ENVIRONMENT, HEALTH & SAFETY
UNIVERSITY OF MICHIGAN

Makerspace Guideline

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Applies To: This Guideline applies to all University employees, students, and visitors that use 3D printers, laser cutting equipment, laser etching equipment, soldering pens, soldering guns, and other pieces of electronic equipment that have the potential to create high heat levels, fire hazards, elevated levels of particulate matter (PM), or hazardous fumes during operation.

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All University of Michigan (U-M) employees, students, and visitors using *makerspace* equipment (equipment) should comply with the requirements contained in this document and complete all required training.

All employees, students, and visitors using the equipment must adhere to the roles and responsibilities listed in the Academic Laboratory and Research Safety Policy.

Makerspace Guideline

The Makerspace Guideline is derived from government regulations, the U-M Academic Laboratory and Research Safety Policy, the Hazard Communication Program, and guidance and best practices from research studies.

It provides guidance about the safe design, installation and use of shop, lab, studio, and other spaces that house sophisticated and potentially hazardous electronic equipment such as 3D printers and laser cutting equipment, or house potentially hazardous work areas such as soldering stations.

Given the diverse sophistication, intricacies, and capabilities of the various models of 3D printers, laser cutting equipment and soldering equipment, the purpose of this guideline is to standardize health and safety items across all University Makerspaces and address general health and safety concerns associated with equipment and work operations.

Related Makerspace Guideline Documents

- Laser Safety Guideline
- Personal Protective Equipment (PPE) Guideline
- Machine Shop Safety for Academic Departments Guideline
- Hazard Communication Program
- Flammables and Combustibles Standard Operating Procedure
- Irritants Standard Operating Procedure
- Laser Safety Standard Operating Procedure

Additional Resources

All reference guidelines, regulations, and other documents are available in Appendix A of this document.

Potential Hazards

The purpose of the Makerspace Guideline is to protect employees, students, and visitors from the potential hazards of equipment, which are as follows:

- Respiratory hazards including respiratory irritation or occupational diseases caused by breathing air contaminated with harmful dusts, fumes, sprays, mists, fogs, smokes, vapors, or gasses.
- Eye damage/injury is possible with laser cutting or etching equipment if the equipment laser interlocks are tampered with, bypassed or if optic maintenance is not conducted in conjunction with the manufacturer's specifications.
- Fire hazard if not properly operated/maintained, if the wrong material is used or if used within close proximity to flammable or combustible materials.

Training

For all electronic equipment, it is critical to read and have an understanding of the manufacturer's provided information including but not limited to: operator's manuals, maintenance manuals/schedules, safety manuals, and any provided training materials. Only those trained directly by the manufacturer should conduct maintenance and repair on the equipment.

Responsible Persons and the University of Michigan, *Environment, Health & Safety (*EHS) Safety Coordinators provide training for following topics, including but not limited to: general Lab/Shop/Studio

safety, Hazard Communication, Incident/Near-Miss and Corrective Action information, Emergency Preparedness, Use of Fire Extinguishers, and Accident/Near Miss Reporting.

Responsible Persons must provide equipment and site specific training, whether through the manufacturer, or based on their own knowledge and experience. This training must be documented in the form of a training roster for review by EHS. Refer to the Makerspace Proof of Training Roster for a sample roster.

Purchase Considerations/Space Considerations

Given the increasing trend of using these technological advances to assist with engineering, graphic planning, and product development, it is important that Responsible Persons and Research Administrators consult with EHS to conduct a *hazard assessment* and evaluate the following health and safety items in regard to the makerspace prior to making any purchases and setting up the makerspace location:

- The candidate spaces for the equipment
- All potential equipment purchases
- Any materials that are not identified in this guideline are to be used
- Fire safety code
- Electrical codes
- Adequate ventilation.
  NOTE: If a ventilation system is required, it should be compatible with the equipment or the materials that will be worked with in the space and must be engineered to be adequately control emissions.

In addition, the Responsible Persons and Research Administrators may be required to review applicable Safety Data Sheets (*SDS*s) to properly evaluate the safe use of the material.

Finishing Products

Special finishing processes for printed or cut materials such as sanding, spray coating, painting, etc. should be discussed with EHS prior to conducting the process. Some processes require additional engineering, administrative, or personal protective controls.

Access Controls

Spaces should be controlled by lock and key, or key card access so that only *authorized users* may enter the space.

Responsible Persons are to evaluate each potential Authorized User's use of the equipment in the space and provide instruction and supervision per prospective work.

Only users authorized and trained to use the equipment are permitted to access the space to conduct work and research activities.

All visitors must be cleared by the Responsible Person before entry. Upon entry they must follow PPE protocol and participate only as an observer.

Maintenance

The equipment should be used and maintained according to the Manufacturer's safety and general operating instructions.

Modifications to any pieces of equipment should be done only with proper permissions from the manufacturer.

All maintenance activities should be recorded in maintenance logs which should be located either within the *HCP Binder* or near the equipment. Examples of logged maintenance events for equipment can include, but are not limited to optic replacement, part replacement, or cleaning of internal components.

Maintenance logs also apply to ventilation systems attached either to the equipment, or as standalone units. Examples of logged maintenance events for these systems include but are not limited to, filter changes, hose replacement, or fan repair.

Recordkeeping and Housekeeping

All training, maintenance, and inspection documents should be kept either in the HCP Binder or in a common area where Responsible Persons, Research Administrators, and Authorized Users can access the information.

Work spaces should be kept free of walking and working surface obstructions including anything that poses a slip, trip, or fall hazard.

Chemicals used in the space must be kept in their appropriate storage locations. Quantities of flammable materials greater than 5 gallons must be stored in a flammable materials storage cabinet.

All spaces should have required signage posted on doors and areas near equipment warning Authorized Users of hazards and/or advising the use of PPE during operation or entry into the space.

Personal Protective Equipment

Safety Glasses must be worn at all times when work is being conducted in a Makerspace.

Read and adhere to the *personal protective equipment* (PPE) guidelines established by the manufacturer of the equipment and the manufacturer of the media (SDS, section 8, i.e., information regarding exposure controls/personal protection).

Appropriate gloves should be worn to protect hands when there is a potential for cuts, lacerations, heat-related injury, or the potential for contact with hazardous molten filaments.

Any processes that require the use of corrosive, caustic or other hazardous finishing agents should be evaluated by EHS – proper chemical storage will be discussed as well as the need for an emergency eyewash or shower, additional PPE requirements (such as a *respirator*), and proper waste disposal considerations.

Technical Assistance

All referenced Guidelines, regulations, and other documents are available through EHS (647-1143). Assistance in hazard evaluation, recordkeeping, and selection adequate ventilation is also provided by EHS.

Appendix A: Referenced Documents

Reference Regulations/Standards

- MIOSHA Part 33 - Personal Protective Equipment (PPE)
- MIOSHA Part 38 - Hand and Portable Power Tools
- MIOSHA Part 92 - Hazard Communication (General Industry)
- MIOSHA Part 301 - Air Contaminants for General Industry
- MIOSHA Part 12 – Welding and Cutting (General Industry)
- ANSI Z136.1-2014 – American National Standard for the Safe Use of Lasers
  Appendix G. – Supplemental Information Regarding Laser Generated Air Contaminants (*LGAC*s)

3D Printers References

- Emissions of Ultrafine Particles and Volatile Organic Compounds from Commercially Available Desktop Three-Dimensional Printers with Multiple Filaments - P. Azimi et.al.

Laser Cutting References

- Universal Laser Systems – Laser System Media/Materials Library: https://www.ulsinc.com/material/materials-library
- ANSI Z136.1 – 2007: American National Standard for Safe Use of Lasers (2007)

Appendix B: 3D Printer Specific Guidance

- Materials
  - All materials used for the 3D Printing process are to be compatible with the printer in-use, per manufacturer's specifications and recommendations.
  - Any material not listed in the operational or safety manuals, specifications, standard operating procedures (*SOP*s) or manufacturer recommendations must be brought to the attention of EHS. EHS will evaluate the material in question and will request the Responsible Person provide the material's SDS in order to understand the material's properties. The manufacturer of this equipment must also confirm that any materials used are compatible with the equipment.
  - EHS strongly encourages the Responsible Person to select printing filaments made with materials which emit little or no *volatile organic compounds* (VOCs) when used in the printing process.
  - EHS also strongly encourages the Responsible Person to select printing filaments which do not contain hazardous compounds which could emit toxic gasses when melted or burned.
  - Any 3D printing processes which use powdered media (especially metals) must be cleared through EHS prior to purchase of equipment and setup of the space. **Some powdered media can be classified as combustible** and must be handled with care.
  - All materials and filaments used to print with must have a SDS located in the HCP Binder.
- *Engineering Controls*
  - EHS recommends the use of 3D printers built with complete or partial enclosures, as these have been shown to reduce odors and particulate emissions into the workspace.
  - All 3D printers without an enclosure need to be evaluated by EHS to ensure that it would be permissible to use without such an enclosure or if engineering controls or alternative work practices would be required.
  - 3D printers using only *PLA* filament can be operated in a lab space without special ventilation considerations as long as the *general ventilation* equates to at least 4 ACH *(air changes per hour*), and only one printer is in use. If more than one printer is in use, EHS should be contacted to evaluate the need for increased ventilation.
  - 3D printers utilizing *Acrylonitrile Butadiene Styrene* (ABS) filament, shall be ventilated using any of the following:
    - A compatible attached ventilation system (filtered or direct exhausted)
    - An EHS-approved fume extraction *local exhaust ventilation* system (LEV) (filtered or direct exhausted – LEV)
    - A fume hood
    - Single-pass general ventilation and no less than 6 ACH.
  - 3D printing processes which require the use of inert gasses may pose asphyxiation hazards. It is important to ensure all engineering controls are in good condition prior to operating a 3D printer which uses an inert gas system.
- Administrative Controls
  - All other filaments or printing materials must be brought to the attention of EHS along with their respective SDSs.
  - No more than two unventilated 3D printers should be present in the same lab space, unless EHS evaluates the area and approves.
  - Some newer 3D printing materials, or materials that are not commonly used may require workspace air monitoring to be conducted by EHS.

Appendix C: Laser Cutting/Etching Specific Guidance

- Materials
  - All materials used for laser cutting, etching, and engraving are to be compatible with the equipment per manufacturer's specifications and recommendations.
  - Materials that have not been identified as compatible by the manufacturer should be evaluated by EHS with an SDS to determine its suitability for use.
  - Certain materials such as Polyvinyl Chloride, Fiberglass, and ABS should not be used as they emit toxic or otherwise hazardous fumes when melted or burned (Appendix 2.1).
  - All materials with the exception of wood, metal, and paper products, must have a SDS located in the HCP Binder. Certain woodlike products, e.g., OSB (Oriented Strand Board), MDF (Medium-Density Fiberboard), and others require an SDS because of the binding agents that hold them together.
  - A table or list of all current materials in use during laser cutting, etching, and engraving operations should be posted within the work space or stored in the HCP Binder.
- Ventilation Requirements
  - Ventilation systems should be integrated within the laser cutting equipment, or should be connected to, and compatible with the laser equipment per manufacturer's recommendations.
  - Ventilation systems should be directly exhausted outside, but some filtered ventilation systems may be permissible in certain environments.
    - For exhausted ventilation systems:
      - Contact EHS during the planning stages of duct routing for exhaust.
      - Turn ventilation system on prior to starting the laser operation, and leave it on 10-15 seconds after the laser has finished operating.
    - For filtered ventilation systems:
      - Only use the appropriate filter media for the ventilation system and operations as directed by the ventilation system manufacturer.
      - After turning on the ventilation system, check to see that no filter change warnings or indications are displayed.
      - Conduct routine filter replacements on a schedule as suggested by the ventilation system manufacturer, or as indicated by the system.
      - Keep at minimum one set of replacement filters (for each stage if multi-stage filtration is used) on hand for quick replacement.
      - Record all filter changes in the maintenance log for the filter ventilation system.
      - Leave the ventilation system on for 10-15 seconds after the laser has finished operating.

Prohibited Materials and Commonly Used Materials In Laser Systems

PROHIBITED MATERIALS, **DO NOT USE**:

MATERIAL	HAZARD	CAUSE/CONSEQUENCE
PVC (Polyvinyl Chloride) artificial leather	Emits pure chlorine gas when cut!	Never cut this material as it will ruin the optics, cause the metal of the machine to corrode, and ruin the motion control system.
Thick (>1mm) Polycarbonate	Cuts very poorly, discolors, catches fire	Polycarbonate is often found as flat, sheet material. The window of the laser cutter is made of Polycarbonate because polycarbonate strongly absorbs infrared radiation! This is the frequency of light the laser cutter uses to cut materials, so it is very ineffective at cutting polycarbonate. Polycarbonate is a poor choice for laser cutting.
ABS	Emits cyanide gas and tends to melt	ABS does not cut well in a laser cutter. It tends to melt rather than vaporize, and has a higher chance of catching on fire and leaving behind melted gooey deposits on the vector cutting grid. Fumes from cutting operations can contain cyanide gas!
HDPE/milk bottle plastic	Catches fire and melts	Does not retain a solid composition when used.
PolyStyrene Foam	Catches fire	It catches fire, it melts, and only thin pieces cut. This is the primary material that causes laser fires nationwide.
PolyPropylene Foam	Catches fire	Like PolyStyrene, it melts, catches fire, and the melted drops continue to burn.
Fiberglass	Emits fumes	It's a mix of two materials that cannot be cut. Glass (etching only) and epoxy resin (fumes)
Coated Carbon Fiber	Emits noxious fumes	A mix of two materials. Thin carbon fiber mat can be cut, with some fraying - but not when coated.

Permitted Materials with Proper Ventilation:

Material	Notes	WARNING
Many woods	Avoid oily/resinous woods	Be very careful about cutting oily woods, or very resinous woods as they also may catch fire
Plywood/Composite woods	These contain glue, and may not laser cut as well as solid wood	
MDF/Engineered woods	These are okay to use but may experience a higher amount of charring when cut	
Paper, card stock	Cuts very well on the laser cutter, and also very quickly	
Cardboard, carton	Cuts well but may catch fire	Potential for fire
Cork	Cuts nicely, but the quality of the cut depends on the thickness and quality of the cork. Engineered cork has a lot of adhesive in it, and may not cut as well.	Avoid thicker cork
Acrylic/Lucite/ Plexiglas/PMMA	Cuts extremely well leaving a smooth, polished edge	
Delrin (POM)	Delrin comes in a number of shore strengths (hardness) - harder Delrin tends to work better	
Kapton tape (Polyimide)	Works well, in thin sheets and strips like tape.	
Mylar	Works well if thin - thick mylar has a tendency to warp, bubble, and curl	Gold coated mylar will not cut
Solid Styrene	Smokes a lot when cut, but can be cut	Must be thin
Depron foam	Used a lot for hobby, architectural models, and toys - 1/4" cuts well, with a smooth edge	Must be constantly monitored
Gator foam	Foam core gets burned and eaten away compared to the top and bottom hard paper shell	Can be cut if watched
Cloth/felt/hemp/cotton	All cut well	No plastic coated or impregnated cloth
Leather/Suede	Leather is very hard to cut, but can be if it's thinner than 1/8"	Real leather only – Pleather emits toxic fumes
Magnetic Sheet	Cuts well	
NON-CHLORINE-containing rubber	Fine for cutting	Assure no chlorine content
Teflon (PTFE)	Cuts fine in thin sheets	If not properly ventilated, can cause occupational illness similar to the flu
Carbon fiber mats/weave that have not had epoxy applied	Can be cut, very slowly	Do not cut carbon fiber that has been coated

Appendix D: Soldering Specific Guidance

- Materials
  - Lead exposure is possible when working with Lead-Based Solder without appropriate PPE, Engineering Controls, and good housekeeping measures.
    - Alternatives to Lead-Based Solders such as: Tin/Silver, Tin/Copper, or Tin/Zinc/Bismuth should be used whenever possible.
  - Rosin-containing solder flux emits fumes that may cause occupational asthma or worsen existing cases of asthma.
    - If possible, alternatives to rosin-containing solder flux should be sought.
    - If rosin-containing solder flux remains in use, adequate LEV must be in place to insure that workers are not exposed to fumes.
- Work Practices
  - The heating element and tip of the soldering gun or soldering pen should never be directly touched for any reason. If cleaning is necessary, utilize a moist cleaning sponge.
  - When handling wires or pieces of soldering media during operation, always handle with clamps, tweezers, or tongs.
  - When not using the soldering gun or pen, return it to the stand, never set it on a benchtop or tabletop.
  - Always thoroughly wash hands with soap and water immediately after conducting solder operations.
- Ventilation Requirements
  - An adequately sized and properly maintained benchtop fume extraction system must be used for all soldering operations.
    - Only use the appropriate filter media for the ventilation system and operations.
    - After turning on the ventilation system, check to see that no filter change warnings or indications are displayed (if equipped).
    - Conduct routine filter replacements on a schedule as suggested by the ventilation system manufacturer, or as indicated by the system.
    - Keep at minimum one set of replacement filters (for each stage if multi-stage filtration is used) on hand for quick replacement.
    - Record all filter changes in the maintenance log for the filter ventilation system.
  - Additionally, general ventilation in these spaces should equate to at least 4 ACH.
- Hot Work Permits
  - Hot work permits are not required as long as soldering is conducted within a space designated for soldering.
    - If soldering outside of a designated space, contact EHS to assess the proposed new workspace and determine the need for a work permit.

Attachment 1: Makerspace Program Related Documents

- Makerspace Proof of Training Roster
- Makerspace Equipment Maintenance Log

Glossary of Terms

TERM	DEFINITION
Acrylonitrile Butadiene Styrene (ABS)	One of the two more common thermoplastic polymers. ABS is widely used in many applications as it is highly resistant to chemicals and has good impact resistance. Due to the composition of ABS, special considerations must be taken when using it as a filament in 3D printing applications.
Air Changes per Hour (ACH)	The general ventilation measure of the air volume added to or removed from a space divided by the volume of the space.
Authorized Users	Persons who have been certified in the use of equipment as per this Guideline and Manufacturer's Instructions and are authorized to access the space.
Environment, Health & Safety (EHS)	The University of Michigan entity responsible for promoting health, safety, and environmental compliance for the entire University community. EHS provides leadership and guidance at all levels of the University to maintain a safe workplace in a protected environment.
Engineering Controls	Equipment used to eliminate or reduce exposure to a chemical or physical hazard through the implementation or substitution of engineered machinery or equipment.
General Ventilation (GV)	The process of supplying fresh air to an enclosed space or room to refresh/remove/replace the existing atmosphere.
Hazard Assessment	An evaluation of the workspace or a work process by an EHS professional which may include observation, discussion, or environmental testing to identify the potential for injury, exposure, of a compromised work environment. These hazard assessments can also be conducted by Authorized Users or other persons deemed "experts", as long as this assessment is reviewed by EHS staff.
Hazard Communication ("HazCom") Plan (HCP) Binder	A collection of University health and safety policies for shops, studios and other applicable work locations & operations which contains pertinent materials such as: applicable guidelines, training documentation, Safety Data Sheets (SDSs), Standard Operating Procedures (SOPs), emergency contact information, and other information.
High Efficiency Particulate Air (HEPA) Filters	Filters capable of trapping and retaining at least 99.97% of all particles of 0.3 micrometers (µm) in diameter. The equivalent NIOSH 42 CFR 94 particulate filters are the N100, R100, and P100 filters.
Laser Generated Air Contaminants (LGACs)	Airborne chemicals or compounds that can pose hazards to human health or the environment. LGACs are generated when a Class 3b or Class 4 laser strikes matter in a system without adequate ventilation.
Laser Interlock	An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in a safe mode.

TERM	DEFINITION
Local Exhaust Ventilation (LEV)	An engineering control system to reduce exposures to airborne contaminants such as dust, mist, fume, vapor or gas in the workplace. LEV may be fixed in the workplace, or portable, and may be connected to building exhaust ducts or a filtration system.
Makerspace	Any shop, studio, or space that employs the use of electronic equipment for the design, development, or fabrication of materials or products with the assistance of software products.
Personal Protective Equipment (PPE)	Protective clothing, helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury or infection. The hazards addressed by PPE include physical, electrical, heat, chemicals, biohazards, and airborne particulate matter.
Polylactic Acid (PLA)	One of the two more common thermoplastics polymers. It is a biodegradable and bioactive thermoplastic derived from renewable resources, such as cornstarch, tapioca roots, chips or starch, or sugarcane. While controls are still necessary for use in 3D printing with PLA, it is considered the safest filament to use in this equipment.
Responsible Person	A person designated by college faculty to be the main point of contact for the laboratory. The Responsible Person's duties include: overseeing/restricting access for authorized users, training individuals on shop/lap specific practices and procedures, maintaining contact with EHS, abate any discrepancies found during EHS inspections, and maintain documentation for training, standard operating procedures, and safety data sheets. Also known as: shop/lab manager, administrator, or coordinator
Safety Data Sheet (SDS)	A document that contains information on the potential health effects of exposure to chemicals, or other potentially dangerous substances, and on safe working procedures when handling chemical products. Current SDSs will comply with the Globally Harmonized System (GHS) for Hazard Communication, consisting of 16 sections with all required information.
Standard Operating Procedure (SOP)	Formal written description of the safety and administrative procedures to be followed while performing a specific task.
Teflon™ or Polytetrafluoroethylene (PTFE)	A family of high-performance products that are used in a wide variety of industrial applications and consumer applications. A high-molecular weight compound consisting completely of carbon and fluorine.
Volatile Organic Compounds (VOCs)	Any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates and ammonium carbonate, which participates in atmospheric photochemical reactions, except those designated by EPA as having negligible photochemical reactivity.

Revision History

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