INDIANA UNIVERSITY

Laboratory Safety Guideline

Electrical Safety

Introduction

The typical laboratory contains a wide variety of electrically-powered equipment including stirrers, shakers, pumps, hot plates, heaters, power supplies, ovens, and electrophoresis equipment. Many laboratory electrical devices have high voltage requirements carrying even more risk. Large capacitors found in many laser flash lamps and other systems are capable of storing lethal amounts of electrical energy and pose a serious danger even if the power source has been disconnected.

The major hazards associated with electricity are electrical shock and fire. All electrical devices used in the lab setting present a potential danger of injury due to improper procedures, poorly installed and/or maintained systems or fires due to sparks serving as an ignition source for flammable or combustible materials.

Electrical Shock

Electrical shock occurs when the body becomes part of the electric circuit, either when an individual comes in contact with both wires of an electrical circuit, one wire of an energized circuit and the ground, or a metallic part that has become energized by contact with an electrical conductor.

The severity and effects of an electrical shock depend on a number of factors, such as the pathway through the body, the amount of current, the length of time of the exposure, and whether the skin is wet or dry. Water is a great conductor of electricity, allowing current to flow more easily in wet conditions and through wet skin.

The effect of the shock may range from a slight tingle to severe burns to cardiac arrest. Currents only slightly in excess of one's let-go current (the current at which a person is frozen to the circuit and unable to let go) are said to “freeze” the victim to the circuit. Prolonged exposure to currents only slightly in excess of a person’s let - go limit may produce exhaustion, asphyxia, collapse, and unconsciousness followed by death.

The chart below shows the general relationship between the degree of injury and amount of current for a 60-cycle hand-to-foot path of one second's duration of shock. While reading this chart, keep in mind that most electrical circuits can provide, under normal conditions, up to 20,000 milliamperes (20 Amps) of current flow.

Current	Reaction
1 Milliampere	Perception level
5 Milliamperes	Slight shock felt; not painful but disturbing
6-30 Milliamperes	Painful shock; "let-go" range
50-150 Milliamperes	Extreme pain, respiratory arrest, severe muscular contraction
1000-4,300 Milliamperes	Ventricular fibrillation
10,000+ Milliamperes	Cardiac arrest, severe burns and probable death

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Fires

In addition to the electrical shock hazards, sparks from electrical equipment can serve as an ignition source for flammable or explosive vapors or combustible materials.

Lab workers can protect themselves from the hazards of electricity by following some basic guidelines. The guidelines include maintaining awareness of the condition of lab equipment, the proper use of lab equipment and safe work practices.

Electrical Repairs and Modifications

Electrical repairs and alterations must be performed by authorized individuals only. Unauthorized alterations are not permitted. The three general categories of electrical repairs that may occur are 1) repairs and alterations to building electrical service, 2) repairs or alterations of commercial electrical appliances, instruments, and equipment, and 3) repairs and alterations to experimental research equipment being developed in the laboratories.

1. Building and Laboratory Wiring, Outlet Receptacles, and Breaker Panels

Any modifications to existing electrical service in a laboratory or building must be approved by the building facility manager and/or a qualified electrical engineer from the Physical Plant.

Maintenance or modifications to existing electrical service such as breaker panels, outlet receptacles, wall switches or wiring must be performed by licensed electricians and **not** by laboratory personnel.

Laboratory personnel may **only** reset ground fault circuit interrupters (GFCIs) or shut off breakers or reset tripped breakers in panels and only if authorized to do so by the facility manager. Laboratory personnel may not replace GFCIs or circuit breakers in panels or manipulate wiring in breaker panels.

Unauthorized alterations to building electrical service:

- Is a violation of the Building, Electrical, and Fire Code.
- Is a violation of worker union policy.
- Increases the liability of the University.
- Puts building occupants at risk.

Any unusual laboratory modifications discovered during laboratory surveys or other activities will be reviewed to determine whether they meet building code specifications.

2. Commercial Appliances, Instruments, and Equipment

Maintenance or modifications to commercial appliances, instruments, and equipment must be performed by the manufacturer or the department's maintenance shops by qualified electricians and **not** by laboratory personnel.

Unauthorized alterations to commercial electrical equipment:

- Voids the manufacturer's warranty.
- Voids the manufacturer's liability.
- Increases the liability of the owner.

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3. Experimental Electrical Equipment and Research Apparatus

Laboratory research personnel may **only** perform maintenance or modifications to experimental electrical equipment used or developed in research and **only** if they are properly trained, qualified and under adequate supervision of an experienced associate.

Preventing Electrical Hazards

There are various ways of protecting people from the hazards caused by electricity including insulation, guarding, grounding, and electrical protective devices. Laboratory workers can significantly reduce electrical hazards by following some basic precautions:

- Inspect laboratory electrical equipment and cords to be sure they are in good condition. Remove equipment from service if in poor condition and replace or have it repaired by an authorized, qualified repair person.
- Use safe work practices every time electrical equipment is used.
- Know the location of your electrical panels and shut-off switches so you can quickly disconnect power in the event of an emergency. Be sure to always leave at least a 3-foot clearance around electrical panels for easy access.
- Minimize the potential for water or chemical spills on or near electrical equipment.
- Plan ahead for what steps will be taken in the event of a power loss. Think about potential vapor/gas release from vapor-generating processes or chemical fume hoods if power is lost.

Power Cords and Insulation

All electrical cords should have sufficient insulation to prevent direct contact with wires. In a laboratory, it is particularly important to check all cords before each use, since corrosive chemicals or solvents may erode the insulation.

Damaged cords should be repaired or taken out of service immediately, especially in wet environments such as cold rooms and near water baths.

- Inspect power cords to be sure they are not frayed or have exposed wiring.
- Electrical tape is **not** an acceptable repair for a damaged cord, replace the entire cord.
- Carefully place power cords so they don't come in contact with water or chemicals. Contact with water is a shock hazard. Corrosives and solvents can degrade the cord insulation.
- Do not allow cords to dangle from counters or hoods in such a manner that equipment could be unplugged, fall, or cords could be tripped over.
- Do not allow cords to contact hot surfaces to prevent melting insulation.
- Do not lift a piece of electrical equipment by the cord or pull the cord to disconnect from the outlet in order to prevent damage.
- Power cords must have grounding plugs or be double insulated.

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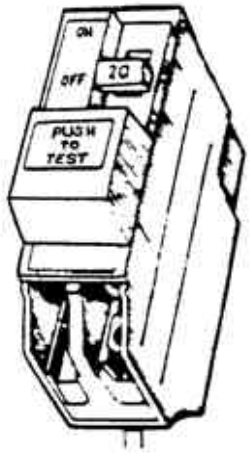
- Extension cords are for temporary use only for short periods of time. The only exception is that electrical power strips (UL Approved) are allowed only for personal computers and their components. In all other cases, request installation of a new electrical outlet.
- Multi-plug adapters are for temporary use only for short periods of time and must have circuit breakers or fuses. Multiple plug outlet adapters are not allowed for long periods of service. For permanent applications request installation of an additional electrical outlet.

Circuit Protection

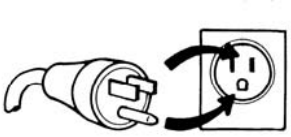
Circuit protection devices are designed to automatically shut off the flow of electricity in the event of a ground-fault, overload or short circuit in the wiring system. Ground-fault circuit interrupters, circuit breakers and fuses are three well-known examples of such devices.

- No more than two high current draw devices such as ovens and centrifuges should be plugged into the same outlet to prevent an overloaded circuit. Overloading can lead to overheated wires and arcing. This can cause electrical shock injury and fire.
- Fuses and circuit breakers prevent over-heating of wires and other electrical components. This overload protection is useful for equipment that may be left on for a long time such as stirrers, drying ovens, vacuum pumps, Variacs, etc.
- Ground-fault circuit interrupters, or GFCIs, shut off the electrical current if a ground-fault is detected and protect the user from electric shock. GFCI outlets or portable GFCIs are used near sinks and potentially wet locations. Keep electrical equipment (and yourself while you are using electrical equipment) away from water/chemical or their spills unless you are sure the equipment is rated for this type of use. Since GFCIs can cause equipment to shutdown unexpectedly, they may not be appropriate for certain apparatus. Portable GFCI adapters (available in most safety supply catalogs) may be used with a non-GFCI outlet.



Grounding

Only equipment with three-prong plugs should be used in the laboratory. The third prong provides a path to ground for internal electrical short circuits, thereby protecting the user from a potential electrical shock.



- Electrical appliances are grounded through the electrical receptacles.
- Electrical outlet receptacles must have a grounding connection and accept three-prong plugs.
- Grounds to prevent static load and/or discharge should be grounded to a grounding terminal and **not** to the ground of an electrical receptacle.

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Shielding and Equipment Guarding

Exposed, un-insulated electric components provide a source of electrical shock.

- Equipment operating at 50 volts or more (i.e., electrophoresis devices) must be guarded against accidental contact.
- Plexiglas shields may be used to protect against exposed live electrical circuits and parts.
- Shields may be removed for service only after the equipment has been de-energized.

Power Supplies

Portable power supplies are commonly used in the laboratory. These devices are extremely high electrical energy sources and must be used carefully.

- Power supplies should be shielded and grounded.
- Power supplies and electronic equipment used with aquariums and open water tanks, tubs, and containers must be positioned away from the tanks so that they will not fall into the water and electrical circuits must be equipped with GFCI type breakers.
- Use only approved connectors. Never attach an exposed connector such as an alligator clip to a power supply.

Electric Motors, Switches, and Sources of Ignition

In laboratories where volatile flammable materials are used, motor-driven electrical equipment should be equipped with non-sparking induction motors or air motors. These motors meet National Electric Code (US DEC, 1993) Class 1, Division 2, explosion resistance specifications for locations where flammable vapors may exist outside the housing of the equipment. Many stirrers, Variacs, outlet strips, ovens, heat tape, hot plates and heat guns do not conform to these code requirements. Keep them away from flammable liquids and vapors.

Avoid series-wound motors, such as those generally found in some vacuum pumps, rotary evaporators and stirrers. Series-wound motors are also usually found in household appliances such as blenders, mixers, vacuum cleaners and power drills. These appliances should not be used unless flammable vapors are adequately controlled.

Although some newer equipment have spark-free induction motors, the on-off switches and speed controls may be able to produce a spark when they are adjusted because they have exposed contacts. One solution is to remove any switches located on the device and insert a switch on the cord near the plug end.

- Be aware of sources of ignition (motors, lights, switches, thermostats, etc.) associated with electrical equipment.
- Use intrinsically safe explosion proof equipment where flammable vapors are known to exist.
- Do not use ordinary electrical appliances where flammable vapors may accumulate.
- Ventilate and control all flammable vapors.

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Flammable and Combustible Materials

Electrical devices, plugs, cords, and other equipment can provide a source of ignition sufficient to ignite combustibles and flammable or explosive vapors.

- Keep flammable materials away from electrical equipment.
- Do not store flammable organic liquids above electrical devices.
- Extension cords, power strips, and power cords located on the floor can provide a source of ignition in the event of a flammable liquid spill. Position these items carefully.
- Receptacles providing power for equipment used inside a fume hood should be located outside the hood.
- Make sure that equipment used where flammable vapors may be present is specially rated to not produce sparks. Many household appliances such as hot plates, vacuum cleaners, and drills don't meet this requirement so they should be used only under very controlled conditions.
- If refrigeration or freezing is needed, flammable materials should only be stored in laboratory safe flammable refrigerators or explosion proof equipment. These do not contain any ignition sources such as lights and switches.
- Do not plug heating mantles directly into a 110-volt outlet as they can overheat, leading to fire hazard. They need a variable autotransformer to control the input voltage.
- Be aware that if drying ovens are used to dry organic materials that they or their vapors may accumulate inside the oven and ignite or escape into the lab atmosphere. Take care to prevent developing explosive mixtures in air by using the ovens properly, not packing them too full or not drying organic materials that can create these conditions.

Power Loss

Be prepared for a power loss. The loss of electrical power can create hazardous situations.

- Flammable or toxic vapors may be released as chemicals warm when a refrigerator or freezer fails.
- Fume hoods may cease to operate allowing vapors to accumulate or be released into the laboratory.
- Magnetic or mechanical stirrers that fail to operate may compromise safe mixing of reagents.

High Voltage Equipment

Repairs of commercial high voltage equipment can **only** be performed by trained electricians. Laboratory workers who are authorized and experienced to perform such work on their **own** laboratory equipment must first receive specialized electrical training and electrical safety training in safe work practice controls

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High Voltage Safety Requirements

1. **Shielding:** Live parts of all electrical equipment must be completely enclosed or otherwise guarded against accidental contact.
2. **Interlocking:** Where continual maintenance or adjustments must be performed, enclosing shields must be provided with interlocks which will disconnect all power to conductors and short out capacitors when the shield is removed or opened.
3. **Disconnects:** Provide an accessible, labeled main power disconnect switch.
4. **Grounding:** Ground all exposed non-current carrying parts. (Metallic table tops should be grounded to a grounding terminal.)
5. **Bonding:** All grounded parts must be bonded to each other to keep them at the same grounded electrical potential.
6. **Insulators:** Adjustment mechanisms must be insulated from live electrical parts or be made of nonconductive material.
7. **Space:** A minimum of 30 inches width should be maintained on all working sides of equipment operating at 600 volts or less; 36 inches if over 600 volts.
8. **Floors:** Regard all floors used in high voltage applications as conductive and grounded unless covered with well maintained dry rubber matting suitable for electrical work.
9. **Working Alone:** Working alone at any time is not allowed.
10. **CPR:** It is recommended that all persons working with lasers have training in cardiopulmonary resuscitation, available through the EH&S, Risk Management, or through the American Red Cross.

Safe Work Practices

Safe work practices are an administrative hazard control used to prevent injury and accidents. The following safe work practices will reduce risk of injury or fire when working with electrical equipment. Personnel must understand and be trained to practice the following procedures:

1. Avoid contact with energized electrical circuits.
2. Treat all electrical devices as if they are live or energized.
3. Disconnect the power source before servicing or repairing electrical equipment.
4. Use only tools and equipment with non-conducting handles when working on electrical devices.
5. Never use metallic pencils or rulers, or wear rings or metal watchbands when working with electrical equipment.
6. When it is necessary to handle equipment that is plugged in, be sure hands are dry and, when possible, wear nonconductive gloves and shoes with insulated soles.
7. If it is safe to do so, work with only one hand, keeping the other hand at your side or in your pocket, away from all conductive material. This precaution reduces the likelihood of accidents that result in current passing through the chest cavity.
8. Minimize the use of electrical equipment in cold rooms or other areas where

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condensation is likely. If equipment must be used in such areas, mount the equipment on a wall or vertical panel.

9. If water or a chemical is spilled onto equipment, shut off power at the main switch or circuit breaker and unplug the equipment.
10. If an individual comes in contact with a live electrical conductor, do not touch the equipment, cord or person. Disconnect the power source from the circuit breaker or pull out the plug using a leather belt.
11. Equipment producing a "tingle" should be disconnected and reported promptly for repair.
12. “Shorts” (ground faults) are extremely hazardous especially where in contact with metal frame-work of an exhaust hood or damp floor.
13. Do not rely on grounding to mask a defective circuit nor attempt to correct a fault by insertion of another fuse or breaker, particularly one of larger capacity.
14. Keep use and length of extension cords to a minimum.
15. Never work on live equipment.
16. Drain capacitors before working near them and keep the short circuit on the terminals during the work to prevent electrical shock.
17. Never touch another person’s equipment or electrical control devices unless instructed to do so.
18. Enclose all electric contacts and conductors so that no one can accidentally come into contact with them.
19. Never handle electrical equipment when hands, feet, or body are wet or perspiring, or when standing on a wet floor.
20. Whenever possible, use only one hand when working on circuits or control devices.
21. When it is necessary to touch electrical equipment (for example, when checking for overheated motors), use the back of the hand. Thus, if accidental shock were to cause muscular contraction, you would not "freeze" to the conductor.
22. Do not store highly flammable liquids near electrical equipment.
23. Be aware that interlocks on equipment disconnect the high voltage source when a cabinet door is open but power for control circuits may remain on.
24. De-energize open experimental circuits and equipment to be left unattended.
25. Unplug cords by gripping the plug end; do not pull on the cord.
26. Do not wear loose clothing or ties near equipment.

References

Prudent Practices in the Laboratory – Handling and Disposal of Chemicals, National Research Council, National Academy Press, Washington, D.C., 1995.

CRC Handbook of Laboratory Safety, CRC Press, Washington DC, 2000.