Department of Electrical Engineering

University of Massachusetts Lowell

Safety Fact Book

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4/1/95

The overall responsibility for safety and health (including housekeeping) rests with the Department Chairperson. Each member of the Department, whether faculty, staff, or student, is responsible for knowing and observing the departmental safety rules. Typical rules are presented in the next chapter of this publication.

Each faculty member is responsible for developing, posting, and enforcing any special safety precautions or rules particular to his/her area arising from the nature of the research or laboratory course. The faculty member and teaching/research assistant are responsible for explaining and enforcing the departmental safety rules in their classes/laboratories, and for reporting all infractions to the Chairperson or appropriate faculty member. Each student in a laboratory class is responsible for knowing and following all safety rules as explained to him/her. All affected persons have the added responsibility of being alert at all times for unsafe situations that could affect them, their coworkers, fellow students, or visitors.

The safety program for an engineering department has many aspects, including:

- Recognizing actual and potential hazards in research and teaching laboratories and in the general academic environment
- Evaluating the magnitude of these hazards
- Controlling the hazards by eliminating their causes, modifying procedures, removing personnel, instituting effective engineering controls, or using appropriate personal protective equipment
- Planning for accident/injury prevention
- Educating the faculty, staff, and students in proper safety techniques for the environment peculiar to the department
- Establishing emergency action plans appropriate for any hazards present.

Electrical Hazards[14,15]

Students in engineering laboratory courses typically have some knowledge of electricity and magnetism through previous physics or electrical engineering courses. They should be required to review the concepts of circuits and grounds when possible electrical hazards exist. A circuit is a complete loop. Electric current can flow only if a circuit is complete. In 120-volt distribution systems, one wire is the current source and the other is the ground wire. If a person or object contacts the circuit or current path and forms an alternate route to ground, current will flow through the alternate path. All 120-volt distribution systems have a separate wire intended to form a low-resistance, alternate route to ground. The bodies of electrical devices are attached to this ground wire to ensure that inadvertent contact between the circuit wires and the body of the devices do not create an electrical hazard for users. Circuit grounds and safety ground wires must be attached to approved electrical grounding systems. Electrical systems and equipment must meet local and national electrical codes[16] and OSHA standards.

Effects of Electric Current

Table 6-4 shows the general relationship between the degree of injury and amount of amperage for a 60-cycle hand-to-foot path of 1 second's duration of shock. As this table illustrates, a difference of less than 100 milliamperes exists between a current that is barely perceptible and one that can kill. Muscular contraction caused by electrical stimulation may not allow victims to free themselves from the circuit, and increased duration of exposure increases the danger. For example, a current of 100 milliamperes for 3 seconds is equivalent to a current of 900 milliamperes applied for 0.03 seconds in causing fibrillation. The so-called low voltages can be extremely dangerous because the degree of injury is proportional to the length of time a body is in a circuit. **LOW VOLTAGE DOES NOT IMPLY LOW HAZARD!**

Electric Shock

Shock occurs when the body becomes a part of the circuit, with current entering the body at one point and leaving at another. Shock normally occurs in one of three ways. The person must come into contact with: (1) both wires of the electrical circuit; (2) one wire of an energized circuit and the ground; or (3) a metallic part that has become "hot" by being in contact with an energized wire while the person is also in contact with the ground.

The severity of the shock received when a person becomes a part of an electrical circuit is affected by three primary factors: (1) the amount of current flowing through the body (measured in amperes); (2) the path of the current through the body; and (3) the length of time the body is in the circuit. Other factors that may affect the severity of shock are the frequency of the current, the phase of the heart cycle when shock occurs, and the general health of the person prior to shock. The effects from electric shock depend on the type of circuit, its voltage, resistance, amperage, pathway through the body, and duration of the contact. Effects can range from a barely perceptible tingle to immediate cardiac arrest.

A severe shock can cause considerably more damage to the body than is visible. A victim may have internal hemorrhages and destruction of tissues, nerves, and muscles. In addition, shock is often only the beginning in a chain of events. The final injury may well be from a fall, cuts, burns, or broken bones. Electric shock can also cause injuries of an indirect or secondary nature in which involuntary muscle reaction from the electric shock can cause bruises, bone fractures, and even death resulting from collisions or falls. In some cases, injuries caused by electric shock can contribute to delayed fatalities.

Table 6-4. Effects of Electrical Current in the Human Body[14]

Current	Reaction
1 Milliampere	Perception level. Just a faint tingle.
5 Milliamperes	Slight shock felt; not painful, but disturbing. Average individual can let go. However, strong involuntary reactions to shocks in this range can lead to injuries.
6-25 Milliamperes (women) 9-30 Milliamperes (men)	Painful shock, muscular control is lost. This is called freezing current or "let-go"* range.
50-150 Milliamperes	Extreme pain, respiratory arrest, severe muscular contractions.[a] Individual cannot let go. Death is possible.
1-4.3 Amperes[b]	Ventricular fibrillation. (The rhythmic pumping action of the heart ceases.) Muscular contraction and nerve damage occur. Death is most likely.
10 or more Amperes	Cardiac arrest, severe burns and probably death.

[a] If the extensor muscles are excited by the shock, the person may be "thrown" away from the circuit by quick muscular contractions caused by the externally applied current affecting the muscles.

[b] Where shock durations involve longer exposure times (5 seconds or greater) and where only minimum threshold fibrillation currents are considered, theoretical values are often calculated to be as little as 1/10 the fibrillation values shown.

Electrical Burns

The most common shock-related injury is a burn. Burns suffered in electrical accidents are of three types: (1) electrical burns, (2) arc burns, and (3) thermal contact burns. Electrical burns are the result of the electrical current flowing through tissues or bone. Tissue damage results from the heat generated by the current flowing through the body. Electrical burns are one of the most serious injuries that can be sustained and should be given immediate attention. Arc or flash burns are the result of high temperatures in close proximity to the body and are produced by an electric arc or explosion. They should also be treated promptly. Thermal contact burns are those normally experienced when the skin comes into contact with hot surfaces of overheated electrical conductors, conduits, or other energized equipment. In addition, clothing can be ignited in an electrical accident and a thermal burn can result. All three types of burns can be produced simultaneously.

Factors Causing Electrical Hazards

Electrical accidents appear to be caused by a combination of three possible factors--unsafe equipment or installation, workplaces made unsafe by the environment, and unsafe work practices. There are various ways of protecting students from the hazards caused by electricity, including insulation, guarding, grounding, circuit interruption, mechanical devices, and safe work practices.

One way to safeguard individuals against electrically energized wires and parts is through insulation. An insulator is any material with high resistance to electrical current and physical damage. Insulators--such as glass, mica, rubber, and plastic--are placed on conductors to prevent shock, fires, short circuits and physical damage. When preparing to work with electrical equipment, it is always a good idea to check the insulation to be sure there are no exposed wires before making a connection to a power source. The insulation of flexible cords, such as extension cords, is particularly vulnerable to damage. Extension cords are rated as light, medium and heavy duty to indicate the durability of the insulating material.

Live parts of electric equipment must be guarded against accidental contact. Live parts can be guarded by:

1. Location in a room, vault, or similar enclosure accessible only to qualified persons.
2. Use of permanent, substantial partitions or screens to exclude unqualified persons.
3. Location on a suitable balcony, gallery, or platform elevated and arranged to exclude unqualified persons.
4. Elevation to 8 feet or more above the floor.

Entrances to rooms and other guarded locations containing exposed live parts must be locked and marked with conspicuous warning signs forbidding unqualified persons to enter.

Safe Work Practices for Electrical Equipment

Students working with electrical equipment need to use safe work practices. All students must know how to shut off power to a piece of equipment either through the use of the power switch on the equipment or the circuit breaker. Circuit breakers or switch boxes must be secure but readily accessible. Each circuit must be clearly labeled to indicate the equipment or area that it activates. Students must be shown how to use the master electrical switch under emergency conditions. (The circuits should be checked to ensure that room lighting is on a separate box.) This is the time to teach students the "left-hand rule." Anytime they prepare to turn the master switch back on, but especially after changing a fuse, they should stand to the side, facing the wall instead of the box, and use their left hand to push the switch back on. In this way, if the box explodes when power is restored, they are less likely to suffer severe burns to the face or even death.

Lockout and Tagout

The accidental or unexpected starting of electrical equipment can cause severe injury or death. Before ANY inspections or repairs are made--even on the so-called low-voltage circuits--the current should be turned off at the switch box and the switch padlocked in the OFF position. Each person involved in maintenance must affix his/her individual padlock, and all must "clear" the circuit before it is re-energized. At the same time, the switch or controls of the machine or other equipment being locked out of service should be tagged securely to show which equipment or circuits are being worked on. Lockouts and tagouts should be removed only by the person(s) who installed them. OSHA lockout and tagout procedures are found in 29 CFR 1910.147.

Checking Electrical Equipment Prior to Use

All electrical components and equipment must be inspected before use. Frayed or worn wiring and extension cords; cracked plugs, switches, or receptacle and switch-plate covers; missing grounds; and two-wire to three-wire plug adaptors with missing "pigtails" or ground prong all render the device or system unfit for use until repaired. All repairs must be made only by qualified personnel: shop technicians or others (teaching assistants, the Laboratory Director) who have been certified as competent by an electrician. Students are not normally qualified to make repairs to or construct electrical equipment.

Reporting Unsafe Electrical Conditions

Students must be instructed to report any unsafe electrical condition immediately to prevent an accidental shock. Damaged or unauthorized extension cords must be taken out of service immediately. Make sure that students do not attempt to disconnect a damaged cord without first shutting off the power at the breaker. A good way to ensure that someone else does not attempt to plug in a piece of equipment with a damaged power cord is to clip off the plug with a pair of wire cutters. Since the plug connection is where most damage occurs, removing the plug is the first thing the electrician will do to repair it, anyway. As noted above, all electrical work must be done by experienced personnel. Equipment to be repaired should be tagged and repairs verified before reuse. All electrical equipment and systems must comply with local or national electrical codes.

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Safety Quiz Questions

1. Define the following terms: LEL, UEL, autogenous combustion temperature, flammable mixture.

2. How should oxidants and flammable chemicals be stored in the laboratory?

3. How can the formation of undesirable flammable mixtures be avoided?

4. Describe the difference between "grounding" and "bonding." When is each used?

5. How does the "left-hand rule" protect you when you are operating high-energy electrical switches?

6. What is the "fire triangle?"

7. How are portable fire extinguishers selected? What type(s) of extinguisher should be used on the following types of fires:
   a) smouldering trash in a metal waste-can?
   b) a burning pool of liquid (type unknown) on the bench-top or on the floor?
   c) sparking in the 220-v. switchbox servicing the distillation column?

   What types of fire extinguisher would not be appropriate for those fires?

8. Why must you never use a CO_2 or Halon fire extinguisher to put out the fire in someone's hair?

9. What types of procedures must be carried out in a laboratory fume hood? Why?

10. Explain the differences between "capture" and "transport" velocities with regard to hoods. What is the minimum entrance velocity required for laboratory fume hoods? How is this velocity measured?

11. What external factors affect the proper use of fume hoods? How can the entrance velocity be affected by these factors?

12. How should all power cords be unplugged? What do you do if there is any visible damage to the extension cord or plugs you need to use for your experiment?

13. Why is a two- or four-plug box on the end of an extension cord not acceptable for laboratory (or home) use?

14. What are the general criteria used to select protective clothing and equipment?

15. What types of hazards are associated with the use of electric-powered tools in the laboratory?

16. What precautions are necessary to protect the use of an electric-powered tool from shock?

17. What factors affect the severity of an electric shock? In general, what is the minimum electric current "across the heart" that will result in a fatality?

18. What are the precautions that you should take to protect yourself and your group from an electric shock?