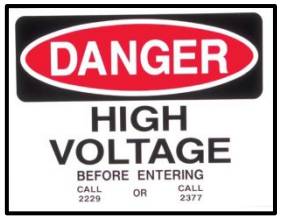
E_001 - Electrical Safety Training

LLE Plasma Electrode Pockels Cell Driver

If it is 50 Volts or Greater -



Scott Householder, Electrical Safety Officer
John Reid, Larry Powell, Electrical Engineers
University of Rochester Laboratory for Laser Energetics

It is High Voltage

Safety is everyone's business and compliance with safety procedures is MANDATORY

UR LLE

Summary

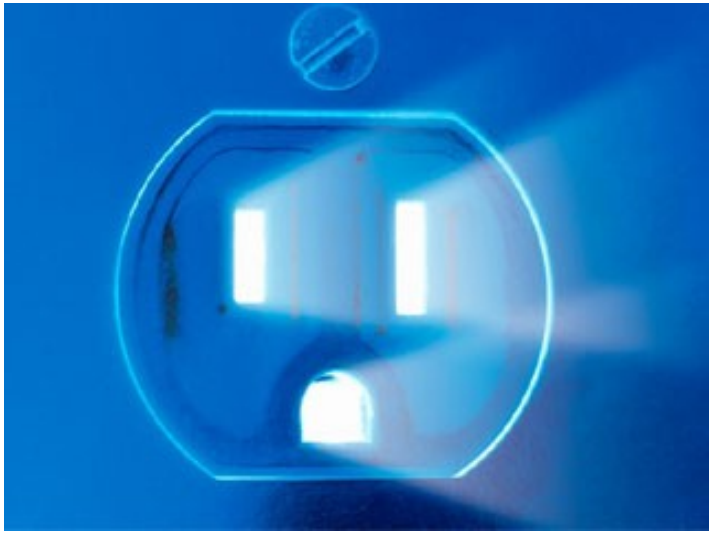
- Electricity is a serious safety hazard when handled improperly
- 50 Volts or higher is considered HIGH VOLTAGE at LLE
- Training - only perform activities for which you are qualified
- If an activity seems unsafe, "Stop Work" and address concerns
- Promptly report safety deficiencies or events
- Never defeat engineering safeguards
- Lockout/Tagout (LOTO) & Safety Inspection Policy
- LLE policy – Work on energized equipment follows DOE guidelines

Ensuring a safe working environment at LLE is a responsibility shared by all personnel

Safety is part of the Culture of LLE

- **Everyone receives training to ensure they understand and adhere to LLE Safety Policies**
- **Safety is emphasized in all aspects of training**
  - **i.e. Takes about 1 year to be trained to work in Laser Facility**
- **Safety discussion begin at the conceptual design level**
- **If there are ever questions or concerns ‘raise your hand and ask’**
- **Safety Officers rely on all of you**
  - **8 members of the LLE Safety Office**
  - **350+ people at LLE**

Electrical Safety = Awareness + Prevention



- Shocks > 50mA can kill
- Fire – can be caused by overloaded circuits, defective equipment, and inadequate ventilation
- Explosion – can result if sparks occur near a flammable gas, as a result of an arc-flash event, or rapid overheating

✓ Avoid Complacent Behavior
✓ Maintain Mental Alertness

The Shocking Facts: How electricity affects your body

- **Shock is the nerve sensation caused by electric current flowing through the body**
- **A shock occurs when your body becomes part of a circuit**
- **The severity of shock is determined by three factors:**
  - **The current flowing through your body**
  - **The path the current takes**
  - **The total time current flows**

What factors influence the severity of a shock?

- Your skin's electrical resistance
  - Work in a dry environment
    - Below 600 volts, dry skin is 100× more resistive
  - Minimize contact area
    - A finger contact is higher resistance than a whole hand.
  - Minimize contact pressure
    - Pressure decreases resistance, increases the risk of a burn.
- Duration of contact
  - The longer the contact, the more likely the burn.

Use proper tools and appropriate Personal Protective Equipment

Shock is not the only threat from electricity…

The Dangers of High-Voltage Electricity include:

- Hearing loss
- Eye injury (projectiles, burns, intense light)
- Burns (internal and external)
- Broken bones (reflex reaction causing fall or impact injury)
- Cardiac arrest
- Death

2009 US Statistics – Electrical injuries in the workplace[1]

170 Fatalities
2620 Non-fatal injuries
4 Median Number of lost days work from injuries

1. The Electrical Safety Foundation International (ESFI) - http://www.esfi.org/index.cfm/page/Workplace-Electrical-Injury-and-Fatality-Statistics,-2003-2010/cdid/12396/pid/3003#sthash.qlnDMIiq.dpuf

Physiological Effects of an Electric Shock

Effects of Electrical Current* on the Body[3]

Current	Reaction
1 milliamp	Just a faint tingle.
5 milliamps	Slight shock felt. Disturbing, but not painful. Most people can "let go." However, strong involuntary movements can cause injuries.
6–25 milliamps (women)† **9–30 milliamps** (men)	Painful shock. Muscular control is lost. This is the range where "freezing currents" start. It may not be possible to "let go."
50–150 milliamps	Extremely painful shock, respiratory arrest (breathing stops), severe muscle contractions. Flexor muscles may cause holding on; extensor muscles may cause intense pushing away. Death is possible.
1,000–4,300 milliamps (1–4.3 amps)	Ventricular fibrillation (heart pumping action not rhythmic) occurs. Muscles contract; nerve damage occurs. Death is likely.
10,000 milliamps (10 amps)	Cardiac arrest and severe burns occur. Death is probable.
15,000 milliamps (15 amps)	Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit!

*Effects are for voltages less than about 600 volts. Higher voltages also cause severe burns.
†Differences in muscle and fat content affect the severity of shock.

Electric shock victims suffering from ventricular fibrillation will die if they do not receive prompt, emergency medical attention

Responding to an Electric Shock Event

- When you witness someone ***being*** shocked, don't panic and rush into action.
  - Immediately call for emergency medical assistance
  - Assess the situation to avoid being electrocuted yourself
- Don't pull them away from the circuit! If the victim is contacting an energized object - contacting them will shock you also
  - If possible, shut off the power
  - If not, separate the person from the circuit using an insulator (e.g. dry wooden broom handle, a fiberglass ladder or a piece of PVC pipe)
  - Once the victim is free,
    - Try to keep the person calm and still until help arrives
    - Provide first aid assistance if you are trained
- When shocked, involuntary muscle contractions may prevent you from releasing your grip
  - Allow your knees to collapse. Body weight may pull you away from the circuit

Electric shocks can cause significant internal injuries, and have delayed onset of symptoms. Advise shock victims to seek medical attention.

What to do if an electrical shock event occurs

- **STOP WORK**
  - **Secure the area. De-energize affected equipment unless doing so introduces known hazards**
  - **Assess the victim's status. Call for emergency medical assistance if injuries are suspected, or if the victim is acting abnormally.**
  - **Talk with the victims. Investigate. Learn exactly what happened.**
- **The Electrical Safety Officer (ESO) or his designee must ensure that ALL necessary actions have been completed to establish safe operating conditions before resuming operation**
- **Report all electrical shock events that occur at LLE (except those from static electricity) to your supervisor and the ESO or Chief Safety Officer**

An employer may not retaliate or take unfavorable personnel action for reporting a workplace safety deficiency when the complaint is made in good faith

LLEs Approach to Training

- **No Employee is expected OR PERMITTED to undertake a job until he or she has received appropriate instructions on the performance of that task.**

- **This may include any or all of:**
  - **Safety Training**
  - **Technical Training**
  - **Equipment Training**

OSHA 29 CFR 1910 Section 399: A qualified person is "one who has received training in and has *demonstrated skills and knowledge* in the construction and operation of [electrical] equipment and installations and the hazards involved."

LLE Electrical Safety Training

- **Three levels of Electrical Safety Training**
  - **Basic Electrical Safety Training**
    - **Fundamentals and awareness**
  - **HV Worker Training**
    - **Basic Electrical Safety Training**
    - **Area and task specific training**
  - **Energized Work Training**
    - **HV Training**
    - **Task specific training**
    - **Special permissions**

High Voltage Worker Qualification

- **ONLY those who NEED to perform work on high voltage systems will be qualified**
- **Their group leader will ensure that they have received area/equipment specific training**
  - **For power distribution and facility infrastructure:**
    - **Craig Carnahan**
    - **Scott Householder**
  - **For instrumentation, controls and related equipment:**
    - **Greg Brent**
    - **Bob Peck**
    - **Scott Householder**
- **Final signoff will be given by the Electrical Safety Officer**

HV workers are expected to verify equipment is fully discharged and install LOTO before any work is performed

Performing Electrically Energized Work – Shall be Avoided Whenever Possible

- **ONLY those who NEED to perform electrically energized work will be qualified**
- **Must be trained as a high voltage worker**
- **Their group leader, the Chief Safety Officer, the Electrical safety Officer AND, one of the following Responsible Individuals (RI's) must review the work**
  - **For power distribution and facility infrastructure:**
    - **John Sawyer**
    - **Craig Carnahan**
  - **For instrumentation, controls and related equipment:**
    - **Greg Brent**
    - **Bob Peck**

Individuals must work within the scope of their training and qualification

Electrically Energized Work Practices

Implement safeguards prior to starting and while energized-work is in progress:

- **Employ the buddy system**
- **Maintain safe working distances from energized equipment**
  - **Use barriers to restrict access**
- **Test for presence of voltage before making contact**
- **Use insulating materials, tools and wear rubber soled shoes where possible**
- **Remove conductive jewelry, buttons and (metal) zippered clothing**
- **Use one hand for work, keep other behind or in pocket**
- **INSIST on proper lighting**
- **Control your environment to avoid distractions and unsafe activities**

Electrical Safety Common Sense Practices

- Allow proper ventilation for power dissipating equipment
- Investigate “hot” or unusual smells around equipment
- Ask for help if you have questions
- Turn off unused equipment (except computers)
- Verify area is clear and secure prior to activation of remote (OUT OF SIGHT) equipment
- Never leave a potentially hazardous situation unattended for ANY REASON
- Recognize and mitigate hazards
- Use simple warning signs to communicate danger or possible risks
- Insist on proper lighting for your work area
- Be vigilant in checking for overhead conductors when using ladders, elevated work platforms or other conductive objects
- Use a fiberglass ladder when performing elevated electrical work

Engineering Controls – Electrical Safety is Addressed During the Design Phase of Every Project

- Include equipment interlocks for hazardous voltages existing behind closed doors or panels
- Preclude access to non-insulated electrical terminals or wiring
- Ground all conductive frames, enclosures and accessible metallic components including optical benches and tables:
  - Ground conductors must be permanent and continuous
  - Ground conductor size must provide sufficient impedance for all frequencies and anticipated fault currents
- Affix appropriate warning labels to all high-voltage equipment

Safety features such as interlocks, alarms, detectors may only be bypassed on a case by case basis following Safety Officer review

Personnel Protective Equipment (PPE) for Electrical Work

- **PPE is your *last line of defense* when all else fails to prevent an accident**

- **PPE doesn't prevent accidents, but may reduce the severity of injuries**
- **These factors are critical to working safely:**
  - **Robust equipment engineering design**
  - **Proper equipment maintenance**
  - **Proper training**
  - **Good work practices**
- **What PPE is required/recommended? It depends on the job!**
  - **Impact resistant eyewear (Always!)**
  - **Electrical hazard (EH) safety-toe shoes protect the wearers' feet from completing an electrical circuit at up to 600 volts. Protection may be compromised when wet, soles are worn, or metal particles are embedded in the sole or heel.**
  - **Electrically insulating gloves**
  - **Arc-flash garments (tight-weave cotton preferred over synthetics)**
    - **Nomex or similar is required for cleanroom work**
  - **Hearing protection**

Consult with the Electrical Safety Officer to discuss task-specific PPE requirements

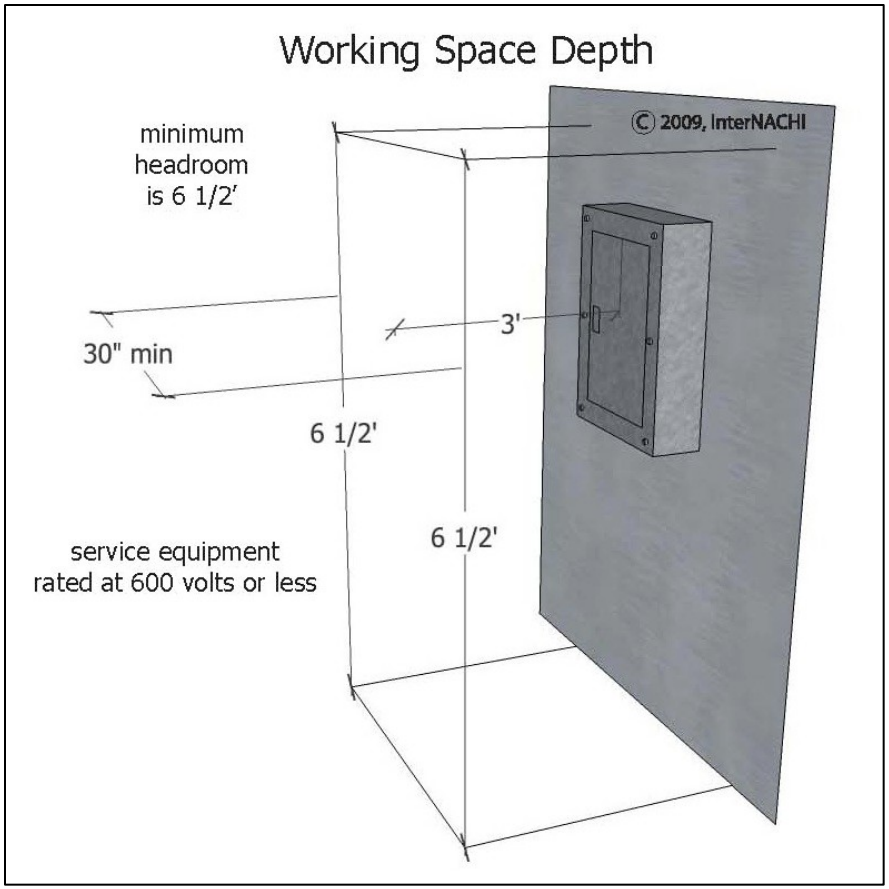
LLE Policy for Facility Modifications of the Electrical Distribution System

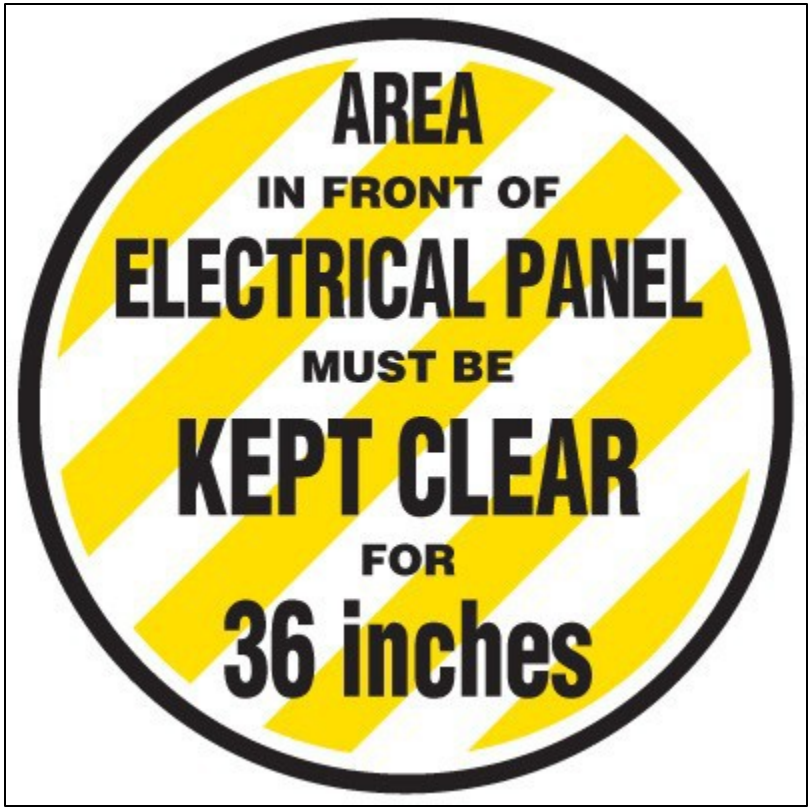
ONLY **electricians reporting to the Facilities Group Supervisor may service or modify Building Power Distribution equipment. This includes:**

- **120 / 208 / 240 / 480 VAC**
- **Wall switches and outlets**
- **Circuit breakers**
- **Panel boxes**
- **Transformers**
- **Conduit**
- **Uninterruptable power supplies (UPS) > 1500 VA rating**

General LLE Staff may operate circuit breakers only when following written procedures approved by the Electrical Safety Officer

Maintain 36” clearance around ALL breaker panels





Electrical Safety Protection Devices

- Fuses and circuit breakers are switches that "open" when the flow of electric current exceeds safe levels for the circuit or equipment involved
  - ***Fuses and circuit breakers (those without ground-fault interrupt, below) are designed to protect building wiring, and do not reduce the risk of a shock injury***
  - Tripped breakers and blown fuses indicate an overloaded circuit which may be a fire hazard and can damage equipment
  - Do not reset a tripped circuit breaker
  - Replacement fuses must meet the manufacturer's specifications
- Ground fault circuit interrupters (GFCIs, or GFI), provide shock and overload protection, and are mandatory outdoors, near sinks, and in damp/wet locations
  - ***GFI's are designed to protect people***
  - The GFI compares the current flowing in the "hot" and neutral conductors
  - When a 5 milliamp difference is detected (typical threshold for a person to feel an electrical shock), the GFCI will quickly trip
- Transient surge suppressors protect sensitive electronics from voltage spikes, but do not eliminate shock hazards

Test Ground Fault Circuit Interrupters (GFI's) in your work area regularly

LLE Electrical Equipment Policy

- **DO:**
  - **Use only UL Listed 3-wire appliances**
  - **Limit the load according to the manufacturer's device label**
  - **Investigate abnormal operation, smells, etc.**
  - **Discard or tag out damaged equipment**
  - **Have qualified & authorized personnel repair devices**

- **DO NOT:**
  - **Daisy Chain (connect in series) devices**
  - **Use damaged equipment**
  - **Take damaged equipment home**

When specifying or purchasing equipment, understand the markings that indicate safety agency qualification status

These example markings are used by the Underwriters Lab (**UL**) for equipment and component safety qualification. The reverse "***UR***" symbol means the item is a **U**L **R**ecognized **component** intended for integration into a product.

For more info: http://ul.com/marks/ul-listing-and-classification-marks/appearance-and-significance/marks-for-north-america/

These are example **CSA** marks that indicate that a sample of the product has been certified to applicable standards written or administered by the American National Standards Institute (ANSI), Underwriters Laboratories (UL), CSA Group (CSA), NSF International, and other North American organizations.

For more info: http://www.csagroup.org/global/en/about-csa-group/certification-marks-labels/csa-marks

Batteries present electrical, chemical, fire and physical hazards

Battery-operated uninterruptable power supplies are commonly used with sensitive electronics (e.g., computers). When de-energizing equipment, look for and secure ALL power sources

During battery maintenance (e.g., charging, replacing), consider electrical, physical, chemical and explosion hazards including:

- **Electric shock**
- **Burns and shrapnel-related injuries from a short circuit**
- **Chemical burns from electrolyte spills or surface contamination**
- **Fire or explosion due to hydrogen**
- **Physical injury from lifting or handling the cells**
- **Fire from overheated electrical components**

Immediately remove a battery from service if it shows abnormal signs of distortion, overheating, or chemical discharge. Properly dispose of batteries.

LLE Policy for Lockout / Tagout

POLICY: **Refer to LLEINST6300**
Supplemental Within the Laser Facility: INST3000

LOCKOUT: **Installation of a physical barrier, or removal of a connecting link, to isolate hazardous energy before starting maintenance**

TAGOUT: **Placement of tag on breaker, switch, control device or valve stating "DANGER DO NOT OPERATE"**

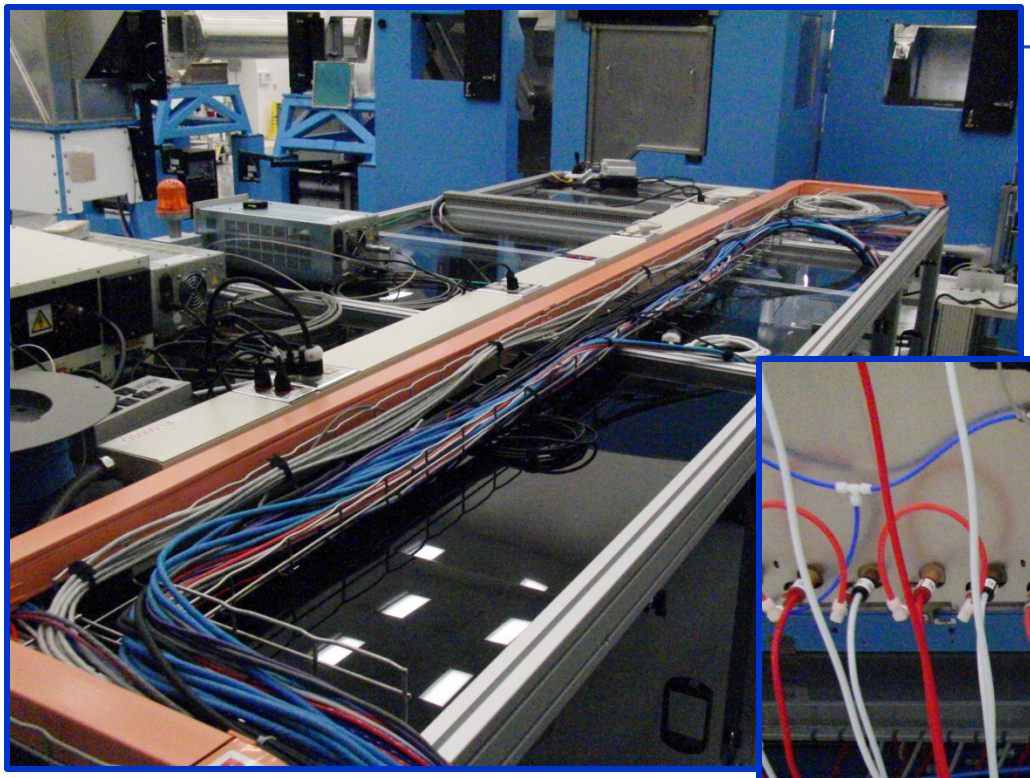
A Tagout will only be used when the installation of a Lockout is not possible

Examples of Acceptable Electrical Lockout / Tagout

Lockout / Tagout Guidelines

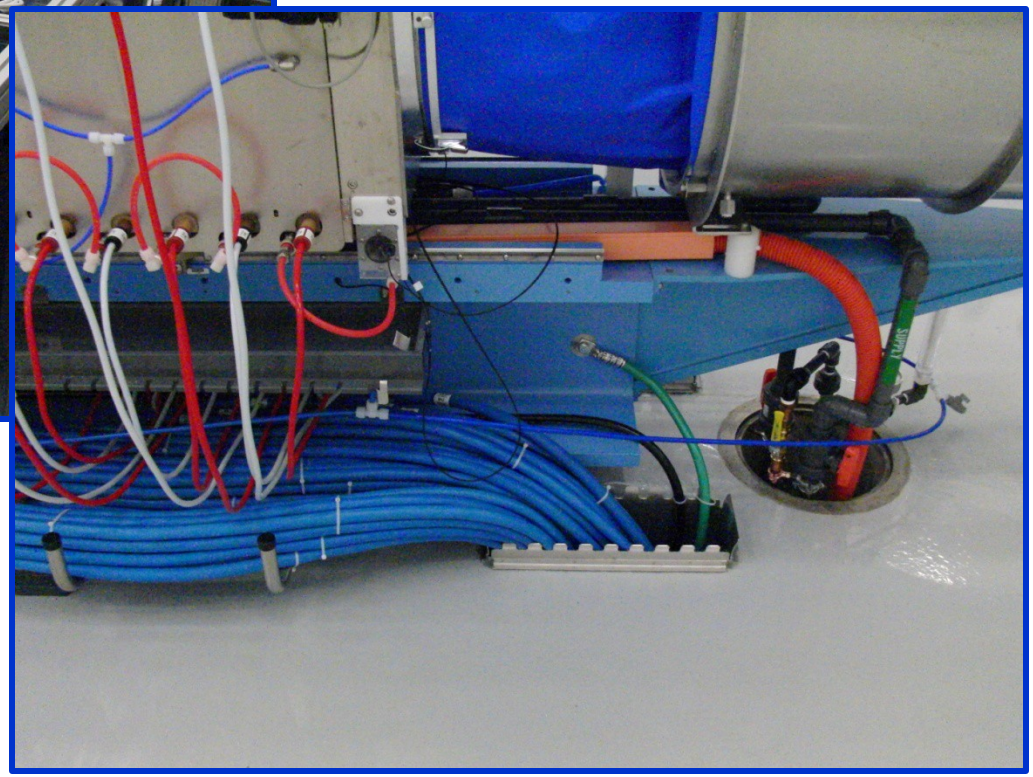
- **Lockout/Tagout (LOTO) equipment suspected of presenting a hazard to personnel or other equipment if operated.**
- **Install a LOTO prior to beginning maintenance**
- **Verify potential hazardous energy is discharged, dissipated**
- **Tags must be legible, and indicate: initiator, reason, time & date**
- **NEVER operate locked or tagged-out equipment.**

Cable installations must be planned, engineered, documented, and properly executed to be safe and reliable



Cable installations must comply with LLE Documents

- M-TM-M-002 and
- E-CB-G-001



Cables must not inhibit access, or cause trip or overhead hazards. Cables must be rated for the environment.

General Housekeeping - Do NOT use Electrical Raceways as Shelves

Equipment will be De-energized to the Greatest Extent Possible Before Work May Proceed

- Guidelines for De-energizing Electrical Equipment
- Identify and isolate equipment from energy source(s)
- Verify power is off
  - Attempt to operate
  - Measure voltage *
- Release stored energy
  - Electrical *
  - Mechanical, hydraulic, pneumatic, gravity, chemical
- Ground chassis with clip leads or ground cables to ensure zero-volt safe state *
- Lockout and tagout to prevent unexpected activation

* These operations must be done by a qualified electrical worker

Obtain assistance from a qualified electrical worker when necessary or unsure

LLE's Electrically Energized Work policy

Definitions

High voltage: ≥ 50V potential relative to earth ground

Electrically Energized: Conductors are exposed with high voltage

- **Work on Electrically Energized equipment is permitted *only when essential*:**
  - **If disabling power will affect critical safety systems**
  - **When necessary to evaluate operation of electrical equipment**
  - **In all other situations, high voltage equipment MUST be de-energized before servicing**

LLE will apply DOE guidelines (DOE-HDBK-1092-2013) to establish criteria for electrically energized equipment safe work practices.

***ONLY* qualified electrical workers may work on high voltage equipment or perform Electrically Energized Work**

De-energize equipment before starting work

- **Written procedures approved in PDM may be executed by qualified persons, as-needed, at the discretion of the work-area supervisor (e.g., Shot Director)**
- **Work performed in the Omega facility must be managed by a WAP (Work Authorization Procedure; see LLE Instruction 3000 (LFORM) section 4003A)**
- **Bench-top diagnostic and troubleshooting (e.g. in Electronics shop) does not require a WAP**
- **A work plan for the testing/commissioning of new/modified high voltage equipment is to be presented for review and approval prior to execution (per LLE Instruction 7700 - Preliminary Qualification Review section)**
- **Emergency repairs and in-situ troubleshooting require a review by cognizant work-area supervisor, safety officers and/or management**
- **Energized work on high-ampacity systems (e.g. power distribution) may only occur after an Energized Electrical Work Permit (ref E_003) has been filled out and approved. Additional requirements include:**
  - **A person trained in CPR is in the immediate vicinity**
  - **A knowledgeable electrical worker is present and prepared to safe the system in the event of an emergency**

How does one become qualified? (continued)

- By co-signing the quiz, the group leader is indicating:
  - Concurrence that the individual needs to perform energized work,
  - The individual is competent to perform the assigned tasks,
  - Energized electrical work is avoided except when essential,
  - Procedures are followed for repetitive energized work tasks,
  - Safeguards are enforced when energized-work is conducted,
  - The work area is suitable for the task
- By co-signing the quiz, the RI is indicating the individual:
  - Has the requisite training to safely execute the tasks,
  - Is competent to perform the tasks

ONLY qualified electrical workers may perform the following tasks, and only when authorized

- **Build, test, commission, troubleshoot or repair high voltage equipment**
- **Override electrical safety interlocks**
- **Open electrical covers or doors**
- **Reset circuit breakers or replace fuses**
- **Remove switch or receptacle covers**

Authorization may take several forms:

- **Work order assignment**
- **Execution of an authorized WAP**
- **Assignment by your supervisor**
- **Approval of a qualification plan**
- **Execution of an energized work permit**

Laboratory Safety Inspection are Performed Semiannually

Semiannual inspection of all lab spaces is mandated by LLE Instruction 6550

- **Electrical Safety Guidelines**
  - **Compliance with the NFPA National Electric Code**
  - **Undamaged Cables, Leads, and Plugs**
  - **Guarding for Electrical Terminals**
  - **Electrical Interlocks Installed and Operational**
  - **Equipment De-energized Prior to Maintenance**
  - **Appropriate Labels on High Voltage Equipment**
  - **Optical Tables and Benches Properly Grounded**
  - **GFI Outlets Utilized Near Sinks**
  - **Non-UL Approved Equipment Not In Use**

Electrical Safety Inspections are mandated on a Case by Case Basis when Modifications Occur

- **New Construction**
- **New System Installations**
- **Milestones**
- **Modifications of Existing Equipment**

Electrical Safety Awareness is a Mindset at LLE

- Plan jobs thoroughly; review procedures with your supervisor
- Include safety plans and actions in Design Reviews
- Maintain safe working distance from exposed circuitry
  - 0.6 meters minimum from 1 to 15 kV
  - Use barricades and warning signs
- Maximize use of insulating materials
- Review emergency response procedures
- Review means of evacuation
- Employ Good Housekeeping
- Immediately report deficiencies

Responsibilities

- **University of Rochester and LLE (EH&S)**
  - **Provide and maintain a safe working environment**
  - **Establish safety guidelines and protocols**
  - **Monitor to ensure regulatory compliance and employee safety**

- **Safety Officers**
  - **Provide training, support, audits, and guidance in safety related matters**

Responsibilities

- **Supervisors / Advisors**
  - **Ensure that all supervised personnel are adequately trained and qualified for assignments**
  - **Ensure that LLE safety policies are adhered to, and proper Personnel Protective Equipment (PPE) is worn for all activities**
- **Employees / Staff / Students**
  - **Complete ALL training required for your work**
  - **Abide by safety policies**
  - **Request further training if required**
  - **Understand the hazards present in your area**
  - **Question unsafe practices; inform Safety Officer(s) if necessary**
  - **Wear PPE as directed**

Electrical Safety Conclusions

- Understand and follow all LLE safety policies
- Seek further training / use Safety Officers when required
- It's your experiment, it's your lab, take responsibility
- Clearly communication with co-workers
- Plan jobs and discuss with your supervisor
- Follow Lock out / Tag out procedures
- Clearly label all recognized and potential hazards
- Have an emergency response plan
- Clearly post emergency numbers
    - Medical Emergency dial 55101 or 53941
    - After Hours University Security dial 13

Safety is everyone's business and compliance with safety procedures is MANDATORY

Summary

- Electricity is a serious safety hazard when handled improperly
- 50 Volts or higher is considered HIGH VOLTAGE at LLE
- Training - only perform activities for which you are qualified
- If an activity seems unsafe, "Stop Work" and address concerns
- Promptly report safety deficiencies or events
- Never defeat engineering safeguards
- Lockout/Tagout (LOTO) & Safety Inspection Policy
- LLE policy – Work on energized equipment follows DOE guidelines

Ensuring a safe working environment at LLE is a responsibility shared by all personnel

Remember, Stay Alert - Be Safe

Disclaimer: Resemblance to LLE employees, past or present, is purely coincidental.