

Engineering & Technology, Manufacturing Clusters

General Considerations

Many technology education courses utilize lab spaces that employ a range of tools and equipment that pose hazards to students and others. Technology and engineering facilities must follow guidelines for electrical safety, safe use of equipment, and proper use and management of space.

Technology education students use a wide variety of tools and machines. They work in teams on projects, as well as work as a class. A facility must be well-lit, have a storage area, have sturdy work tables and classroom facilities. Storage may be in cabinets, under countertops, in a room devoted to storage or, in the case of tools and power equipment, on countertops. Sufficient room must be allotted for the safe use of tools and machines. Some high school or teacher-only-use machines may require floor space with safe zones around them. Some automated equipment and machines, such as 3D printers, may be permanently mounted on countertops. Other devices, such as robots, drill presses, and computer numeric control (CNC) machines may need to be located in the same way. These machines are typically run by computers, which must be convenient to the equipment. Provide proper ventilation to avoid dust accumulation.

Robots and automated equipment are powered mechanical equipment and must follow the same safety precautions observed when operating any computer-controlled machine. Automated equipment may be safer than standard equipment due to the fact that the user is generally removed from the point of processing, but they may also present hazards if the user or operator is distracted.

When using automated equipment, the user must follow four general recommendations:

1. **Be aware of tool limitations.** Take special caution to ensure safety operations because the operator does not directly control the machine. A common safeguard comes in the form of guards with emergency shut-off switches that trip when opened.
2. **Keep cables neat and inspect connections regularly.** Poor connections or overlapping wires may cause interruptions in data flow between the controller and the machine, inducing erratic movements in the machine.
3. **When programming computer-controlled machines, check machine movements with the Step option on the controller.** This option allows the individual to check each program line, thus avoiding hazardous situations.
4. **Two emergency shut-off systems—a mechanical power-off switch and a soft switch—are found in CNC and robotic equipment.** These immediately stop the program execution and, coupled with the user's quick reaction, will prevent injury and damage to the machine.

Minimum Tools, Equipment, and Materials Recommended for Student Use

Guidelines for PPE must be followed in all technology education courses. In particular, proper protective eyewear must be worn. Eye Protection Standard: 29 CFR1910.133 (a)

Storage of Materials

- Place/locate the material storage area so that it is convenient for unloading of delivery trucks and adjacent to production/fabrication areas, with easy access for the teacher using cutting tools and machines for cutting materials into smaller sizes for student use.
- Place machines and equipment in each work area so that it allows for the normal flow of materials through the operational process. There must be minimal cross traffic of both material and/or students. Lay out project-storage areas to minimize congestion at the start and end of class and provide lockers, open cubicles, shelves, bins, or racks to accommodate a variety of project types and sizes.
- Store inflexible three-dimensional materials (e.g., angle iron, square tubing, bar stock, lumber, conduit, and plastic bar stocks) vertically or horizontally. In the horizontal position, store the heavier materials on lower levels and the lighter materials at higher levels. Vertical storage of materials must lean toward the wall, with the height limited to eight to 10 feet, allowing a person to grasp the material above its midpoint.

- Store materials which need to remain flat (such as sheet metal) horizontally on wide shelving or vertically between full-width dividers.
- Store oxygen cylinders and fuel gas cylinders so that they are protected by a ½ hour fire-rated barrier or are stored at least 20 feet apart. All compressed gas cylinders must be stored secured and upright.
- Store finishes in a flammable-materials cabinet.

Processes

Make sure that equipment has the appropriate guards and shields in place. All guards and shields should function properly so that specific hazards can be avoided. Monitor students closely when they perform operations on equipment. Consult and follow all manufacturer's operating instructions. Caution students extensively about the potential hazards of operations in the processes studied.

Separating

Separating processes involve converting material size and shape through the extraction of excess material. It is through these processes that the material is cut or sheared. These processes include an expansive family of operations, such as sawing, planing, grinding, sanding, cutting, slicing, etching, chip removal, drilling, boring, turning, machining, and even electrochemical machining processes. This is by far the largest family of most frequently used, hazardous processes found in technology and engineering laboratories. Other hazards that are shared by many of these processes involve:

- moving parts and blades/cutters;
- the potential of the work piece to become lodged in, or pulled into, the machine at higher-than-desired rates;
- the potential for the work piece to be thrown out of the machine and toward the operator;
- hands or limbs positioned near moving blades;
- blades, drills, or abrasive wheels shattering from excessive impact or poor condition;
- tools or accessories being thrown by centrifugal force;
- improperly set-up or attended CNC machines or automated equipment causing collisions between parts and work pieces;
- improperly clamped work pieces being grabbed by machines;
- inappropriate use of portable power tools;
- flying dust and chips;
- attempting to cut large pieces of material without adequate support or aid; and
- equipment failure due to poor maintenance.

Assembly

Assembly is the process of temporarily or permanently holding two or more materials together. This large family of operations includes welding, brazing, soldering, gluing, nailing, clamping, bolting, stapling, jointing, taping, binding, and a host of other assembly techniques. During assembly, adhere to the following guidelines:

- Heat-shielding apparel and specialized eye protection is required, especially in the welding, brazing, and foundry areas.
- Machinery with moving parts, and hammering operations used in sewing, stapling, pressing, and other processes require special attention to the protection of the hands and limbs.
- Proper eye, lung and skin protection when dealing with chemicals.

Conditioning

Conditioning involves the use of heat, mechanical force, or chemical reaction to alter the internal properties of a material. Some examples of conditioning include curing thermosetting plastic with heat, forging steel, annealing copper, curing epoxy with a catalyst, and many others. The most common hazards occurring within these processes include:

- hazards associated with heating equipment and/or handling hot materials;
- dangers associated with spilling or splattering of chemicals; and
- mishaps involving hammering or compressing (forging).

To prevent injury from one of the above-mentioned hazards, users must wear protective clothing, including gloves and aprons made of leather for high-temperature protection. Wear plastic or rubber protection for work involving chemicals. For added protection, use full-face shields.

Casting and Molding

The process of casting and molding involves the pouring or forcing of liquids or semisolid materials into a prepared mold. The material is given time to become solid and is then detached from the mold. The main hazards involved in casting and molding are linked to the methods used to make the material into a liquid or plastic state. Take special care while managing liquid materials. Potential hazards for casting and molding include:

- hand or limb injuries resulting from water, chemical, or gas leaks, and the ramming of molds;
- ruptures in a crucible of molten metal;
- liquid plastics or metals spilled onto skin or clothing;
- splashing of molten materials during pre-pouring and pouring;
- premature opening of molds (before proper curing and cooling is completed); and
- handling of freshly cast products while still hot.

For high-temperature protection, full-face shields are a necessity. Gloves, aprons, leggings, and sleeves of leather are necessary safety measures. For chemical protection, use the appropriate rubber or plastic gloves.

Forming

Forming involves the use of direct force to cause a material to take a permanent shape. A die, mold, or roll is most commonly used to shape the material, but there is no change in the volume of the material. Some examples of forming processes include metal spinning, thermoforming plastic, bending band iron by hand, and steam-bending wood. Forming hazards depend mostly on the forces used and the way they are applied. Depending upon the materials and the type of processes used, heat, pressure, rotating machines, chemicals, pneumatic or hydraulic action, mechanically amplified forces, and heavy equipment are all involved. At times, hands are very near the application point of the force (as in metal spinning). Forming hazards include:

- smashing, pinching, or crushing of the hands and limbs;
- burns associated with the heat sources and hot materials;
- entanglement with rotating and powered equipment;
- fragments breaking away from the product and becoming airborne as the dies and molds close; and
- equipment or product breakage due to the application of excessive force.

To prevent injury from one of the above-mentioned hazards, users must wear protective clothing correctly, including eye protection, gloves, aprons, leggings, and sleeves of leather are necessary safety measures. For added protection, use full-face shields.

Finishing

Finishing involves the protection and/or restoration of the surface of a material. The finishing process depends on the material to be finished and its intended use. Wood demands different finishing techniques than metal, but wooden picnic tables require different processes than wooden floors. In spite of these variations, many finishing processes involve paints or other chemicals. Before these are used, they must be mixed. When applied, they are brushed, spread, poured, and/or sprayed. The solvents used in these products and for their cleanup are hazardous to your health (e.g., avoid exposure to fumes and skin exposure). Follow these guidelines:

- Use appropriate eye protection for all finishing operations, to protect the eyes from splashes.
- Use plastic or rubber gloves, depending upon the chemicals used.
- Use adequate ventilation and, if necessary, respirators, to provide additional safety protection. Concentrated fumes can become explosive when near heat sources as small as the arcing inside an electrical switch.
- Finishing and flammable substances must be stored in a flammable storage cabinet.

It is inappropriate to use compressed air as part of the finishing process to dry off materials. Inappropriate use of compressed-air hoses may result in blindness, air or foreign objects injected into the skin or bloodstream, internal damage to organs, or even death.

General Safety Practices

The following are safety practices to consider for technology and engineering education:

- Paint Booths:
 - Keep the spray area clean of combustible residue.
 - Ensure that finishing room floors and baffles are noncombustible.
 - Ensure that finishing rooms have explosion-proof lights or are lit through sealed, clear panels.
 - Use mechanical ventilation during spraying and drying operations.
 - Ensure that finishing rooms have independent exhaust systems.
 - Ensure that exhaust rates meet minimum requirements.
 - Ensure that air exhausted from spray operation is removed from the ventilation system.
 - Ensure that ducts have access doors to allow cleaning.
 - Ensure that intake air is free of contaminants.
- Equipment:
 - Double-check to see that all controls are in the proper starting position before attempting to start a motor.
 - Ensure all power-driven belts, chains, propellers, gears, and cutting blades have guards to prevent accidental contact.
 - Prohibit the use of compressed air to clean clothing, equipment, and the work area.
 - Frequently open the air-tank drain valve on the compressor to prevent excessive accumulation of liquid.
 - Maintain and regularly test relief valves on compressors.
 - Protect and maintain pressure-control gauges on compressors.
 - Never place fingers or hands in machinery while in operation.
 - Only one person may operate a machine at a time.
 - Do not talk to or distract a machine operator.
 - Avoid handling electrical equipment with wet hands.
 - Do not operate equipment at excessive speeds.
- Storage:
 - Store all flammable chemicals and finishes in an approved flammable materials storage cabinet when not in use.
 - Stack materials properly and securely.
 - Store tools in their proper place.

Electricity

When working with electricity or electronics be sure to follow LEA guidelines of what a teacher should do versus what the LEA maintenance should be doing.

- Turn the power off and/or unplug and lock out before working on any tool or machine.
- Use only one hand inside equipment or panels, even if power is removed.
- Avoid touching grounded points with other parts of the body.
- Be extra cautious around water.
- Ensure that all electrical installations, modifications, and alterations conform to federal, state, and local standards, codes, and specifications.
- Surge protectors and extension cords must be plugged into permanent outlets and not daisy chained together. All multiplug adapters must be equipped with surge protection.
- Extension cords are temporary, must be inspected regularly, and must not be used for permanent installation.

Electronics

Electronics can be potentially dangerous. Any circuit that works with 120 VAC power from an electrical outlet is especially dangerous and could potentially kill you.

- Never work on a circuit while power is applied.
- Do not connect power to a circuit until the circuit is finished and you have carefully checked your work.
- If you smell anything burning, immediately disconnect the power and examine your circuit to find out what went wrong.
- Keep your work area dry.
- Always wear safety goggles.
- Be careful around large capacitors; they can continue to hold voltage long after they are disconnected from power. Discharge electrolytic capacitors.
- Be especially careful when you solder because a hot soldering iron can easily burn you.
- Always work in a well-ventilated space.
- Have safety equipment such as a fire extinguisher, a first-aid kit, and a phone nearby.

Materials and Processes

- Machines:
 - Never use a machine without all guards in place.
 - Always turn the power off immediately after using a machine.
 - Machines should be left to coast to a stop after being switched off.
 - Before processing materials, remove all nails, staples, foreign objects, etc from used lumber.
 - Do not manually adjust and gauge (caliper) work while a machine is running.
 - Remove chuck keys and other equipment before starting a machine.
 - Avoid contact with projections on work or stock, faceplates, chucks, etc., while the machine is operating.
 - Use splashguards, shields, and other means to minimize contact with cutting oils that may cause skin irritation.
 - Ensure that the work rests on grinders that are adjusted to within a maximum of one-eighth inch from the wheel.
 - Ensure that the tongue guards on grinders are adjusted to within a maximum of one-quarter inch from the wheel.
 - Provide safety set screws on all four jaw chuck, screw plate, or lathe dogs drive plate and revolving accessories.
 - The tool rest should be set so that the lathe tool is above the center of the piece being turned on the lathe.
 - Never attempt too heavy a cut with the machine. Take several light cuts.
 - Never attempt to plane or joint short stock. (See the manufacturer's specifications.)
 - Never attempt to make an adjustment while the machine is running.
 - Ensure that all welding equipment and apparatus for gas and arc welding, cutting, and brazing meet American Welding Society standards (<https://www.aws.org/library/doclib/AWS-Z49-2021.pdf>).
 - Saws and blades:
 - The saw blade should project through the table no more than 1/4" above the stock being cut.
 - When cutting material on a table saw, the operator should stand to the side of the material if possible.
 - Never attempt to clear a saw table of chips or dust while the machine is running.
 - When using a band saw, stand in front of it, and never step around to the side, in line with the direction of the travel of the band saw wheel in case a blade should break.
 - Make sure band saw blade guides are set properly.
 - Always use push sticks or push blocks when required (4" minimal distance from all blades, cutters, knives) by the machine and work being done.
 - The blade guard on the bandsaw should be set ¼" above the material being cut.

- Materials:
 - Ensure that all materials are stored properly and securely to prevent sliding, falling, or collapsing.
 - Use a brush, vacuum, or special tools for removing chips.
 - Never generate, pipe, or use acetylene at a pressure exceeding 15 psi.
 - Ensure that all compressed-gas cylinders are legibly marked as to gas content with the chemical or trade name.
 - Keep all gas cylinders away from all sources of heat. Inside a building, store cylinders in a well-protected, well-ventilated, dry location.
 - Store cylinders in specifically assigned places away from elevators, stairs, or aiseways, where they will not be knocked over or tampered with.
 - Secure cylinders upright with a chain or other suitable device.
 - Ensure that cylinders are not dropped, struck, or used as rollers or supports.
 - Unless cylinders are secured on a cylinder hand truck, ensure that regulators are removed and valve protection caps are in place before cylinders are moved.
 - Ensure that empty cylinders have their valves closed, protective caps on, and that cylinder valve protective caps are hand tightened, except when cylinder is in use.
 - Store oxygen cylinders separately from fuel-gas cylinders or combustible materials.
 - Keep cylinders, cylinder valves, couplings, regulators, hoses, and apparatus free from oily or greasy substances.

For more information on makerspaces, refer to the International Technology and Engineering Educators Association's (ITEEA) *Safer Makerspaces, Fab Labs, and STEM Labs: A Collaborative Guide!* (<https://www.iteea.org/Publications/STEMProducts/SaferMakerspaces.aspx>).