EHRS
Environmental Health & Radiation Safety
UNIVERSITY of PENNSYLVANIA

# Design Guidelines for Makerspaces, Robotics Laboratories and Academic/Research Shops

Penn
UNIVERSITY of PENNSYLVANIA

jss
4-30-2021

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Technologies that in the past were primarily associated with high-tech and manufacturing industries, are rapidly being incorporated into higher education programs. Robots, 3D printers, laser cutters/etchers, water jet cutting machines and benchtop computer numerical control (CNC) machines are rapidly appearing on campus. Of concern, is that in some cases, the facilities they are installed in are not properly evaluated or designed for their safe use. This can result in retroactive efforts to mitigate identified hazards which is undesirable to everyone involved.

The most common identified facilities-related health and safety concerns include the following:

- Inadequate ventilation to control ultrafine particulates, volatile organic compounds and other contaminants.
- Lack of proper storage for process chemicals and waste.
- Inappropriate finishes and furniture such as carpeted floors and upholstered furniture in areas where chemicals are used.
- Absence of emergency irrigation equipment where chemicals are used or certain particulate-generating tasks are completed.
- Insufficient controls to limit access and use of the equipment to those who have been trained and qualified/authorized to use it.
- Lack of safeguards to protect humans from contact with robots and end effectors or debris created from tasks they perform.
- Fire hazards associated with hot work, lasers cutters/etchers, non NRTL listed/labeled electrical equipment and improper storage of flammable chemicals.

## 1.0 PROGRAM OBJECTIVE

The Design Guidelines for Makerspaces, Robotics Laboratories and Academic/Research Shops is presented to assist design professionals and end users within the schools and centers to proactively consider health and safety in their selection of machines and equipment and the design of the facilities where they are located.

Detailed information on the operation and machine specific safety requirements are contained in Penn's Machinery, Robotics and Power Tool Safety Program.

## 2.0 SCOPE

These design guidelines apply to facilities owned or operated by the University of Pennsylvania.

## 3.0 DEFINITIONS

3.1 **Additive Manufacturing** - The process of joining materials to make objects from digital model data. 3D printing is a common methodology of additive manufacturing.

3.2 **American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE)** - An organization that develops state of the art consensus standards for the design criteria of ventilation systems. Typically incorporated by reference into local building codes.

3.3 **Binder Jetting (BJ)** - 3D Printing process where a liquid binder is selectively deposited onto the powder bed, bonding these areas together to form a solid part one layer at a time. Heat sintering or chemical infusion such as cyanoacrylate to strengthen the object is required.

3.4 **Bound Metal Deposition (BMD)** - 3D printing process where metal components are constructed by extrusion of a powder-filled thermoplastic media. The metal powder which is bound together with wax and a polymer binder is heated and extruded in thin layers on the build plate to create the object. The binder is then removed, and the object sintered at high temperature to solidify it.

3.5 **End-Effector** - Device specifically designed for attachment to the mechanical interface to enable the robot to perform its task.

3.6 **Fused Deposition Modeling (FDM)/Fused Filament Fabrication (FFF)** - 3D printing process where a spool of solid thermoplastic material (typically ABS or PLA) is fed through a heated extruder nozzle where it is liquefied and deposited on a build plate in fine layers to create an object**.**

3.7 **Hot Work** - An operation or activity that utilizes or produces open flames, sparks or heat sufficient to ignite combustible materials or flammable atmospheres. Examples include welding, soldering, cutting (including laser, torch, electrical), burning, heating, grinding, spark producing, etc.

3.8 **Internet of Things (IoT)** - Emerging technology that enables the link between various sources of information and physical objects.

3.9 **Makerspace** - A place in which people with shared interests, especially in computing or technology, can gather to work on projects while sharing ideas, equipment, and knowledge.

3.10 **Material/Poly Jetting (MJ/PJ)** - 3D printing process where a photopolymer resin is deposited through a print head which emits hundreds of droplets of photopolymer, curing and solidifying them using UV light.

3.11 **Maximum Space** - Space which can be swept by the moving parts of the robot as defined by the manufacturer plus the space which can be swept by the end-effector and the workpiece.

3.12 **Robot – Collaborative** - Robots that are purposely built to work in direct cooperation with a human within a defined workspace.

3.13 **Robot – Industrial** - Automatically controlled, reprogrammable multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications. Typically, industrial robots must be contained within a safeguarded space to prevent contact with humans.

3.14 **Safeguarded Space** - Space defined by the perimeter safeguarding.

3.15 **Selective Laser Sintering (SLS)** - 3D printing process where a thin layer of thermoplastic powder is deposited on the build platform. A laser is programed to fuse the powder into the shape of the object.

3.16 **Stereolithography (SLA)** - 3D printing process where a photopolymer resin liquid is deposited on the build plate and selectively cured/solidified by a laser which creates the object.

## 4.0 RESPONSIBILITIES

*4.1* ***Environmental Health and Radiation Safety (EHRS)*** shall be responsible for:

4.1.1 Developing and periodically reviewing and updating the Design Guidelines for Makerspaces, Robotics Laboratories and Academic/Research Shops.

4.1.2 Reviewing planned renovation or new construction documents and plans that involve makerspaces, robotics laboratories and academic shops.

4.1.3 Participating in design and construction meetings, as required, to support prevention of health and safety hazards through design of the project.

4.1.4 Approving of location, quantity and type of emergency irrigation equipment installed in makerspaces, robotics laboratories and academic shops.

4.1.5 Conducting periodic audits of makerspaces, robotics laboratories and academic/research shops to ensure compliance with applicable environmental health and safety standards.

4.2 ***Schools and Centers*** *shall be responsible for*:

4.2.1 Notifying EHRS of planned renovations or new construction projects that involve makerspaces, robotics laboratories and academic/research shops as early in the conceptual design as possible.

4.2.2 Notifying EHRS of machines or equipment typically associated with makerspaces, robotics labs or shops identified in spaces that were not specifically designed to include them.

4.2.3 Providing the appropriate facilities and infrastructure to support the intended activities and equipment.

*4.3* ***Facilities & Real Estate Services (FRES)*** shall be responsible for:

4.3.1 Notifying EHRS of planned renovations or new construction projects that involve makerspaces, robotics laboratories or academic/research shops as early in the conceptual design as possible.

4.3.2 Including EHRS in appropriate aspects of the design phase of projects involving makerspaces, robotics laboratories and academic/research shops.

4.4 ***Division of Public Safety – Department of Fire and Emergency Services (FES)*** shall be responsible for:

4.4.1 Reviewing planned renovation or new construction documents and plans that involve makerspaces, robotics laboratories and academic/research shops.

4.4.2 Reviewing the storage, use and disposal of combustible materials.

4.4.3 Reviewing spray finishing, pressurized hydraulic fluid, dust collection systems, and battery charging systems.

4.4.4 Determining the need for hot work programs and assisting end users with implementation.

4.4.5 Evaluation of fire and life safety systems.

4.4.6 Evaluating facilities for type and placement of portable fire extinguishers. Coordinate fire extinguisher training if applicable.

## 5.0 GENERAL

5.1 **Ventilation:**

5.1.1 Ventilation demands, especially with respect to exhaust and air exchange rates, must be carefully considered. Experience has shown that the demands on the ventilation system change as the equipment technologies and the tasks performed in the spaces evolve. Some types of facilities fit clearly into existing ASHRAE HVAC mechanical design classifications, while some including 3D-printing do not at this time.

5.1.1.1 *Energy Conservation - Setbacks* - Air exchange rates where general dilution ventilation is used to maintain acceptable indoor air quality may be decreased by programming setbacks that are activated when the processes that require the higher air exchange are not in use. Air monitoring can be incorporated into the systems to trigger an increase to the air exchange rates when contaminants are detected such as a chemical spill or equipment activation or malfunction.

5.1.1.2 *Energy Conservation - Dedicated Areas* - A means to minimize the number of required air changes in a large area is to locate the equipment and processes requiring the higher air exchange rates into smaller dedicated areas.

5.1.1.3 *Energy Conservation - Local* Exhaust - Some machines have the capability to be directly connected to exhaust. For equipment such as open desktop 3D printers, enclosures can be purchased or fabricated that can be directly connected to building exhaust or an air filtration system. In some applications such as 3D printing and laser cutting/etching, local capture and scrubbing with high efficiency and carbon filtration with exhaust routed outdoors or back into the facility may be an option.

5.2 **Finishes and Furniture:**

*5.2.1 Finishes*

*5.2.1.1* Flooring - Flooring materials should be easily cleanable. Floors in work areas shall not be carpeted. Consideration should be given to the types of materials and contaminants that are likely to be found on the floors as the facility is used. Select flooring or coatings that incorporate the appropriate level of slip resistance.

*5.2.1.2* Walls - Wall finishes should be easily cleanable and resistant to the types of materials that may contaminate them. This is commonly an issue in machine shops where cutting fluids and oils accumulate on walls surrounding the machines.

*5.2.1.3* Materials used for flooring, ceiling, wall finishes and sound attenuation shall meet the requirements of Penn, City of Philadelphia codes, and FM Global. They shall be installed in accordance with the manufacturer's instructions.

*5.2.1.4* Tables & Shelving - Non-combustible materials should be selected for use in facilities where heat generating machinery and equipment is used in order to control spread of fire if the machine or equipment fails. Some equipment falling in this category includes 3D printers, laser/cutter/etchers, vacuum formers, hot wire cutters, welding, soldering, etc.

5.2.2 *Furniture* - Easily cleanable, non-upholstered materials should be selected.

5.3 **Layout and Machinery Specifications**

5.3.1 The following should be considered with respect towards layout of machinery and equipment:

5.3.1.1 Place high hazard machines such as table saws, metal and wood working lathes, metal mills, wood and metal CNC machinery, laser cutters and etchers etc. in areas where access can be controlled.

5.3.1.2 Only SawStop brand table saws may be installed in facilities used by students. SawStop table saws are equipped with technology that prevents amputations and minimizes the potential for serious lacerations.

5.3.1.3 Provide adequate segregation between machinery and equipment that requires use of personal protective equipment (PPE) such as hearing protection and safety glasses, from areas where tasks are performed that do not require the use of PPE.

5.3.1.4 Noisy equipment such as air compressors, CNC routers, power saws, dust collection systems etc. should be isolated, if possible, from other equipment.

5.3.1.5 Three feet of clearance must be maintained around electrical equipment that may require servicing such as a circuit breaker panel.

5.4 **Electrical:**

5.4.1 Installation of wall and ceiling-mounted cord reels is recommended. They provide flexibility for providing power in areas where it is needed and can be stowed out of the way. In practice, they have been helpful in minimizing the need for extension cords which create tripping and fire hazards. Cord reels shall be labelled with their rated capacity (amps) and their supplying circuit.

5.4.2 All electrically powered machines and equipment shall be listed or labeled by a Nationally-Recognized Testing Laboratory (NRTL). Be careful to check the specifications or machinery and equipment specified for installation. This can be an issue with machinery and equipment sourced outside the USA and with lower cost desktop 3D printers.

5.4.3 The need for receptacles equipped with Arc-Fault Circuit Interrupters (AFCI) and/or Ground Fault Circuit Interrupters (GFCI) must be carefully considered. Aside from those required by electrical code at time of construction, future potential of the space to host activities involving water such as wave pools and flumes used in sedimentation research should be considered.

5.5 **Noise/Vibration Attenuation:**

5.5.1 *Noise/Vibration Study* - Consider using an acoustical consultant to evaluate noisy equipment and provide mitigation recommendations. Equipment such as air compressors, dust collection systems, power saws and CNC machine are commonly found in shops and makerspaces. This equipment tends to run for long durations and generate noise and vibration. Carefully evaluate not only the space the equipment resides in, but adjacent spaces that may be impacted as well.

5.6 **Storage:**

5.6.1 Architects report that lack of adequate storage space is one of the most common complaints from end users. During the design phase, architects/designers tend to include adequate storage space, but it is commonly reduced at the request of end users in favor of programmatic space. This change is commonly regretted. The following storage needs should be carefully assessed:

5.6.1.1 Personal Belongings - Day use and longer-term lockers for students/users to place backpacks, jackets, and other personal belongings in while using the spaces. This is especially important for spaces with machinery and robots. Some state-of-the-art IoT systems use RFID information from school IDs to access the lockers.

5.6.1.2 Raw Materials - bulk raw materials such as metals, wood, particle board acrylic sheets, foam, etc. Some of these products off-gas volatile organic materials, therefore exhaust ventilation requirements must be considered.

5.6.1.3 Chemicals - Both processing chemicals and waste must be considered. Penn collects all chemical waste. No chemicals may be disposed of down the drain. Adequate storage for flammable liquids, acids, bases and for chemical waste containers and the required secondary containment must be considered.

5.6.1.4 Finished Products - Adequate storage must be planned for finished products, especially those that require curing time and may off-gas volatile organic compounds while curing.

5.6.1.5 Personal Protective Equipment (PPE) - PPE requirements should be understood, and storage must be provided to maintain PPE clean and ready for use. Ideal setup is a location near the entrance of the facility where the users can don the equipment on the way in and doff it on the way out. Common PPE required in makerspaces, robotics labs and shops consists of lab/shop coats, eye/face protection (safety glasses, goggles, face shields) and hearing protection including ear canal inserts or muffs.

5.6.1.6 Combustible Material Storage - The storage of combustible materials shall be reviewed by the Division of Public Safety - Department of Fire and Emergency Services (FES).

## 6.0 INTERNET of THINGS (IoT)

6.1 IoT technology is rapidly evolving and can be a valuable resource to aid in improving safety. Following are some examples of how IoT can be used to help improve safety in makerspaces, robotics labs and shops:

6.1.1 *Area Access Control* - Limit access to areas to authorized personnel only. Access can be limited to personnel who have completed the required training and within defined time periods. A record of who accessed the area and when is available.

6.1.2 *Machine/Equipment Access Control* - Controls can be installed on individual machines or pieces of equipment to limit access to that machine/equipment to authorized personnel only. A record of who accessed the machine and for how long is available. This can be used to track the amount of time that a resource is used or how much time an individual or class of individual uses a resource.

6.1.3 *Networking of 3D Printers* - 3D printers can be networked to allow scheduling and monitoring status of printers. Capability of ordering materials and billing for printer use is available.

6.1.4 *Storage Lockers* - IoT can be used for managing and providing access to long term and day use lockers to store personal belongings while working in the facilities.

## 7.0 ADDITIVE MANUFACTURING - 3D PRINTING

7.1 **Suitability for Use at Penn** - 3D printers and related electrically-powered support/processing equipment must be listed or labeled by a Nationally-Recognized Testing Laboratory (NRTL). This is primarily driven by Occupational Safety & Health Administration (OSHA) standards and the Philadelphia Fire Code, which requires minimum safety requirements for machines and equipment used in the workplace. It is important to note that at this time, many popular lower-cost 3D printers do not carry a NRTL listing or labeling. It is important to inquire about this prior to procurement.

7.1.1 3D printers shall not be field modified and shall use the current version of firmware with thermal runaway protection enabled.

7.2 **Placement of 3D Printers** - 3D printers should be located in areas dedicated for their use as opposed to general office/classroom environments. The furniture materials and finishes in office/classroom and even in general shop settings are typically not appropriate to repel contaminants or designed to adequately control emissions generated from the printers and post processing tasks.

7.3 **Identify 3D Printer Technology** - The types of 3D-printing technology expected to be used in the facility should be understood. The various technologies (BJ, BMD, FFF/FDM, MJ/PJ, SLA and SLS) each have potential hazards directly associated with printing and the post processes such as cleaning and infusion. Post processing may involve dust producing tasks or use of chemicals that may require dedicated exhaust and appropriate storage areas for process and waste chemicals.

7.4 **Ventilation Recommendations** - Most 3D printers emit ultrafine particulate and volatile organic compounds. The quantity of contaminants released depends upon the type of printer, the printing media, the number of printers in the space and if the printer is enclosed. At this time, there are no specific ventilation rates defined by ASHRAE or other building code references for 3D printing. The following ventilation rates are recommended based on the consensus of findings from studies published by the National Institute of Occupational Safety & Health (NIOSH) and practices and procedures implemented at peer institutions.

7.4.1 *General Dilution Ventilation* - In areas where 3D printers are not segregated from other general ventilation, at least 4 air changes per hour for a single printer and 6 air changes per hour for multiple printers should be provided where emissions are not otherwise controlled with engineering controls such as enclosures connected to a local air filtration unit or building exhaust. Air removed from the space should not be recirculated to other areas with differing types of occupancy such as an office or classroom.

7.4.2 *Local Exhaust Ventilation* - 3D printers may be located in areas with lower general ventilation rates if the emissions can be controlled by other means. Some potential emissions control measures may include placing the printers in a dedicated noncombustible enclosed area or within noncombustible enclosures where emissions are controlled by connection to building exhaust or to an air filtration unit with HEPA and carbon filtration which can be exhausted back into the space.

7.4.3 *EHRS Review* - EHRS shall be contacted to participate in the evaluation of the specific printers to be installed. EHRS will work with the end users and designers/engineers to characterize potential printer and post processing task emissions and review proposed control measures.

7.5 **Chemical Processes** - 3D printing cleaning, curing and processing may require the use of chemicals. The following should be considered:

7.5.1 *Chemical Storage* - The volume and classification of the types of chemicals required must be understood. Appropriate chemical storage space must be allocated. Typically, flammable or caustic chemicals may be required which requires dedicated cabinets for each class of chemical.

7.5.2 *Chemical Use* - Emergency irrigation equipment shall be required in any area where chemicals are stored and used in order to flush the eyes, face, and body. Some chemical curing processes such as those that use cyanoacrylate may need local exhaust ventilation to control inhalation exposure.

7.5.3 *Chemical Waste Storage and Disposal* - Penn does not permit drain disposal of any chemicals. Waste chemicals from cleaning or curing baths must be collected and stored on site until EHRS can pick up and dispose of the waste. Adequate space must be allocated for the storage of the waste chemical containers and required secondary containment.

## 8.0 ROBOTS & ROBOTICS LABORATORIES

8.1 **Suitability of Use** - Carefully consider the class of robot to be acquired. While an industrial robot and collaborative robot can complete the same task, an industrial robot will likely have additional safety infrastructure and space requirements than one designed for collaborative operation. Robots designed for collaborative operation must be selected for applications where there is a need for robot and humans to be in the same operating space.

8.2 **Installation Requirements**:

8.2.1 A robot machine safeguarding assessment and risk reduction assessment must be completed and documented by a properly qualified robotics safety risk assessor/integrator to identify required safeguards and prescribe safe work practices. This should be completed as part of the initial design process. Contact EHRS if assistance is required to identify resources for this. This may not be required for collaborative robots used strictly in accordance within their operating manual and safety procedures.

8.2.2 Installation and use of robots shall comply with the appropriate Robotics Industry Association (RIA)/American National Standards Institute (ANSI) robotics R15 series safety standards.

8.3 **Ventilation Requirements**:

8.3.1 The ventilation must be appropriate for the tasks to be performed. Tasks that generate vapors, smoke or particulates will require dedicated exhaust or point source capture and filtration. It is important to not only consider the current tasks, but to also consider future tasks that may require higher ventilation demands and plan accordingly.

8.4 **Guarding Robot & Debris**:

8.4.1 Guarding of robots must be designed in accordance with the robot safeguarding and risk assessments and in compliance with the appropriate RIA standards dictated by the type and class of robot. It is important to also consider the tasks to be performed with the end effectors and ensure that guards provide protection from debris, particles or contaminants generated by the tasks. Catastrophic failure of machining bits or other working parts of the end effectors must be taken into consideration.

8.5 **Control of Hazardous Energy**:

8.5.1 Robots and all related equipment must be equipped with a means to be locked out in a zero-energy state. An equipment-specific control of hazardous energy (lockout/tagout-LOTO) procedure must be developed and used to place the robot system in a safe energy state for service, maintenance or when direct interaction with the robot is required.

## 9.0 LASER CUTTING/ETCHING

9.1 **General Ventilation** - Laser cutters shall only be installed in well-ventilated spaces. Typically, a minimum air exchange rate of six air changes per hour is required and the air from the space may not be mixed with air recirculated to other locations with different types of occupancy, such as offices or classrooms.

9.2 **Exhaust**

9.2.1 *Exterior Exhaust* - This is the preferred option from the perspective of maintaining acceptable indoor air quality. Exterior exhaust is the most adept at discharging the strong odors associated with the use of these machines. Exterior exhaust allows future flexibility in the materials that may be cut or etched since the system is not relying on filters that may not have the capability to adequately capture the emissions.

9.2.2 *Filtration System* - The specifications of the system must be followed, and the air volume must meet the specifications of the laser cutter/etcher. This includes the limitations on materials that can be cut. It is also important to note that some filtration systems recommend exhausting the filtered air to the outdoors because they may not fully capture all odors. Consider ongoing costs and labor associated with filter changes.

9.3 **Fire Protection** - Penn's Department of Fire and Emergency Services shall review all proposed locations for laser cutter/etcher installation in order to evaluate life safety systems, fire extinguisher requirements and proper storage of combustible raw materials.

9.4 **Raw Materials** - Consider the types and quantity of materials expected to be processed and incorporate appropriate storage in the design. Only materials approved by the laser cutter/etcher and exhaust filtration system manufacturer, if installed, may be processed.

9.5 **Waste Containers** - Fire-resistant waste containers must be used in laser cutting/etching facilities. Containers shall meet FM 6921 or UL 1315 or UL 242 standards for combustible material waste containers. Waste containers must be located in areas clear of combustible materials around and overtop the container.

## 10.0 METAL WORKING

10.1 **Energy Isolation** - A means to secure power to each machine must be provided to allow control of hazardous energy procedures (lockout/tagout) to be implemented to facilitate safe servicing of equipment. Energy isolation may also be required to secure hazardous machinery from unauthorized users if other means are not available.

10.2 **Control of Cutting Fluids** - Metalworking machines such as lathes, mills and CNC machines typically splatter cutting oils and fluids on the floor and walls around the machinery. Easily cleanable wall surfaces and appropriate slip resistant flooring or mats must be installed in areas where these machines are installed.

10.3 **Machine Guards** - All machine guards equipped with the machine must be maintained. Additional shielding or guarding may be required to provide protection from debris created by the machining process.

10.4 **Hot Work** - All work involving open flames or other ignition sources shall comply with Penn's Department of Fire & Emergency Services Hot Work Operations guidelines. Adequate space must be allocated for hot work to permit the required clearances from combustible materials

## 11.0 WOODWORKING

11.1 **Dust Collection** - Woodworking machines including saws, sanders, lathes, jointers, planers, and molders must be connected to a dust collection system. The expected use of the space should dictate the best approach. Smaller, limited use applications may be best served by small individual units such as shop vacuums. There are devices available that link the vacuums to the machines so that when the equipment is energized, the vacuum is as well. Larger, higher throughput facilities may require a system that has the capability to capture dust from several machines through a ducted system. Penn's Department of Fire & Emergency Services shall be contacted to review dust collection systems for compliance with life safety requirements.

11.2 **Anti-Restart** - Woodworking machinery must be equipped with anti-restart switches that prevent the machines from unexpectedly restarting if power is momentarily interrupted. If legacy machines without anti-restart technology are being repurposed in a new or renovated facility, the machines must be retrofitted with an anti-restart switch.

11.3 **Table Saw Specification** - SawStop brand table saws have built-in technology that prevents amputations. They shall be procured for all new shops and makerspaces where students interact with the saws. They are also highly recommended for installations in all professional shops where only faculty or staff operate the equipment as well.

11.4 **Noise** - Woodworking machinery and dust collection systems are noisy. Placement of noisy equipment with respect to other tasks conducted in the space should be considered. Noise abatement measures such as isolation of noisy equipment to dedicated areas or use of sound attenuation materials in the areas housing the equipment should be considered.

11.5 **Energy Isolation** - A means to secure power to each machine must be provided to allow control of hazardous energy procedures (lockout/tagout) to be implemented to facilitate safe servicing of equipment. Energy Isolation may also be required to secure hazardous machinery from unauthorized users if other means are not available.

## 12.0 SPRAY FINISHING / VOLATILE CHEMICAL USE

12.1 **Ventilation** - Evaluate the need for safe application of spray finishes and/or working with chemicals and materials with strong odors and potential inhalation hazards including finishes, solvents, epoxies, resins and other composites. Appropriate engineering controls including paint booths, exhaust hoods/snorkels or chemical fume hoods shall be incorporated into the design of the facility.

12.2 **Waste Containers** - In facilities where there is a likelihood to generate rags or other materials soaked with paint thinner, linseed or teak oils, varnish, oil-based stains or polyurethane, special waste containers and procedures will be required to prevent fires caused by spontaneous combustion. The Department of Fire and Emergency Services and EHRS shall be consulted to identify proper procedures and waste containers.

## 13.0 WET LABOROATORIES

13.1 **Wet Laboratory Design** - Wet laboratories, or spaces where fume hoods and biological safety cabinets are to be installed shall be designed and equipped in accordance with Penn's Facilities & Real Estate Services Design Standards and EHRS Laboratory Design and Equipment Standard.

## 14.0 EMERGENCY IRRIGATION EQUIPMENT

14.1 Emergency Irrigation equipment shall be selected and installed in compliance with the most recent version of ANSI Z358.1 Emergency Eyewash and Shower Standard.

14.2 **Design Approval** - The Project Manager, General Contractor, Architect and/or Engineer shall ensure that the location of emergency irrigation equipment is identified in the drawings and approved by EHRS before construction begins.

14.3 **New Construction** - Recessed-mounted emergency eyewash/shower are strongly encouraged. Freestanding eyewash/shower units are also acceptable, but care must be exercised in the placement of the irrigation equipment so that the shower activation handle does not obstruct equipment placement or obstruct pedestrian traffic.


**Preferred facewash shower for new work.**

**Acceptable combination unit for new work.**

14.4 **Existing Construction** - The selection of free standing eyewash stations are encouraged over sink placement because sink locations are frequently crowded and access to the eyewash can be hindered. When eyewash units are installed at sinks, eyewashes that swing across the sink **should be avoided** because these stations are often too large for small sinks. Deck mounted eyewash-drench hoses are recommended for these locations.

14.5 **Installation Requirements:**

14.5.1 All eye/face wash installations shall discharge into a drain line or sink.

14.5.2 Floor drains are not required for shower locations.

14.5.3 Tempered water is not required for individual shower or eyewash installations. When multiple emergency showers are installed, tempered water shall be provided. Only eyewashes associated with emergency showers require tempered water. Stand-alone sink mounted eyewash units should not be connected to a tempered source.

14.5.4 Eyewash and shower locations must be identified with signs or decals.

14.5.5 The City of Philadelphia requires trap primers for eye wash drain connections.

14.5.6 Eyewash unit shall be installed such that after activation it does not require the continued use of the operator's hands.

14.6 **Installation Locations and Quantity**

14.6.1 Emergency irrigation equipment shall be located such that all tasks it is designed to serve are within 10 seconds travel. EHRS shall assist with specifying optimal locations and quantity of emergency irrigation equipment.

14.7 **Testing and Certification**

14.7.1 All units must be flow tested and tagged as described in ANSI Z358.1 (most current). Written certification of the test shall be provided to the Project Manager.

## 15.0 RELATED PROGRAMS

15.1 **Machinery, Robotics, and Power Tool Safety Program -** https://ehrs.upenn.edu/sites/default/files/2019-03/Machinery%2C%20Robotics%20%26%20%20Power%20Tool%20Program%202019.pdf

15.2 **Control of Hazardous Energy - Lockout/Tagout Program -** https://ehrs.upenn.edu/health-safety/general-safety/control-hazardous-energy-lockouttagout

15.3 **Electrical Safety Program -** https://ehrs.upenn.edu/health-safety/general-safety/electrical-safety

15.4 **EHRS Laboratory Design & Equipment -** https://ehrs.upenn.edu/health-safety/lab-safety/lab-design-equipment

## 16.0 REFERENCES

16.1 **Higher Education Makerspace Initiative (HEMI)**

16.2 **International Symposium on Academic Makerspaces (ISAM)**

16.3 **American Society on Engineering Education (ASEE)**

16.4 **Student Shop Managers Consortium (SSMC)**

16.5 **Association for Advancing Automation (A3)**