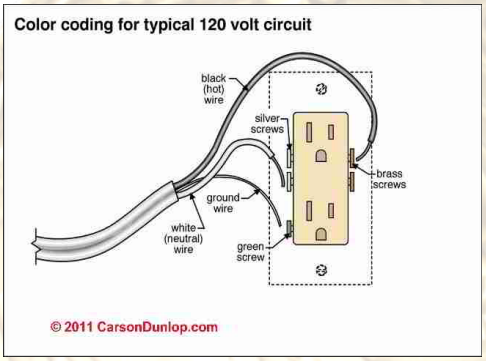
Grounded versus Ungrounded Outlets

A Shocking Incident…….



A Shocking Incident…….

- The researcher connected the green wire to hot terminal, white to neutral and black wire to ground – (Note: This is EU color-code for similar wiring!)
- This energized the power supply housing and they were shocked with 120volts through their hand and out their shoes to the floor!!
- They accidentally became part of the electrical-pathway to ground!



ELECTRICAL SAFETY RULE #1:
NEVER BECOME PART OF THE ELECTRICAL-PATHWAY TO GROUND!

Testing your outlet(s)

- Purchase a UL approved “outlet tester” at any hardware store for under $10
- Confirm the outlet is properly wired and has good quality ground wires.
- Never use an outlet that a test determines is improperly wired or does not have a good-quality ground.
- If you find a bad outlet, submit a maintenance repair work-order for repair. Until repaired, cover-over the outlet with tape and attach a warning-sign to it.

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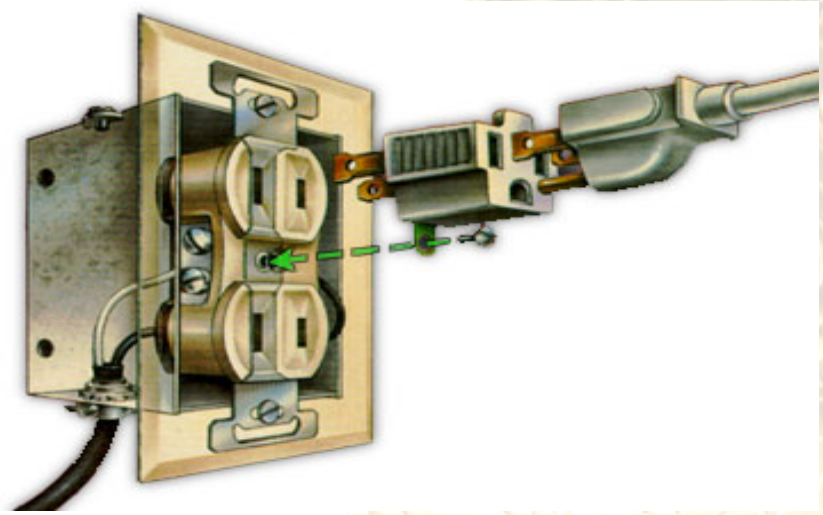
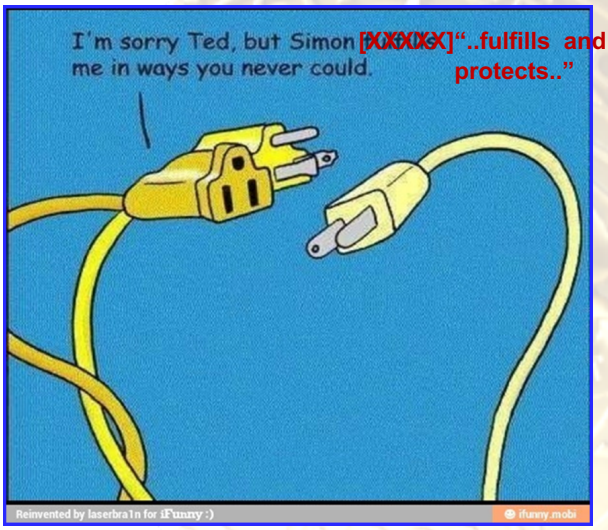
Using Plug Adapters – NOT!!



The Three-Prong Plug….. Use them!

3-Prong Plugs:

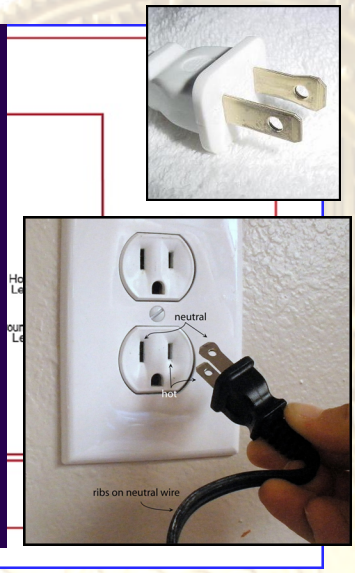
- Ensure a second low-resistance pathway to ground besides the neutral wire
- Ensure you are protected from equipment electrical-malfunction



30, 20 and 15 amp – 120 volt plugs

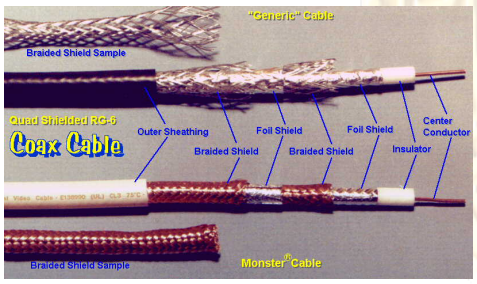
2-Prong plugs and “Double Insulation”

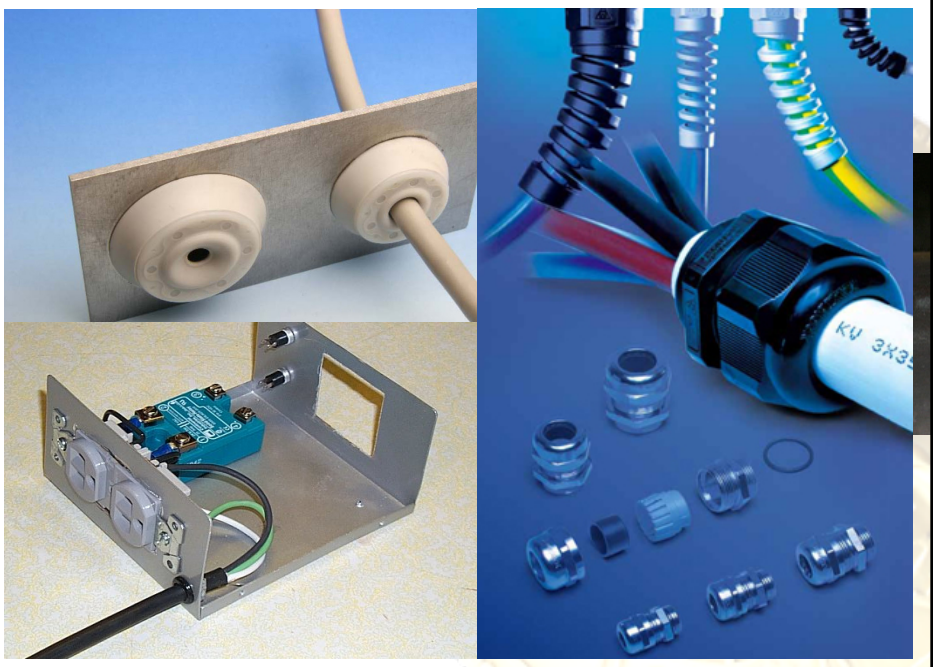
- Two prong plugs have only one-pathway for electricity to flow back to ground
- Safety codes now require 2-prong plugs to be polarized
- Polarized means the neutral wire acts as a ground too and has a larger prong than the hot prong. This prevents reversing the plug in the outlet.
- Only **low-watt, residential use and double insulated** electrical equipment and appliances are allowed 2-prongs.
- Old equipment (pre 1980s) do NOT meet this safety code and won’t have a polarized plug. Replace it if you can.



Wire structures

- Wires are made from many metals. Mostly copper alloys and aluminum.
- Copper is preferred for corrosion and transmission. More costly than aluminum.
- Single insulated wire
- Double insulated wire
- Multi-conductor “cables”





Extension Cords / Power Strips

- Used with electrical equipment in temporary locations
- Must be removed when no longer in use.
- Must run through a cord-protector or under a bridge when they may be stepped on, run-over by vehicle or otherwise damaged.
- Must be at least 3-wire (115 VAC) and sized for greater-than the intended full-amp load. (
- Must be inspected for damage before each use and discarded if damaged in any way. (click for automation)

Wire identification labels

(See samples)

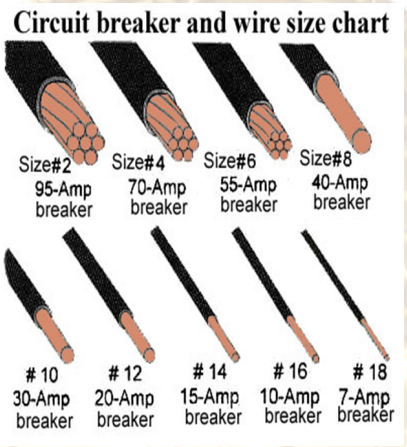
- All commercial grade wires will have identification labeling on the wire itself.
- Cable will have engraved or printed information on the wire-jacket

On this cord, SJTW indicates the jacket type and AWG 18/3 indicates the gauge rating.

Extension Cords – Size Selection

- **Proper Length** – Not under physical-tension, no trip hazards
- **Proper thickness** – Full amps load or more
- **Rule of thumb – 15 amp circuit** - Use 14-gage or less sized wire – Use 12-gage for greater than 50’ runs.
- **Rule of thumb - 20-amp circuit** - Use 12-gage or less sized wire – Use 10-gage for greater than 50’ runs.

Note: Wire thickness gets larger as the size number gets smaller!



Surge Suppressors and Protectors versus Power Taps / Power Strips

SURGE PROTECTOR

POWER STRIP / POWER TAP

Surge Suppressors/Protectors Must:

- Be equipped with an automatic circuit breaker (power strips with fuses or without over current protection are not acceptable).
- Be protected where exposed to foot or wheel traffic to minimize tripping hazards and damage to the cords.
- Be a UL 1449 listed “Transient Voltage Surge Suppressor”.

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When choosing a surge protector, look for the following:

- The UL 1449 Suppressed Voltage rating. The lower the rating, the higher the safety.
  - 500V – Good; 400V – Better; 330V - Best
- Stages of Protection/Surge Current Rating: The more stages, the better the protection.
  - 1 stage – Good; 2 stages – Better; 3 stages - Best
- Clamping Response Time: How quickly does the suppressor respond to shut-off a surge?
  - Microsecond (millionth of a second) - Good
  - Nanosecond (billionths of a second) – Better
  - Picosecond (trillionths of a second) – Best

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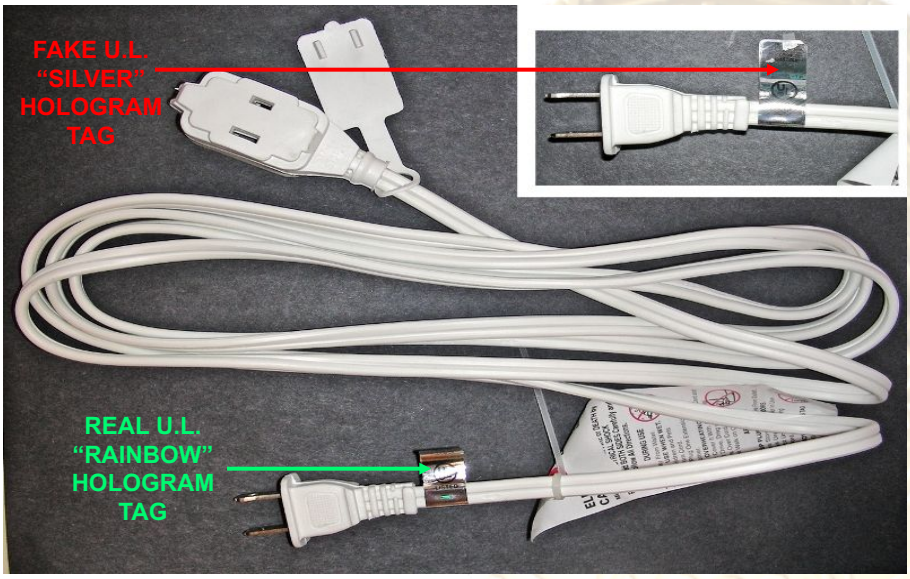
Counterfeit U.L. Label – Beware!

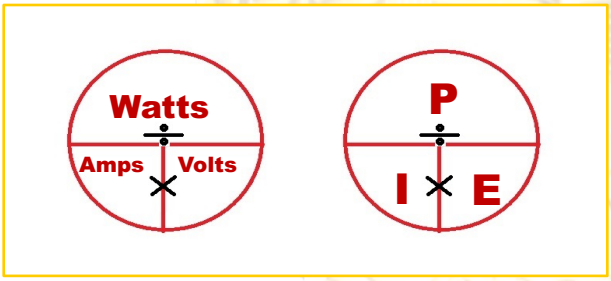


Basic Electrical Theory for Safety

So, ……Watt(s) are Volts and Amps?

(Ohms Law)

- **Volts** = "Pressure" of electric potential (E)
- **Amps** = "Volume" of electric flow (I)
- **Watts** = Power used ("Watt" you pay ($$) for = P)
- And by the math….. **Watts = Volts x Amps**

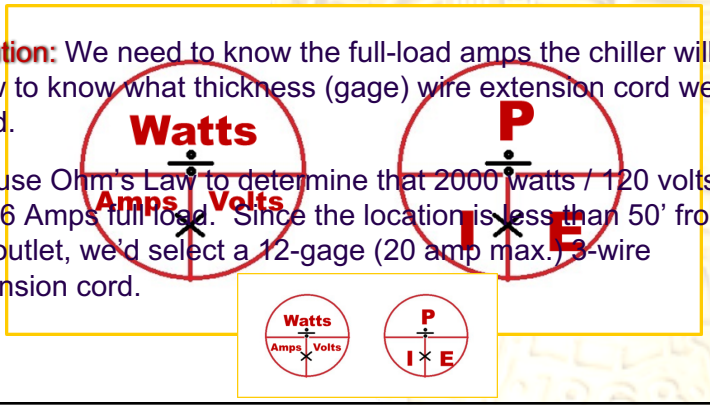


Extension Cord Selection - Quiz

Problem: You want to plug in a water chiller and pump system, but where it's located is 20' from the 120 volt wall outlet. The chiller's manufacturer's plate says that the chiller takes 2000 watts. What size wire extension cord should you use?

Solution: We need to know the full-load amps the chiller will draw to know what thickness (gage) wire extension cord we'll need.

We use Ohm's Law to determine that 2000 watts / 120 volts = 16.66 Amps full load. Since the location is less than 50' from the outlet, we'd select a 12-gage (20 amp max.) 3-wire extension cord.

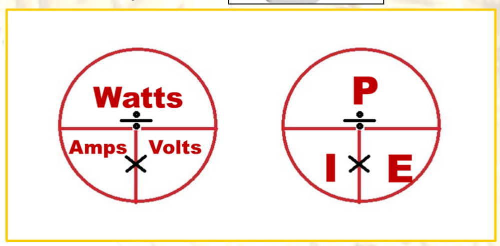


Power Strip Selection - Quiz

Problem: Your lab bench has two power supplies (500 watts each), a magnifying lamp (60 watts), your laptop computer (50 watts), a process pump (75 watts) and a heating tape (1000 watts) that you want to power through a 14-gage 6-outlet 3-prong power strip. Is this safe to do so?

Solution: We need to know the full load amps all the electrical gear will draw, to know what thickness (gage) wire your power strip is safe. Add up all the watts drawn by each piece of equipment = 2185 watts. We use Ohm's Law to get the amperage: 2185 watts / 120 volts = 18.2 Amps full load. A 14-gage power-strip is limited to 15 amps, so this would NOT be safe.

How could you make this safe?



Extension Cord "Don'ts"

- Never Daisy Chain
- Never run through open doors / windows
- Never run in vehicle or foot traffic aisles without protection
- Never run under carpets
- Heaters, Heat Tapes, Ovens, larger power supplies, etc. should always be connected directly to a wall outlet and should never be connected to a Power Strip.
- High wattage appliance can pose a fire hazard. Check with an EH&S Safety Engineer or with the campus Fire Marshal before use.

Hazards of Electricity

- Contact Electric Shock / Electrocution
- Arc Blast / Arc Flash
- Ignition Source (flammable atmosphere / materials)
- Static Accumulation / Discharge
- Induced Electric Charges
- Stored Electric Charges

Keeping Yourself Safe from Electric Shock

Your body is 70% water – a good conductor! To stay safe, don't let any part of your body become part of the electric-pathway to ground.

Electric shock can cause:

- Heart Fibrillation / Stoppage
- Respiratory Arrest
- Severe Burns
- Internal Tissue Damage
- Nerve Damage
- Latch-on Muscle Contraction
- Impeded Brain Function
- Death (Called "**Electrocution**")

Physical Effects of AC Shock

Physical effect	Current (mA)
Tingling	~ 1
"Latch On" threshold	~ 10
Respiratory arrest	20 – 50
Ventricular fibrillation	15 - 120

Contact Electric Shock / Electrocution

Remember:

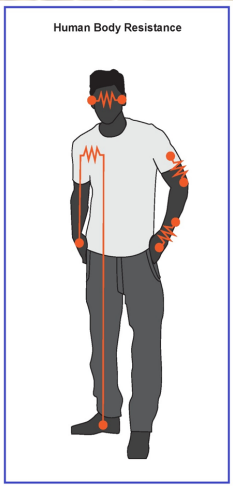
0.015 – 0.030 Amps across your heart will stop it from beating, and it won't restart even if the electricity is removed!

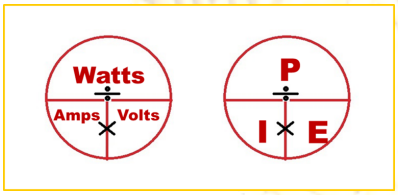
This is 1/1000th of the power available in the outlet you plug your reading-light into!!

Electric Shock Injury

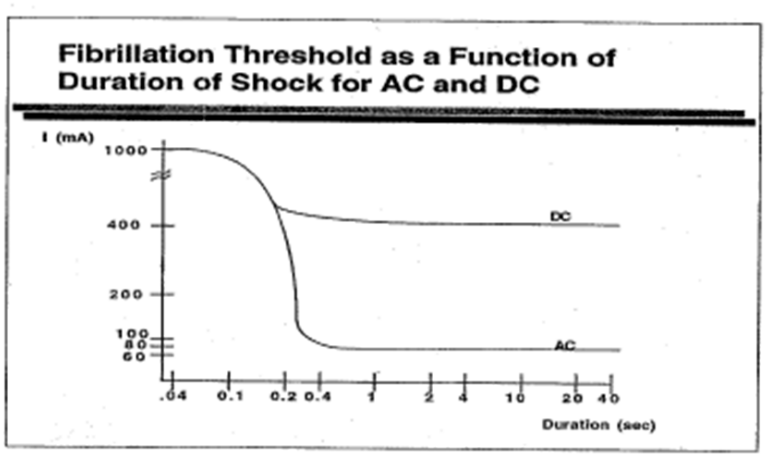
Depends upon:

- Wave form [e.g. A.C., D.C., capacitive discharge]
- Current (Amps = I) or energy available
  - [Watts (P) divided by Volts (E)]
- Duration of the shock
- Current path through the body





AC versus DC Fibrillation Thresholds

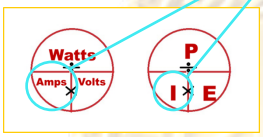


Pulse / Capacitive Shock Injury

- 10 Joules (J) is the threshold for danger
- Over 50 J may be lethal
- Defibrillators use 200-250 J to restart heart
- The most significant danger is from the large dissipated energy in a shock. Can produce significant burns, especially to nerves and soft tissue.

Examples of Electric Shock Effects

At 50 volts or greater, Amps (I) sustained for a duration of time is what kills…….



Form of Electricity	Effects
60 Hz A.C.	100 mA for 3 seconds – **Lethal**
D.C.	500 mA for ~ minute – **Lethal**
Carpet shock	10 A for 1 microsecond – **Hurts like hell but harmless.**
1 MHz A.C. rf	200 mA - **Allowable**

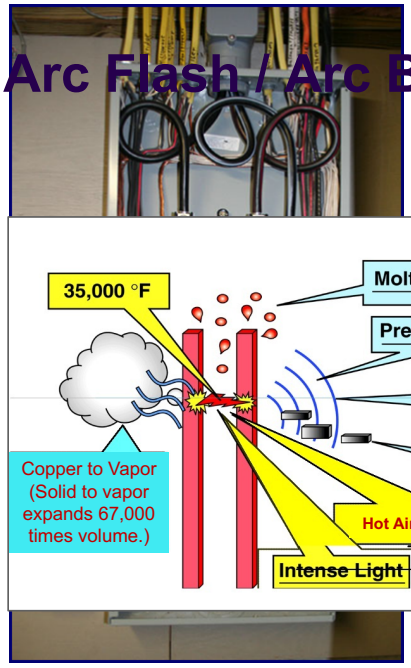
If you have an Electric Shock…..

- Symptoms of injury may NOT be immediate or obvious.
- Symptoms may appear over time (**up to one year!**).
- Report to University Health Services or the local Hospital Emergency Room immediately if you suffer an electric shock greater than 50 volts.
- You will be examined and perhaps monitored over time to determine if you suffered an injury.
- Call 9-1-1 and report a serious electric shock and wait for paramedics.
- Call EH&S Safety Engineering to let them know and determine cause and lessons learned.

If you Witness an Electric Shock or Electrocution…..

- Do not touch the person being shocked and take care not to become part of the circuit if they're latched onto the conductor
- If possible, turn off power at a nearby breaker
- If you can't, possibly try to safely pry them off of the conductor using a non-conductive plastic pipe or a fiberglass board or ladder
- Call 9-1-1 immediately and report as much information to authorities as possible
- Keep yourself and others away from the electrical hazard and the person until medical help arrives.

Arc Flash / Arc Blast



Primarily a hazard at:

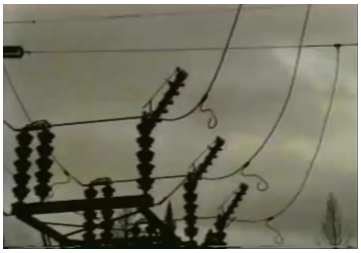
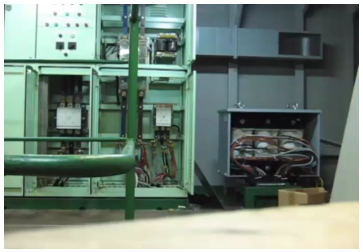
Voltage ≥ 240 A.C.

and

Amperage ≥ 500 Amps

Post Arc Flash / Blast Photos

Arc Flash / Arc Blast - Videos

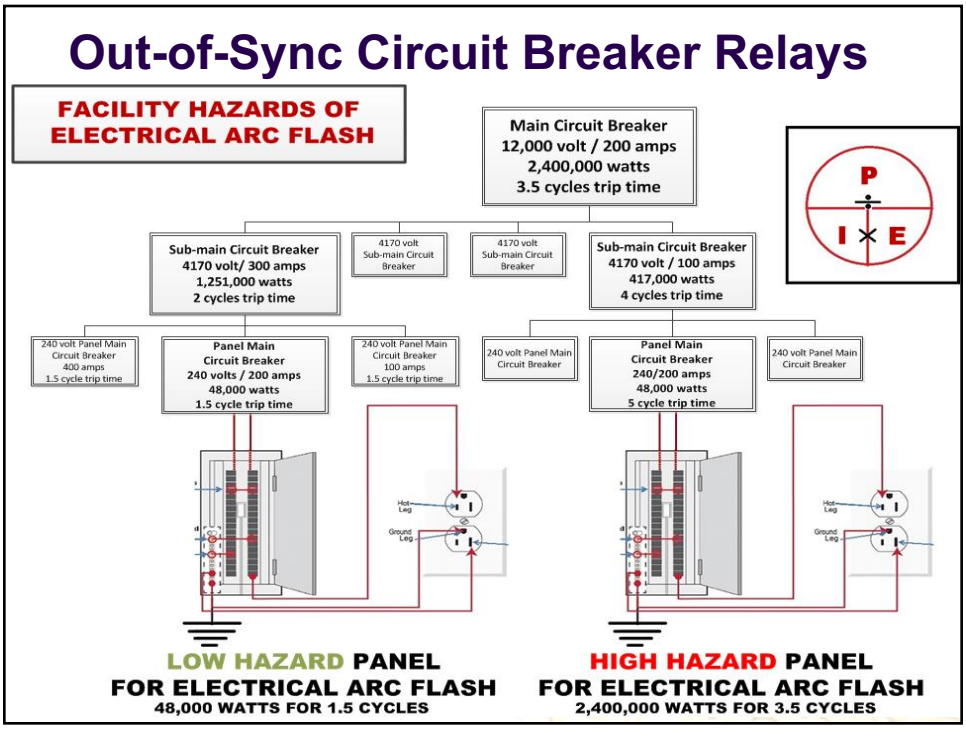

Arc Flash – Equipment Failure Causes

- Dust, impurities, and corrosion at contact surfaces
  - ✓ Produces heat, loosening contact and creating sparks
  - ✓ Sparks start arcs
- Sparks are produced during:
  - ✓ Throwing of higher-voltage switches (≥ 240 volts)
  - ✓ Racking (insertion) of large circuit breakers
  - ✓ Replacement of fuses
  - ✓ Breakers/fuses closing into faulted lines

Arc Flash / Arc Blast – Human Causes

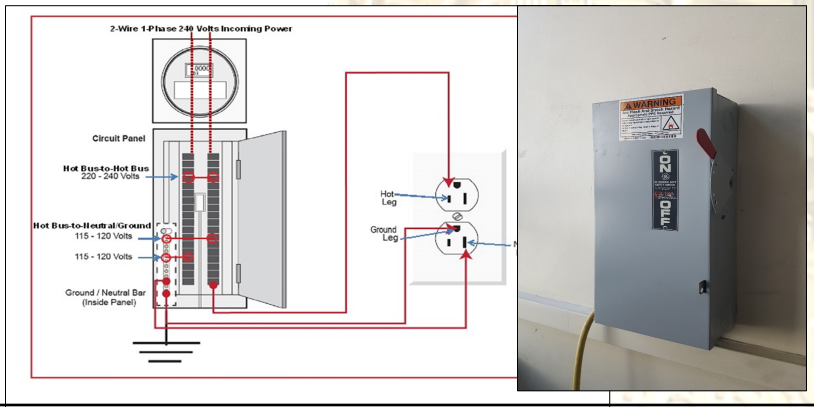
- Dropped tool / fasteners complete fault-circuit and starts the arc (No resistance)
  - Phase-to-Ground Fault (No resistance)
  - Phase-to-Phase Fault (No resistance)
- Old / damaged / poorly maintained equipment (Safe Clearances Reduced due to damage / poor maintenance / age / insulators compromised.)
- Rapid Capacitive Discharge (No ground-resistor installed.)
- Out-of-Synch Circuit Breaker Relays in your facility. (Not correctly selected by designers, or old facilities (20+ years) before arc flash hazards were known.)

Out-of-Sync Circuit Breaker Relays



PROTECTING YOURSELF FROM: Arc Flash / Arc Blast

ELECTRICAL SAFETY RULE #3:
NEVER DIRECTLY STAND IN FRONT OF ANY ELECTRICAL PANEL AND START THROWING SWITCHES! ALWAYS STAND TO ONE SIDE OF THE PANEL TO ACTUATE SWITCHES AND CIRCUIT BREAKERS



ELECTRICAL SAFETY RULES LEARNING SUMMARY SO FAR….

1. **Don’t become part of the pathway to ground!**
2. **Properly size extension cords, power-strips, wires and cables based upon the potential full-load amperage**
3. **Never stand in front of any electrical gear while actuating switches**

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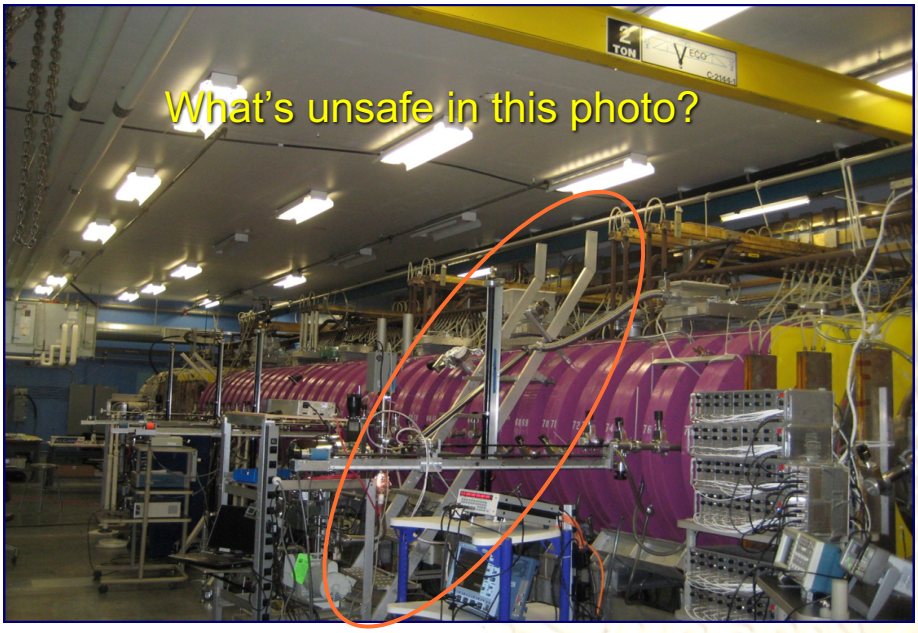
Don't become part of the pathway to ground!



KEEPING SAFE AROUND RESEARCH EQUIPMENT ELECTRIC HAZARDS

1. **Practice "safe work habits", shut off power and don't work "energized", and follow EI-LOTO SOPs**
2. **Design safe-work areas and apparatus with electrically safe clearances based on voltage**

Electrical Safety Rule #4 - "TEST BEFORE TOUCH"

- *"**Test Before Touch** is a fundamental principle for all electrical work, no matter how standard or special…*
- *Always ask yourself how tasks should be performed safely and effectively when planning your work. Your life is on the line!"*
  - Mark Scott, Electrical Safety Engineer, Lawrence Berkeley National Lab

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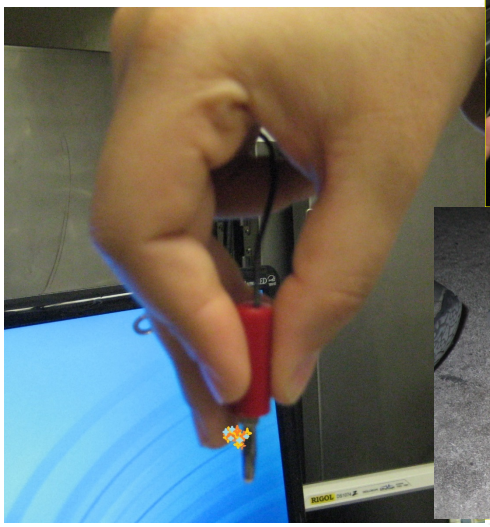
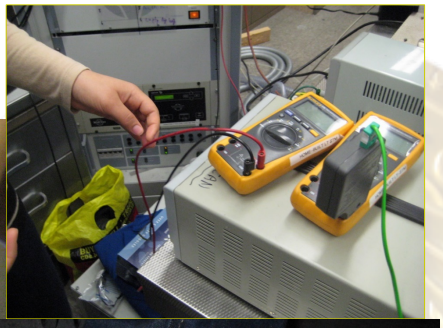
Practice "safe work habits" and EI-LOTO

1. Using a known-well-functioning volt-meter, **verify**….. **Then Verify again**…… **Then Verify AGAIN**, that electricity is "off" before working on conductors. A MINIMUM OF 3 TIMES!!
2. **Never** take someone else's word that "the power's off"!!
3. **Always verify for yourself** power is off using a known-functioning test-meter.
4. Use insulated tools, properly sized wiring and voltage-rated equipment.
5. Purchase and use NRTL-certified equipment
6. Keep one hand in your pocket while working
7. For Electrical Panels – Stand to one side when operating equipment, even if electric conductors are fully enclosed
8. ALWAYS TURN OFF POWER before altering any wiring

Technical Incident Investigation
26kV Electric Shock





Housekeeping

- **Keep at least 3 feet of clearance in front of every electrical panel.**
- OSHA and Fire Safety Fines up to $5000 to your department for repeat offense.

Housekeeping

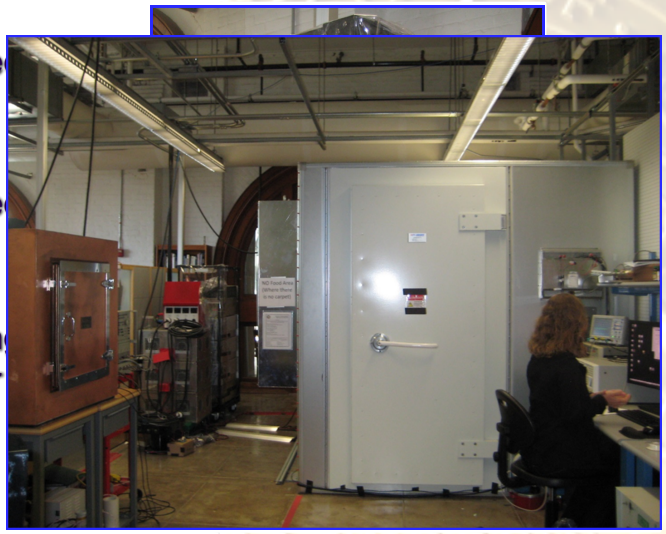
- What would you do to improve electrical safety?

Design safe-work areas and apparatus

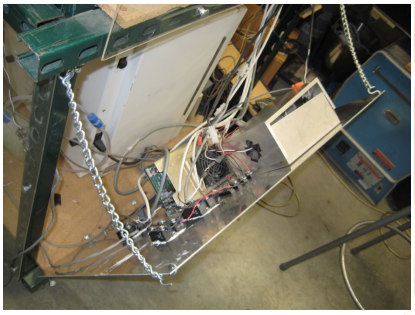
1. Only use 3-prong grounded-plug equipment
2. Stand on insulating floor mats
3. Use electrically non-conductive work-surfaces (wood, fiberglass, plastic, etc…)
4. Cover electric bus and fittings with non-conductive materials
5. Keep cooling water fittings below and isolated from electrical components in case of water leaks
6. Isolate high voltages in research equipment from the researcher by installing guards, interlocks, Faraday Cages, etc.

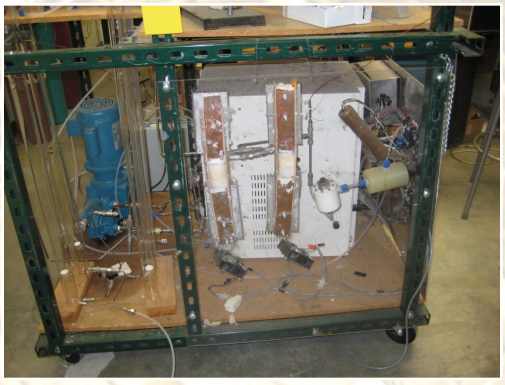
PROTECT YOURSELF with: Guards and Insulation

- Install insulate floor mats
- Install insulate bench tops
- Hang insulatin materials over conductors



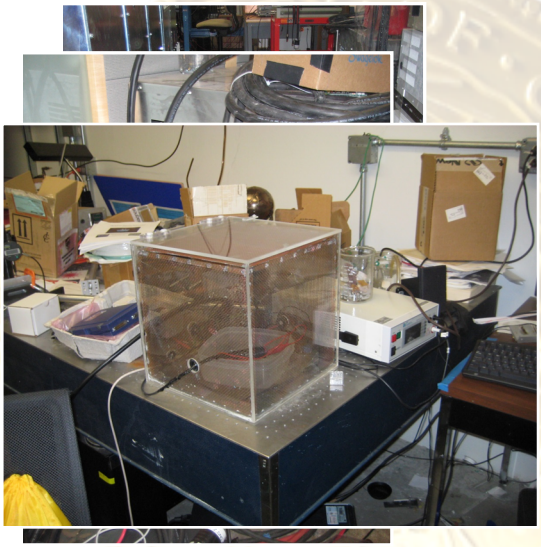
Polycarbonate Guards





PROTECT YOURSELF with: Guards and Cages

- Install guards over exposed conductors and trip hazards
- Install Faraday Cages over exposed conductors

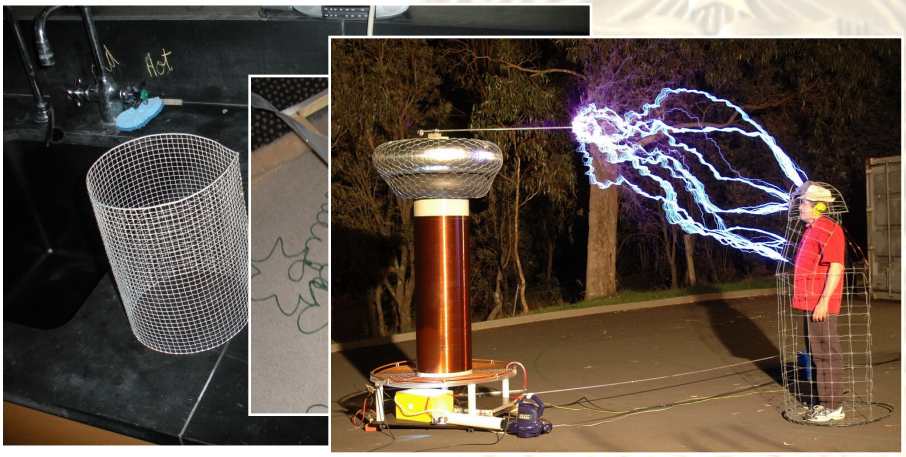


Faraday Cage Interlocks

- Latch grounding relay on safety interlocks
- Grounding wand as secondary precaution

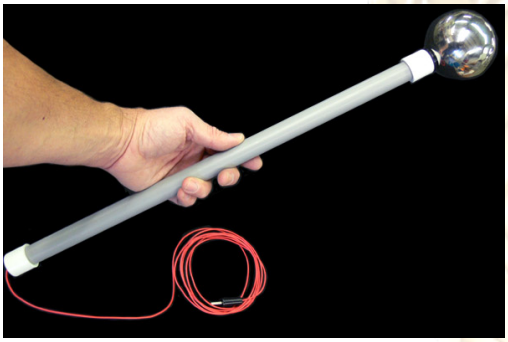
Faraday Cages

- Come in all shapes and sizes.



Grounding Wands

- Use as a secondary safety precaution to verify dead circuits.



Static Accumulation / Discharge

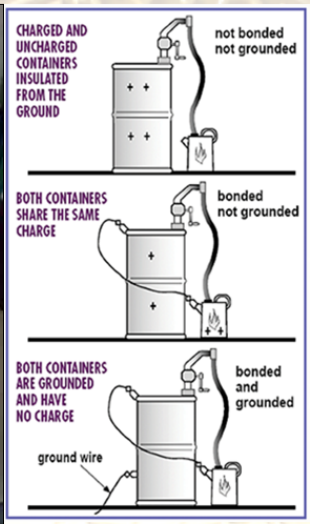
- Wrist and Shoe Straps
  - (Prevent Charge Build-up in You)
- Grounding / Bonding Straps
  - (Prevent Charge Build-up in Equipment)
- E-Floor Mats
  - (Insulate you from Static Discharge)

Anti-static PPE

Electric spark = Ignition Source

- Lead acid batteries can produce hydrogen gas
- Flammable gases / liquids can create explosive atmospheres
- Airborne dusts can create explosive atmospheres
- Use explosion-proof conduits, switches and other special wiring gear in such high-explosion hazard areas. These must be installed by licensed electricians.
- Install clip-on grounding straps when refueling.
- Install grounding / bonding straps on flammable liquids transfer equipment
- Ensure good ventilation.

GROUNDING and BONDING



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Flammable Liquids transfer / distribution

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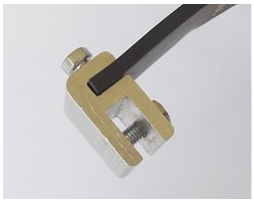
Flammable Liquids and Gas Transfer

- Easy to use devices





http://www.lessemf.com/ground.html

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GROUNDING and BONDING

Flammable Gas Distribution

- Use bonding straps to prevent static-electric charge differentials between system components
- Ground equipment frames, gas-storage racks, piping distribution systems and electrical equipment all to the same building-ground system.

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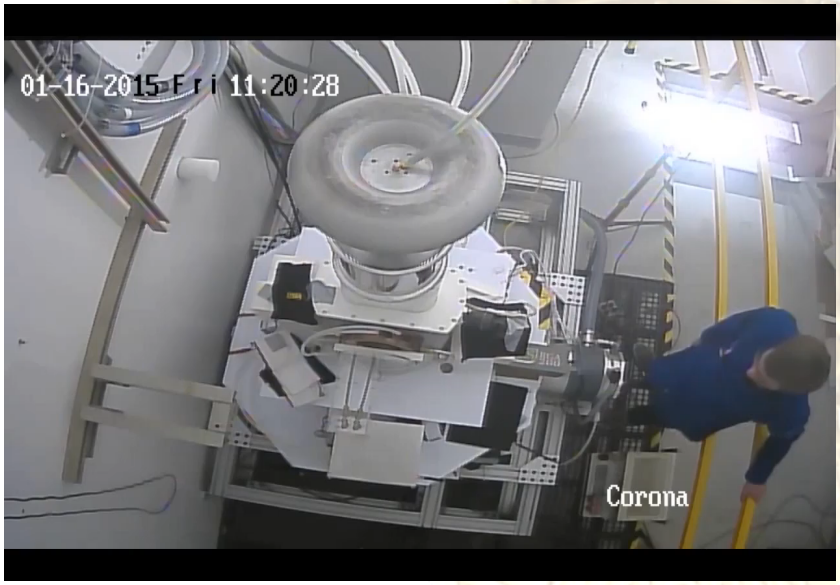
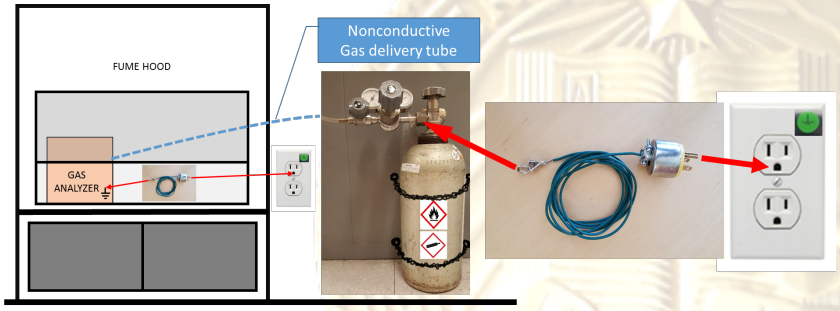
H2 Gas Explosion - Investigation



Grounding / Bonding of Flammable Gas Systems



GROUNDING / BONDING A FLAMMABLE / OXIDIZING GAS DISTRIBUTION SYSTEM

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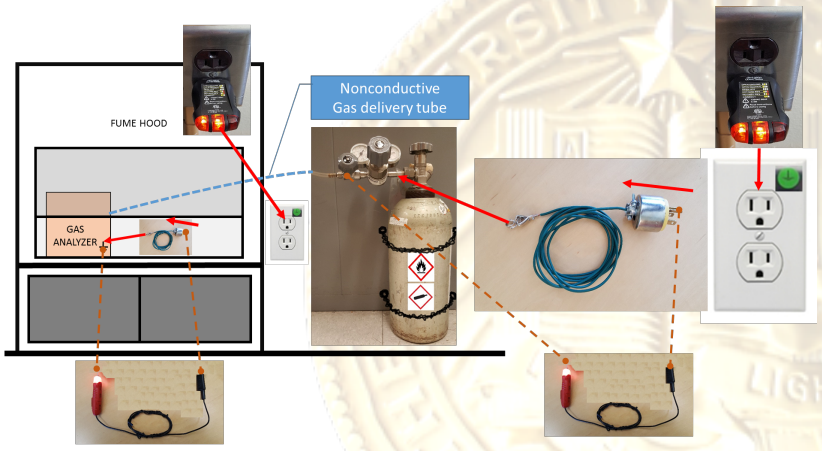
Testing Grounding / Bonding of Flammable Gas Systems



GROUNDING / BONDING A FLAMMABLE / OXIDIZING GAS DISTRIBUTION SYSTEM – LAB USER PASSING TEST PROTOCOL

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LAB DISASTER – FLAMMABLE GAS EXPLOSION

The scene: March 2016

- U. of HI Bio-energy Research Lab
- Research using a mixture of H2 (70%), O2 (25%) and CO2 (5%) gas to bathe the bacterial cell cultures
- The gas mixture is stored in **one tank (!!)** at 100psi fed by high-pressure cylinders
- Supply and distribution piping made of various materials, some conductive some not.
- Using TFE pipe-thread-tape seals

http://cen.acs.org/articles/94/web/2016/04/Spark-pressure-gauge-caused-University.html

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LAB DISTASTER AFTERMATH

These photos, released by the Honolulu Fire Department,
Illustrate the force of the March 16 explosion and its consequences.
(warning: some images are graphic)

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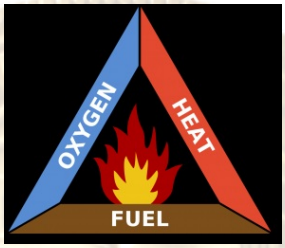
LAB DISTASTER CONTRIBUTING CAUSES



- Explosive gas mixture is stored in the one tank (2-sides of fire-triangle present in one tank). An ignition source was only needed to create an explosion inside the tank/pipe system.
- Piping and tank not grounded or bonded
- Piping used electrically-insulating TFE thread seal tape
- Not using personal grounding / bonding straps or e-floor-mats
- Not using **Intrinsically Safe (IS)** digital pressure meter gage
- ***A static discharge from researcher's hand to the digital meter was the ignition source inside the meter***

http://www.hawaii.edu/news/2016/07/01/independent-investigation-of-lab-accident-complete/

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INTRINSICALLY SAFE (I.S.) VS. EXPLOSION-PROOF EQUIPMENT

I.S. Equipment is:

- Designed to operate on micro-voltages
- Inherently ignition-proof under normal atmospheric conditions
- Incapable of creating an ignition-energy spark due to low voltage
- Not "hermetically sealed" with electronics open to the atmosphere

Explosion Proof Fittings / Equipment:

- Is hermetically sealed from the surrounding atmosphere
- May have voltages / amperages operating inside it that could be an ignition source if exposed to the surrounding atmosphere
- Must never be "opened" when explosion or flammable hazards are surrounding the equipment

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INTRINSICALLY SAFE (I.S.) RATED EQUIPMENT

- Labels for rooms / locations of high flammable / explosion hazard

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INTRINSICALLY SAFE (I.S.) RATED EQUIPMENT

- Equipment Labels / Manuf. Identifiers

Intrinsic Safety in the World

Europe	Europe	USA	USA	Canada	Brazil	Russia	Australia	China	Korea	Japan
IECEx	EU (ATEX)	FM Approval	UL	CSA	INMETRO	GOST-R	ANZEx	NEPSI	KCs	TIIS

Hazardous Area		Class I				Class II & Class III		
		Group A	Group B	Group C	Group D	Group E	Group F	Group G
		Acetylene	Hydrogen	Ethylene	Propane	Combustible metal dust	Combustible carbonaceous dust	Flammable dust
Class I	Division 1	Explosive Gas is present (such as inside of storage tank)						
	Division 2	Explosive Gas may be present (such as outside of shielded storage tank)						
Class II	Division 1					The area with combustible dust present		
	Division 2					The area where combustible dust may be present		
Class III	Division 1					The area with flammable dust present		
	Division 2					The area where flammable dust may be present		

ICOM

Learn more online:
http://blog.icomamerica.com/2014/11/18/intrinsically-safe-radios/

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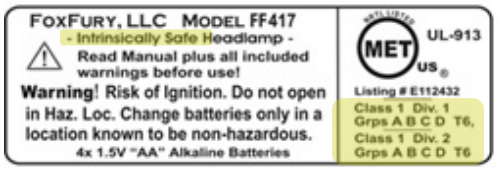
INTRINSICALLY SAFE (I.S.) Label examples



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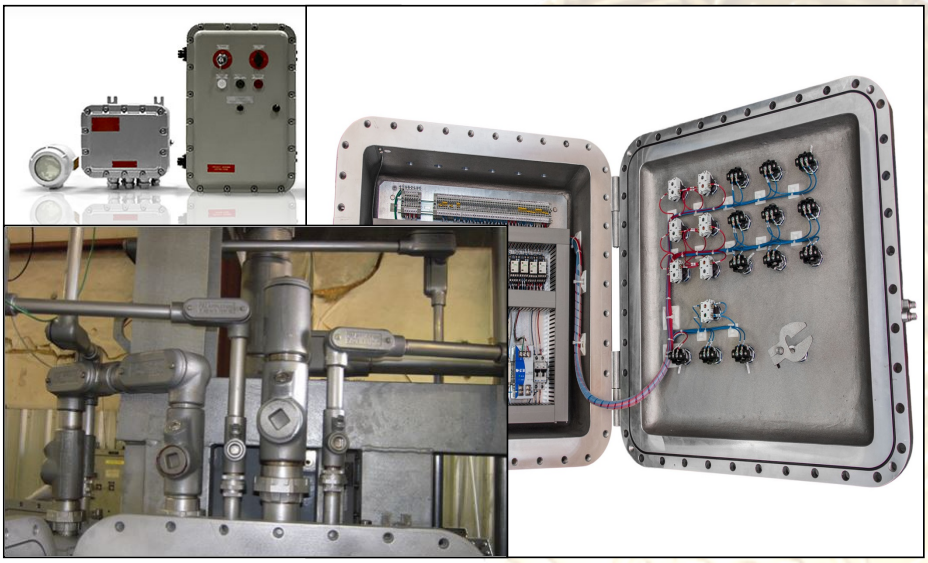
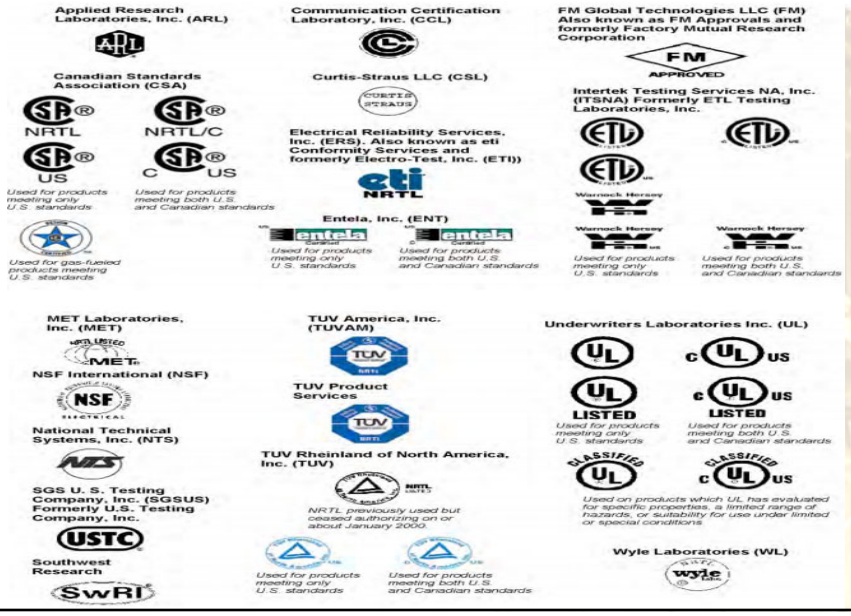
EXPLOSION PROOF EQUIPMENT

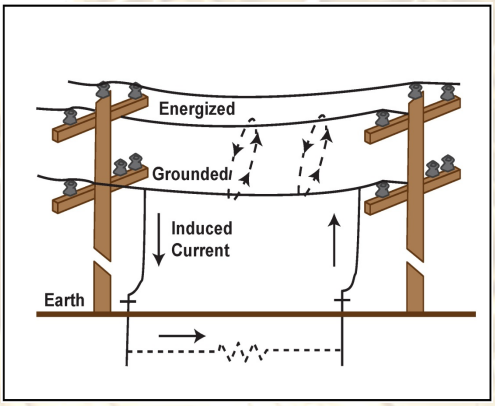


What is NRTL Equipment?



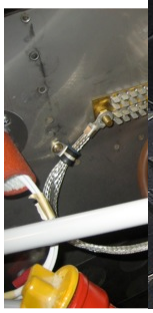
Induced Electric Charges (Inductance)

- Inductance can cause electric flow to happen in “dead” wires that are near conductors that have electricity flowing through them.



Inductance Safety = Grounding

- Grounding Straps
- Bon
- Gro

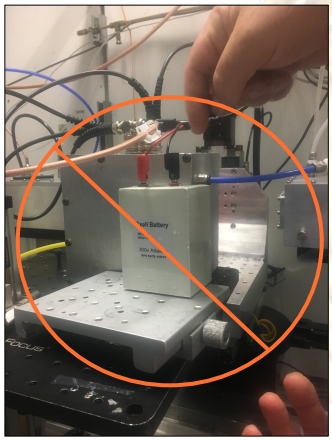


Stored Electric Charges - Batteries

- Follow manufacturer's recommended storage and use procedures for batteries.
- Remove high-voltage (≥100V) batteries from service if possible
- Install lower-voltage batteries designed for "in series" use to obtain higher-voltage if needed
- Ventilate battery storage banks for heat build-up and H2 gas control

Stored Electric Charges - Batteries

It's recommended removing from service batteries greater than 100 volts with amperages ≥ 40mA for safety. These higher voltage batteries have a history of causing potentially lethal shocks to researchers, and require special handling, storage and equipment guards for safe use.



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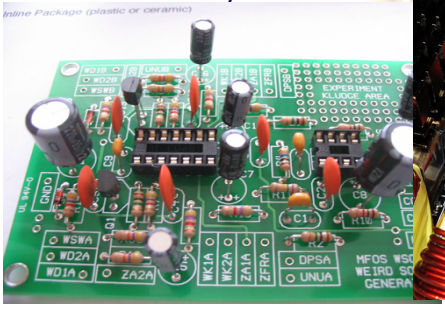
Stored Electric Charges – Capacitors:

- Capacitors store electric charge and can cause electric flow to happen in "dead" wires if a pathway to ground is created.
- Discharge all stored electricity rapidly unless controlled by resistance

WHERE ARE THE CAPACITORS?



Capacitor Banks

Capacitor safety

To “make safe” large capacitors and capacitor banks, they must be “Soft Grounded” through **resistance coils** to fully discharge the capacitors at a slow rate when power is shut off. This should be done automatically by equipment design if possible, or only by Qualified Electrical Workers to ensure safety, as electric shock and arc-blast are major hazards of this operation.

Storing Capacitors

- **WHERE SHOULD THE BONDING CLIPS BE ATTACHED FOR SAFE STORAGE?**

Capacitor safety - PRECAUTIONS

- If you work with hazardous capacitors (≥100 V and ≥10J), consider this work high hazard and get special training to work safely with this equipment.
- If you are not trained, ask Qualified Electrical Workers (QEWs) to discharge and ground-safe any large capacitors for you and never touch them yourself. Always assume they are charged.
- If you see stored-capacitors on a shelf that are not grounded / bonded, consider them DANGEROUS and seek QEWs to determine their safety.
- Remember, for capacitors ≥100 V:
  - ≥ 10 Joules (J) can kill you from ventricular fibrillation
  - ≥ 100 J requires hearing protection
  - ≥ 1000 J requires soft grounding
  - ≥ 10,000 J requires remote (automated) grounding and a QEW assessment for arc flash hazards

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Capacitors – MAKING SAFE

When discharging hazardous capacitors, QEWs must:

- Start with soft grounding if ≥1000 J.
- Ensure the bleed resistor and cable are properly rated for the power and current, and that the appropriate discharge time required is known.
- Always follow soft grounding with hard grounding, still wearing the appropriate PPE in case the discharge-bleed did not work as intended.
- The ground device must be able to connect all poles and the case together, and be connected to the building's earth-ground.
- Only apply a shorting "storage" wire AFTER hard ground has been applied.

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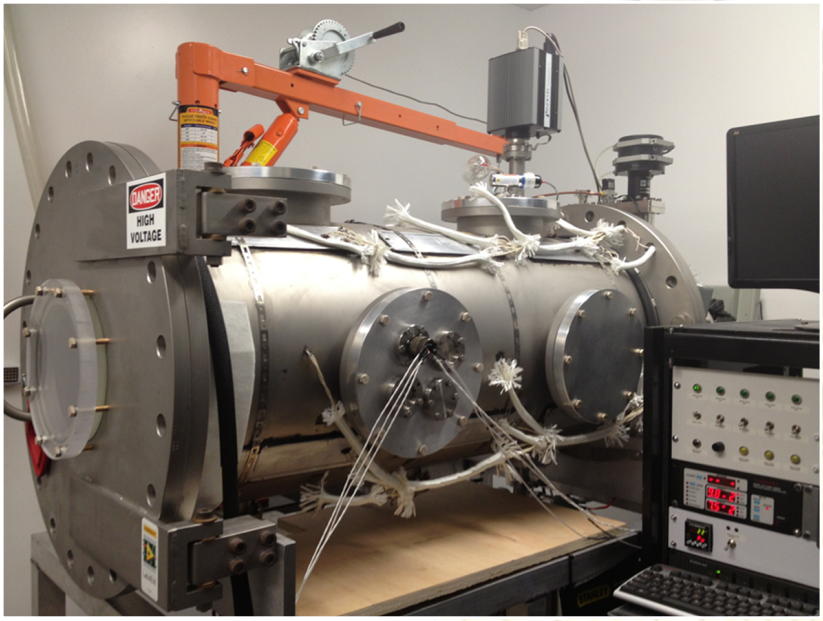
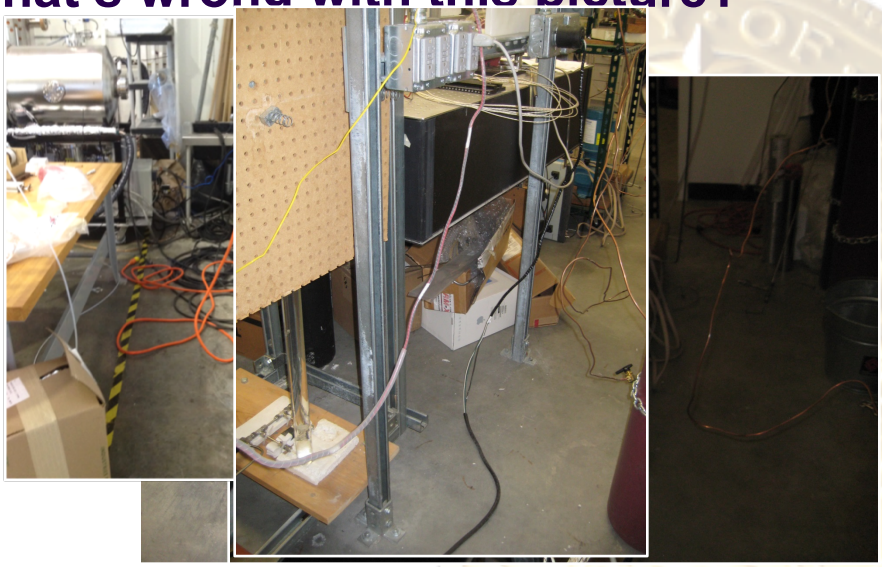
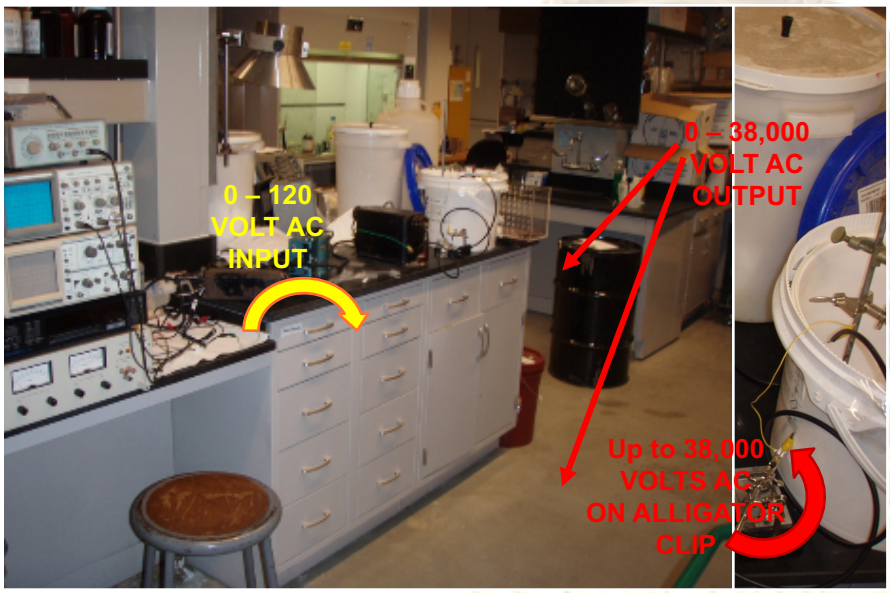
PROTECTING YOURSELF - Quiz



What's wrong with this picture?



A Most Dangerous Apparatus



What are GFCI?

Ground Fault Circuit Interrupters (GFCI):

- Continuously compare power supplied to power returned from electrical equipment
- "Trip off" when difference between power legs is greater than 5mA.
- Are required in wet or outdoor conditions
- Are required when near large "grounds"



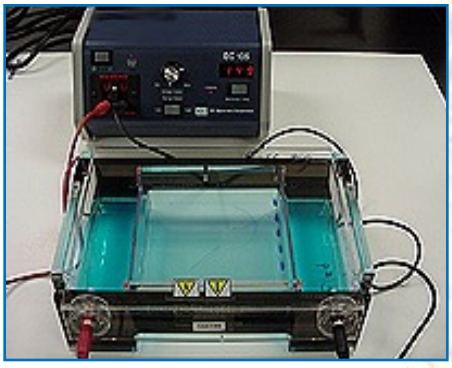
When are GFCI used?

- You must use a ground fault circuit interrupter (GFCI) for:
  - Outdoor use of electrical equipment.
  - Use of electrical equipment near a sink, water, or in a massive ground location.
  - Use of heaters and heating tapes.
- GFCIs can be part of the permanent wiring of a building, or they may be portable units.
- Test the GFCI the first time you use it, and periodically thereafter.

An "Appropriate" Time to Use a GFCI!

[Photo courtesy of Stanford University
"Go Cardinals… And….. DUUH….
Have another brew, Dude....!!"]

Electrophoresis Equipment



- Operate from 100 – 2000 volts on the bench-top
- Operate up to 1 amp
- Newer units can have "onboard" safety features that detect no-load, overload, sudden load change, short circuit, arc or ground leak, etc.
- Older units have no electrical protection
- Building GFCIs may not protect older equipment

Electrophoresis safety

- Replace older units if possible, and purchase power supplies with GFCI / over-current protection built in
- Always turn off the power supply before disconnecting / connecting any wires, and ensure strong physical connections at all connection points
- Keep lab bench work area clean and dry at all times, and remain present when equipment is in operation
- Clean up spills immediately
- Use 3-prong plug GFCI-protected circuits
- Wear latex gloves and use one hand to set up wiring
- Use gel-chambers with lid interlocks that disconnect power when lid is removed

- Thermal Imaging can be used to find electrically-failing equipment

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HIERARCHY OF HAZARD CONTROLS – Applied to Electrical Safety

	Protective Measures	Examples	Influence on Risk Factors	Classification	NFPA70	
Most Effective and Preferred [LOWER RISK]	Elimination or Substitution	• Eliminate Electrical Arc Hazards (Increase air-gaps and clearance) • Intrinsically safe design (Energy limiting) • NRTL-approved equipment • Redesign equipment to eliminate or reduce human interaction / access • Explosion proof equipment / installations • Reduce available energy to lowest needed	• Impact on overall risk (elimination) by affecting severity and probability of harm • May affect severity of harm, frequency of exposure to the hazard under consideration, and/or the possibility of avoiding or limiting harm depending on which method of substitution is applied	Design Out		NFPA70
	Guards and Safeguarding Devices	• Barriers and Locked Access • Interlocks (mechanical and electrical) • Insulating materials, safety mats, non-conductive bench-tops, etc. • Dead front on distribution panel, etc.	• Greatest impact on the probability of harm (Occurrence of hazardous events under certain circumstance) • Minimal if any impact on severity of harm	Engineering Controls		
	Awareness Devices	• Arc Flash Calculations – One Line Dwgs. • Signs and labels – Incident Energy • Lights, beacons, and strobes • Computer warnings • Beepers, horns, and sirens	• Potential impact on the probability of harm (avoidance) • No impact on severity of harm	Administrative Controls	NFPA70E	
	Training and Procedures	• Safe work procedures / switch logs • Two-person rule • Safety equipment inspections • Lock-out / Tag-out • Training	• Potential impact on the probability of harm (avoidance and/or exposure) • No impact on severity of harm			
Least Effective or Preferred [HIGHER RISK]	Personal Protective Equipment (PPE)	• Calorie-rated clothing and blast-suits • Safety glasses and face shields • Ear plugs • Electrically-rated Gloves • Protective footwear	• Potential impact on the probability of harm (avoidance) • No impact on severity of harm	PPE		

SAFETY Programmable Logic Controller (PLC) "Fail Safe" Electrical Control Design

- Safety PLCs provide "Control Reliability" - Ensures the failure of a single component within the equipment or electrical system will not prevent safe shut-down / stopping.
- Safety-rated PLCs can monitor these faults in real time, and automatically shut down equipment safely if a fault is detected.
- PLCs also monitor failure modes such as that of logic-guided relay(s), a fault in safety system monitoring / control logic and insufficient operating voltage.
- Safety rated PLC's are the most economical way to have fail-safe logic control, and are vital when attempting to fulfill the fault detection aspect of a basic "control reliable circuit" for many kinds of research equipment.

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ELECTRICAL SAFETY RULES RECAP

1. **Don't become part of the pathway to ground!**
2. **Properly size extension cords, power-strips, wires and cables based upon the potential full-load amperage and the length of the wire**
3. **Always stand to one side of electrical gear while actuating switches**
4. **Always "Test before Touch" and assume electricity is present until you-yourself have confirmed otherwise**
5. **Adopt and rigorously-apply "Safe Electrical Work Habits"**
6. **Keep one hand in your pocket when working near "energized" parts**
7. **Practice good housekeeping, and build electrically-safe equipment using insulating materials, interlocks, guards and Faraday cages**
8. **Use Bonding and Grounding to control static sparks, flammables ignition sources, inductance charges and capacitor discharges**
9. **Only use NRTL-approved electrical and test equipment**
10. **Always shut-off equipment and utility electrical-power before changing any wiring.**
11. **Respect electrical hazards and get training to work safely**

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Electrical Safety - Summary

- This just familiarizes you with electrical hazards and how to protect yourself
- You are NOT qualified by this training to work on live unprotected electrical parts ≥ 50 volts.
- You may get further training to work live.
- Until then, follow safe-work practices, practice EI-LOTO, build interlocks into equipment, install Guarding, and use grounds and bonds.
- Refer to UCD and UCB Electrical Safety Programs and EI-LOTO Program for reference / guidance.
- Call EH&S Safety Engineering for help.

NOW…… **What's safe for you to do without further training…..?**

Everything it was "safe" for you to do before this training, plus:

- ✓ Use a non-contact meter or test-probe to test for the presence of electricity 250 volts or less in an outlet or other enclosed structure where conductors are not exposed.
- ✓ Replace a blown fuse, or reset a tripped 250 volt or less circuit breaker ONE TIME only……! If the fuse fails or circuit breaker trips a second time, call an electrician.

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UC Resources

- Researcher's Guide to Electrical Safety
- UCB Electrical Safety Program
  - http://ehs..edu/hs/281-electrical-safety.html
  - Excellent resource for safe-work-practices
  - Excellent resource for design / build
  - Excellent resource for guiding students
- UCB EI-LOTO Program: http://ehs.berkeley.edu/hs/88-energy-isolation-lock-outtag-out.html
- UCD's PPM 290-85 http://manuals.ucdavis.edu/ppm/290/290-85.pdf
- UCD's SafetyNet #512 http://safetyservices.ucdavis.edu/safetynet/electrical-safety
- UC Safety Solutions – Procedures Tool and LOTO mobile app – Available through iTunes App Store and Google Play with a UC email address and your campus login credentials. https://ehs.ucop.edu/myboard/splash
- Lawrence Berkeley National Lab – Electrical Safety Field Guides http://electricalsafety.lbl.gov/resources/field-program-guides/

Electrical Safety Questions / Comments

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