

University of Hawaii- Mechanical Engineering Department-Machine shop

Machine Shop Safety Handbook

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THE BASIC SAFETY RULES

1. Never work alone.

At least two team members must be in the lab

2. Never work when you are impaired.

This includes when you are too tired, stressed or hurried to work carefully.

3. If you cannot do a job safely in this shop, don't do it.

There are limits to what we can build here.

4. Always wear closed-toe shoes in the shop.

*Tools, chips and fixtures are sharp, and often hot. Shoes will help protect your feet from injury
Leather shoes are preferred when welding.*

5. Eye protection is essential.

*Eye protection must be worn at all times in H140, H140A and H348
Prescription glasses sold in the US with plastic lenses and side shields meet ANSI Standard Z87.1 for safety.*

6. Long pants must be worn

Long pants are required to be worn in H140, H140A and h348. If they are kept in a locker you must put them on when entering.

7. Remove or secure anything that might get caught in moving machinery.

Rings, necklaces, long hair and loose clothes can get caught in tools and pull you in.

8. Keep your hands away from sharp and rotating tools.

Make sure that nothing that you do will cause you to be cut.

9. Dust, chemicals and smoke can be dangerous

Work in well-ventilated areas, minimize contamination and use appropriate protective equipment.

10. If you're unsure about the safe operation of a tool or any aspect of a job - ask for help!

Have shop staff check you out on a tool the first time you use one you are unfamiliar.

11. Clean up after yourself.

Before you leave the shop each day all tools must be returned to the toolbox, the machine cleaned and wiped down and the floor swept.

Information about the Holmes 348 Shop

The Student Machine Shop in Holmes 348 or the assembly area in Holmes 140/140A is available to Mechanical Engineering students, staff and faculty working on University projects. Everyone must read this safety handout and attend a safety workshop before using the tools in the shop.

The goal of this handout is to summarize the risks that are inherent in metalworking and to provide some guidelines for working safely. It is **not** intended to be a machining training manual. The first step in preventing personal injury or machine damage is to make sure that you know how to operate the equipment you will be using correctly.

If you are unsure - ASK!

Because it is a communal area, used by so many people, it is important to keep the shop clean and orderly. This means that every user must clean the machines and work areas as they move from machine to machine. Put away all tools and material before leaving the shop.

Inattention, hurried work, horseplay, bad judgment, fatigue, improper clothing, defective tools, and poorly secured workpieces cause most accidents. Avoid accidents by following all of the rules in this handout and asking for help if you are unsure about the safest approach.

Disregarding shop rules, working unsafely or leaving a mess will result in suspension of shop privileges.

These rules apply to the entire shop area in Holmes 348 and the project assembly area in Holmes 140/140A

In an Emergency:

Call 956-6911 in an emergency. The shop is in H 348 and the Assembly Area is in H140/H140A have emergency phones installed at central locations. When you lift the receiver you will be in contact with Public Safety dispatch.

Shop Hours:

Regular hours: M-F 9:30-12:00, 1:30-4:30. Access to the student shop may be limited during scheduled classes, and holidays. A monitor is being hired and he will provide more access for ME students

Only senior design teams have 24/7 access to work on their senior projects. Only senior design projects may be worked on during non-shop hours. Only senior design team members may be in the labs during non-shop hours.

General Safety Guidelines

- **Do not attempt to remove foreign objects from the eye or body.** Report to the student health service for medical treatment. If chemicals get in the eye(s), wash eye(s) for 15 minutes in an open flow of water before proceeding for medical treatment. Notify campus security at 956-6911.
- **Avoid excessive use of compressed air** to blow dirt or chips from machinery to avoid scattering chips. Never use compressed air guns to clean clothing, hair, or aim the gun at another person.
- **Machines must be shut off** when cleaning, repairing, or oiling.
- **Do not wear loose clothing**, jewelry, gloves, etc. around moving or rotating machinery. Long hair must be tied back or covered to keep it away from moving machinery. Hand protection in the form of suitable gloves should be used for handling hot objects, glass or sharp-edged items.
- **Wear appropriate clothing** for the job (i.e. do not wear short sleeve shirts or short pants when welding).
- **Do not work in the shop** if you are tired or in a hurry - this almost always ruins the work, and often results in injury.
- **Never indulge in horseplay** in the shop areas.
- **All machines must be operated** with all required guards and shields in place.
- **Remove chips** and shavings with a brush, hook, or special tool from the work area.
 - **Never use your hands to clean cuttings - they are sharp!**
- **Keep your fingers clear** of the point of operation of machines by using special tools or devices, such as, push sticks, hooks, pliers, etc.
 - **Never use a rag near moving machinery.**
- **Use a soft faced hammer.** A hard hammer should not be used to strike a hardened tool or any machine part.
- **Keep the floor around machines clean**, dry and free from trip hazards. Do not allow chips to accumulate.
- **Think through** the **ENTIRE** job before starting. Ask for help if you have questions.
- **Before starting a machine**, always check it for correct setup and always check to see if machine is clear by operating it manually, if possible.
- **Do not drink alcoholic beverages before or during work in the machine shop area. Do not bring food or snacks into the shop.**
- **Check the hazardous materials data sheets** for any specific precautions to be taken while working with a material. Also, ask the shop personnel before cutting any unusual material.
- **Heavy sanding**, sawing, grinding and painting should only be done in well-ventilated areas. Use face masks.
- **Use the PPE** that is required for the chemical you may use.
- **Follow precautions** when working with solvents, paints, adhesives or other chemicals.
- **Check the power cords** and plugs on portable tools for damage before using them.
- **Always store** oily rags in an approved metal container.

Drill Press Safety Guidelines

- **Run drill at correct RPM** for diameter of drill bit and material. Ask shop personnel for the correct RPM.
- **Hold work in a vise** or clamp to the drill table.
- **Use a correctly ground drill bit** for the material being drilled. Shop personnel can help select the correct bit.
- **Use the proper cutting fluid** for the material being drilled. Ask the shop staff about the appropriate fluid for the material you are machining.
- **Remove chips with a brush**, never by hand.
- **Ease up on drilling pressure** as the drill starts to break through the bottom of the material.
- **Inspect the drill bit** before using. Don't use a dull or cracked drill.
- **Do not drill with too much pressure.**
- **Always try to support part** on parallels or a backing board when drilling thru material.
- **Never place taper shank tools in a drill chuck.** Only straight shank tools such as standard drills can be clamped in chucks.
- **Always clean drill shank** and/or drill sleeve, and, spindle hole before mounting.
- **Remove taper shank tools from spindle or sleeve with a drill drift and hammer.**
- **Never try to loosen the drill chuck** while the power is on.
- Lower the drill spindle close to the table when releasing the drill chuck or taper shank drill to reduce the chance of damage should they fall onto the table.
- **Never clean a machine while it is in motion!!**
- If the drill binds in a hole, stop the machine and turn the spindle backwards by hand to release the bit.
- **When drilling a deep hole withdraw the drill bit frequently to clear chips and lubricate the bit.**
- **Always remove** the drill chuck key, or, the drill drift from the spindle **immediately after using it.**
- **Never try to stop the spindle with your hand.** Let the spindle stop of its own accord after turning the power off.
- **Plexiglas and other brittle plastics can be difficult to drill.** Ask the shop superintendent for advice on drill and coolant selection when drilling these materials.
- **Wear eye protection**

Lathe Safety Guidelines

- **Make sure that the chuck, drive plate, or, faceplate is securely tightened onto the lathe spindle.**
- **When removing the chuck, drive plate, or faceplate do not use machine power.**
- **When installing the chuck, drive plate, or faceplate do not use machine power.**
- **Move the tool bit a safe distance from the collet** or chuck when inserting or removing work.
- **Don't run the machine faster than the proper cutting speed** - consult a speed and feed table to determine the best speed.
- **Set tool holder to the left side of the compound** slide to prevent the compound slide from running into the chuck or spindle attachments.
- **Always clamp the toolbit as short as possible** in the toolholder to prevent it from breaking or chattering.
- **Make sure that the toolbit is sharp** and has the proper clearance.
- When filing on work revolving in the lathe, file left handed to prevent slipping into the chuck.

- **Never use a file without a handle.**
- **Make sure tailstock is locked in place** if work is turned between centers
- **Do not grasp or touch chips or turnings** with your fingers, remove them using a blunt instrument.
- **Turn off the lathe before clearing chips**
- **Set the toolbit on the centerline of your work.**
- Do not cut work completely through when turning between centers.
- **Remove chuck key from chuck immediately after using.**
- Turn chuck or faceplate through by hand before turning on the power to be sure there is no binding or clearance problem.
- **Stop the machine before taking measurements.**
- **Remove cutting tool** from the tool post and tailstock before cleaning the lathe.
- **Wear eye protection.**

Milling Machine Safety Guidelines

- **Work must be clamped securely in a vise**
- **Vise must be clamped tightly to the table**, or, work must be clamped securely to the table.
- **Do not climb cut** more than .005in
- **Make sure cutter is rotating in the proper direction** before cutting material.
- Before running machine the spindle should be rotated by hand to make sure it is clear for cutting.
- **Make sure the power is off before** changing cutters.
- Always use the proper cutting fluid for the material being cut.
- **Never run the machine faster** than the correct cutting speed.
- Make sure that the machine is fully stopped before taking any measurements.
- Always use cutters which are sharp and in good condition.
- Don't place anything on the milling machine table such as wrenches, hammers, or tools.
- **Always stay at the machine** while it is running.
- **Do not take too heavy a cut** or use too rapid a feed.
- **Remove the collet tightening wrench immediately after using it.**
- If at all feasible rig a guard or shield to prevent chips from hitting other people.
- Use the milling machine spindle brake to stop the spindle after the power has been turned off.
- **Before cleaning** the mill remove cutting tools from the spindle to avoid cutting yourself.
- **Wear eye protection.**

Band Saw Safety Guidelines

- The upper guide and guard should be set as close to the work as possible, at least within **1/4 inch**.
- **Immediately shut off the power** when the band breaks. Stand clear until the machine has stopped.
- **Examine blade before installing.** Check for cracks; do not install a cracked blade.
- **Use the proper pitch blade** for the thickness of the material to be cut. There should be at least 2 teeth in the material when cutting aluminum and three teeth when cutting steel.

- **Check the speed table** for the material that you are cutting. Do not run the band saw too fast or the blade will wear out quickly.
- If the saw stalls in a cut, turn the power off and reverse the blade by hand to free it.
- **Wear eye protection.**

Grinding Safety Guidelines

- **Abrasive wheel machinery shall not be operated without the appropriate guards in place.**
- Tool rests on bench or pedestal grinders shall be set no more than 1/16 inch from the wheel.
- **Never use a wheel that has been dropped** or received a heavy blow, even though there may be no apparent damage. Such wheels may be weakened or unbalanced enough to fly apart on startup.
- **Stand to one side when starting a grinding machine.** Damaged wheels will sometimes fly apart, and this is most likely to happen when the machine is being started. Stand to the side so that you will not be in-line with the debris.
- **Do not grind on side of wheel** unless wheel is specifically designed for such use.
- **Do not use excessive pressure** while grinding.
- **Report to the area supervisor immediately any cracked, broken or otherwise defective wheels.**
- Have the area supervisor mount and balance new wheels.
- **Keep the grinding wheel dressed.** Dressing a small amount frequently is better than having to dress a lot later and will allow the wheel to cut faster, cooler and with a better surface finish. Dressing is cleaning and smoothing the surface of the grinding wheel.
- **Hold work securely** while grinding, use the toolrest to support the work when off-hand grinding on bench or pedestal grinders.
- **Do not grind aluminum.**
- **Aluminum dust is explosive.**
- **Grinder is for grinding steel and stainless only.**
- **Wear safety shields or safety glasses when grinding on bench or pedestal grinders.**

Table Saw Safety Guidelines

- **Special training is required before using the table saw.**
- You may not operate it without permission from the shop supervisor.
- Stand to one side, never directly in line with, of work being fed through the saw.
- **Use the proper blade for the material** and type of cut. Do not use a rip blade for cross cutting, or, a crosscut blade for rip sawing. Do not use a plywood blade for anything but plywood.
- **Inspect the blade before using it,** to make sure it is the proper blade and is sharp and free from cracks.
- **Never allow your fingers to get near the blade when sawing.** Use a pusher stick to rip narrow pieces of stock. Don't use pusher stick to remove scrap. For scrap removal, shut off machine and wait until blade stops, then remove scraps.
- **Appropriate guards must be in place at all times.** Never remove the blade guard. Ask one of the shop personnel for help if you think the guard is in the way.

- **If the piece of material you are cutting is large, get someone to assist in tailing-off for you.** Never try to do it alone. Tailing off refers to supporting a large workpiece by supporting it underneath with your hands.
- **If you are tailing-off for someone else let them guide the work through the saw.** You should just support the work without influencing the cut.
- **Never reach over the saw** to obtain something from the other side.
- When shutting off the power, never attempt to stop the saw quickly by shoving anything against the blade. Make sure the saw has stopped before leaving it.
- **Never make any adjustments to the saw while it is running.** Turn off the power, unplug the power cord and make sure the saw is completely stopped before attempting to adjust it.
- **Do not allow material to collect on or around the saw table. Sweep up sawdust and material scraps regularly** while working to minimize chances of slipping or stumbling.
- Make sure that you clean up thoroughly around the saw before leaving the area. If you don't you could be the cause of someone else having an accident.
- **The circular blade of the table saw should be set to 1/8 inch above the work.**
- **Wear eye protection.**

Power Hand (Skill) Saw Safety Guidelines

- **Unplug the tool** before making any adjustments.
- Before using any power tool, inspect it to make sure the cord is not damaged in any way, that the ground pin is intact, and that the blade is sharp and undamaged.
- **Do not use the saw in a wet area.**
- Do not run the extension cord across walkways where people might trip over it or where the cord may be run over and damaged.
- Keep your head out of the path of particles thrown out by the blade. Wear eye protection.
- **Disconnect the power cord** before cleaning, changing blades, or making any adjustments to the saw.
- When it is necessary to raise the guard for certain types of cuts, use the guard lever.
- Never wedge, wire, or otherwise jam the guard to prevent it from working. **This is a particularly dangerous practice and will cause your permission to work in the machine shop to be revoked immediately!!!**
- Wait until the saw stops before lifting it from a cut.
- Before setting the saw down, make sure the guard is closed, as the blade may still be turning.
- Don't carry the saw with your fingers on the switch trigger.
- Don't pull the saw backwards in a cut if you can avoid it.
- Use the proper blade for the type of cut to be made.
- Do not use the cord to move or drag the saw.
- Do not use the power hand saw for cuts if you cannot keep a firm and secure grip on the saw and the material being cut. A hand saw is still the best for some kinds of work and often faster.
- Before cutting small workpieces shop personnel should be consulted.
- Adjust the depth of cut 1/8" greater than the material thickness.

Disc and Belt Sander Safety Guidelines

- **Do not operate sanders without the guards in place.**
- On the disc sander always use the downward motion side of the disc to sand. Never the upward motion side as this can throw your part upwards with tremendous force.
- Always attempt to place your work against the rest on the disc and belt sanders.
- On the horizontal belt sander, always sand, so that the belt motion is away from you.
- **Do not operate machines with torn or ripped belts or disks.**
- **Do not sand any material that will give off a dangerous dust. Such materials as beryllium or copper beryllium alloys must not be sanded or filed. Asbestos must not be sanded. Asbestos is an ingredient of brake shoes and pads.**
- **ALUMINUM DUST IS EXPLOSIVE**
- **Do not sand steel or stainless on the disc and belt sander. A spark into the dust collector may cause it to explode.**
- **Wear eye protection.**

Welding Safety Guidelines

- **Shop staff approval is required before using any welding equipment.**
- Welders, assistants, and anyone else in the welding area shall wear glasses or shields of recommended shades during welding operations.
- **The welder is responsible for erecting a screen around the welding area** to protect other personnel in the shop from eye injury.
- **Inspect all welding equipment to be used**, prior to each use, for possible damage.
- **Avoid handling oxygen bottles with greasy hands, gloves or rags.** Fatal explosions have resulted from this cause. (There are currently is no oxygen bottles in H140)
- **Always strap tanks to a welding cart or a fixed object.** Never allow a gas cylinder to be free standing.
- **Replace the safety cap** on all cylinders when not in use.
- Make sure work and/or work table is properly grounded when arc welding
- Do not arc weld in a wet area.
- **Be alert to possible fire hazards.** Move the object to be welded to a safe location, or, **remove all flammable materials from the work area.**
- **Never weld in the same area where degreasing or other cleaning operations are performed.**
- **Keep suitable fire extinguishing equipment nearby** and know how to operate it.
- **Shut off the cylinder valves when the job is completed, release pressure from the regulators by opening the torch valves momentarily and back out regulator adjusting valves. Never leave the torch unattended with pressure in the hoses.**
- **Utilize all protective equipment and clothing.** Do not arc weld with any part of the body uncovered, the arc light is actinic light (excessive ultraviolet) and will cause burns similar to severe sunburn.
- Never weld inside drums or enclosed spaces without adequate ventilation, or, the use of airline respirators or self-contained breathing apparatus.

- Check the ventilation system before starting to weld and periodically thereafter to insure adequate performance. **Welding fumes should not be allowed to get into the rest of the shop working areas.**
- **Never cut or weld any container that has held explosive or flammable materials.** Use prescribed methods for cleaning or flooding.
- **Never use wrenches or tools except those provided or approved by the gas cylinder manufacturer** to open valves. Never use a hammer to open or close valves.
- Abide by any other safety measures required for each particular type of welding.
- Allow for proper ventilation when brazing or soldering. The fluxes are acidic and toxic.
- **Do not weld on painted, galvanized or greasy, oily metals.** Not only can the fumes be toxic, but the welds will not be satisfactory and will fail in use.

Safety Guidelines for Working with Solvents, Resins and other Chemicals

- **Learn about the chemicals that you are planning to use before opening them. Read the instructions and MSDS sheet. Consult shop staff or EH&S if you have any questions.**
- Use water-based cleaners instead of solvents where possible.
- Avoid skin contact. Wear latex gloves.
- **Work in a fume hood** or in a well ventilated area.
- Do not use solvents around hot metal surfaces and flames.
- Do not smoke or light flames in areas where solvents are used and stored.
- **Report and clean up any spills immediately.**
- Only use solvents in well ventilated areas - do not work with them in confined, unventilated areas.
- **Do not drink alcoholic beverages or take medications containing alcohol before or during working with solvents.** Alcohol in the bloodstream sometimes causes synergistic reactions with various solvents that can lead to loss of consciousness, and even possibly, death.
- **Report any ill effects and skin disorders to the area supervisor.**
- Develop and maintain good personal hygiene habits. Remove protective equipment and wash thoroughly after contact with solvents.
- **Fumes from paints, solvents, adhesives can drift into the shop.** Work with staff to minimize these problems.
- **Mix resins in small batches.**
- **Wear eye protection.**

Safety Guidelines for Heavy Sanding of Wood and Foam

- Sand in well ventilated areas away from other machines, only on the patio with the doors to the shop closed.
- **Use a vacuum to collect dust** while sanding to prevent the dispersal over a large area.
- A dust mask must be worn.
- **Safety glasses must be worn when sanding.**

Guidelines for Cleaning

- **Turn off power to the machine before cleaning.** This will avoid accidentally starting the machine and injuring yourself.
- **Remove cutting tools.** Take out drill bits, mills and remove lathe tools to reduce the chances of getting cut. On the table saw lower the blade completely.
- **Put away all hand tools** and other items
- **Clean chips from the tool,** the chip pans. Recycle clean chips where possible.
- **Spray a light coat of NOCOR** on the machine ways
- **Sweep the floor** in the area where you have been working.
- **Do not over use compressed air.** Do not blow air into the bearing surfaces, and do not scatter chips all over the shop. Sometimes a shop vacuum works better than the air gun.
- **Report missing, broken or damaged tools** to shop staff.
- **Spend five minutes on general cleaning around the shop. We're all in this together**

Electrical safety

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Safety is important whenever you use electrical equipment — whether in the classroom, in the laboratory, or in the home. In this article we look at some basic safety considerations, particularly as they relate to the safe use of measurement equipment. The accompanying sidebar on Third-party safety certification explains why safety certification should be an important consideration when choosing electrical equipment.

Safety is everyone's responsibility. Nowhere is this truer than when using electricity.

Using electricity is like swimming, in that novices and experts can both enjoy its benefits provided they follow the rules at all times. None of us can fully depend on others to provide a safe working or playing environment. You have more control than anyone else over your activities and the caution you use when participating in those activities.

Practice safety

Tektronix encourages you to learn and follow these general precautions, and to read and follow instructions specific to circuits or equipment you work with.

- Never work alone.
- Learn first aid, especially cardiopulmonary resuscitation (CPR), for electrical accident victims.
- Except when absolutely necessary, turn off power or disconnect power source before working on electrical or electronic circuits. Consider all wires and terminals to be live until proven otherwise by a safe test method.
- Be sure your test equipment is operating properly before using it.
- Do not work on electronic circuits or equipment while standing on a wet floor, or when touching plumbing or metal objects that may provide a hazardous earth-ground path.
- Remove metal jewelry, watches, rings, chains, etc., before working on electrical circuits or equipment.
- Whenever possible, make current and voltage measurements with one hand in your pocket or behind you.
- Resist the temptation to throw a switch "to see what happens."

- Turn off power and unplug equipment before checking or replacing fuses. Locate and correct the cause of a blown fuse or tripped circuit breaker before replacing the fuse or resetting the breaker.
- Replace defective cords and plugs. Form a habit of inspecting for defects such as frayed wires, loose connections, and cracked insulation.
- Always check the electrical ratings of equipment you use, and be sure you use that equipment within its ratings.
- In general, treat all circuits as if high voltage or high current is present.

Safety measures

A primary safety measure is grounding the equipment chassis through a wire in the power cord. This practice is variously referred to as "green-wire ground" (because of the color of the insulation on the chassis ground wire) or "third-wire ground" (because a ground wire is a third wire).

If an internal electrical fault should somehow apply a dangerous voltage to the chassis of an instrument with a grounded chassis, the chassis ground wire would safely conduct the fault current to ground. In the process, the current might trip a circuit breaker or blow a fuse, which would alert the user that the instrument has a problem. But the main reason for the ground wire is to provide a path for any fault current. No fault current will then flow through the user if he/she touches the chassis.

For the reasons just explained, do not cut off the ground terminals of power cords in order to make "floating measurements" — doing so defeats ground protection. (Floating measurements are referenced to a voltage other than ground potential.) Use safety-approved equipment or procedures for such measurements.



The market offers various products, such as the Tektronix A6901 Ground Isolation Monitor and the A6902B Voltage Isolator, that permit floating measurements.

One technique of making floating measurements is to use a buffer to isolate the device being tested from the measurement portion of the test instrument. The Tektronix A6902B Voltage Isolator uses this buffer technique, which extends the range of the test instrument to 3000 volts (DC + peak AC) or 500 volts (DC + peak AC), depending upon the type of probe used.

Another way of making floating measurements is to isolate the power supply of the test instrument from the AC power-line ground reference. The Tektronix A6901 Ground Isolation Monitor uses this method, which allows an instrument's chassis to float up to ± 40 volts (28 volts rms) from ground.

Safety symbols as marked on equipment

⚡ DANGER — high voltage.

⊕ Protective ground (earth) terminal.

⚠ ATTENTION — see operator's manual.

Safety symbols in manuals

⚠ ATTENTION — This symbol indicates the location of applicable cautionary or other information in Tektronix operator's and service manuals.

What is electric shock?

According to Stedman's Medical Dictionary, electric shock is "a sudden violent impression caused by the passage of a current of electricity through any part of the body." This says nothing about the magnitude of that current.

The human body is electrically controlled; that is, it operates in response to its own minute electrical signals. Different persons have different resistances and sensitivities to electricity.

We recognize that electric shock is voltage dependent. One does not expect to get a shock from a battery or other low-voltage source. Sources below 30 volts are usually no problem. When voltages above 30 volts are present, precautions to prevent electric shock are appropriate. We must guard against any shock that could be fatal itself, or cause a severe reaction. We even want to prevent perception of the current.

The threshold of current perception is about 0.5 milliamps for 99.9% of the population, according to Charles F. Dalziel.¹ In other words, 999 persons out of a thousand will perceive a current of 0.5 milliamps; one will not.

Cord-connected appliances and equipment usually comply with this 0.5 milliamps leakage current limit. Some industrial equipment may exceed this value. Equipment with greater leakage current is usually marked "Warning — the protective grounding conductor provides protection from electric shock; this equipment must be earth grounded for adequate protection."

The "let-go current" is the maximum current a person can tolerate and still release the conductor by using the muscles directly stimulated by the current¹ — the average is 9 milliamps for men and 6 milliamps for women. The "conductor" is the source of current that the person has grasped.

"Further increase in current up to values that are not well-defined but thought to be on the order of 100 milliamps may cause a fibrillation of the heart," according to K. S. Geiges.² He specifies five important parameters, as follows:

Lowest resistance of the body	
Wet skin, outdoors	500 ohms
Dry skin, indoors	1500 ohms
Let-go current for adults	6 to 20 milliamps, AC, depending upon the person
Safe current, adults	
AC (rms)	5 milliamps at 30 volts
DC	5 milliamps at 20 volts

"Current caused by ordinary household voltage (120 V, North America; and 240 V, Europe) will be 240 milliamps (120 V/500 ohms) and 480 milliamps (240 V/500 ohms), showing that lethal shock can occur in the home."² Or, we add, in any place where standard electricity is available.

Fuses and circuit breakers will open the circuit under fault conditions. The time it takes these protective devices to open is rather long compared to body reaction times and, as a result, electric shock can result. Ground Fault Interrupters (GFI) are devices that sense current in the hot and neutral AC power lines. If currents are unequal, the difference must be a ground current, which causes the GFI to open the circuit. A GFI can be used to prevent severe electric shock when line current is diverted into a fault. With a GFI installed in the power circuit, a reaction will occur but fibrillation should not result.

"Currents above those possible from ordinary household voltage across a body impedance of 500 ohms (usually in the ampere range) can affect the nerve centers, causing paralysis. The most common effect of paralysis is respiratory failure. (Power linemen are subject to this.) Such current passing through the body causes hemorrhages and burns."²

Summary of electric shock effects¹

Following is a summary of the effects of electrical shock. Also refer to Figure 1.

- Currents above the reaction-current level may cause involuntary movement and trigger a serious accident.
- If long continued, currents in excess of the "let-go current" passing through the chest may produce collapse, unconsciousness, asphyxia, and death.
- An alternating current as small as 20 microamps may produce ventricular fibrillation if injected directly into the human heart.
- Currents in the order of milliamperes flowing through nerve centers controlling breathing may produce respiratory inhibition that may last for a considerable period, even after interruption of the current.
- Cardiac arrest may be caused by relatively low currents flowing in the region of the heart.
- Current in the order of amperes may produce fatal damage to the central nervous system.

- Electric currents may produce deep burns, and currents sufficient to substantially raise body temperature produce immediate death.
- Delayed death may result from serious burns or other complications resulting from severe electrical shock.
- Capacitor discharges in excess of 20 joules (watt-seconds) are likely to be hazardous.³

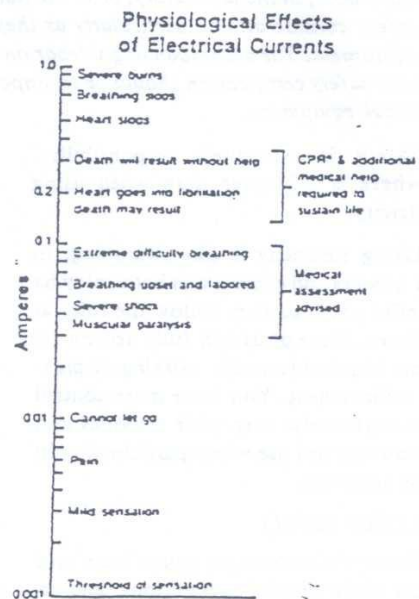


Figure 1. Physiological effects of electrical currents.

References

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