STEM Safety and Health

Introduction

This manual provides safety and health guidance for STEM research, teaching tasks, and club activities. Each student, faculty, staff or volunteer working in the STEM area(s) is expected to read this manual thoroughly and act in accord with the guidelines. This manual should also be kept available for future reference.

The risks associated with STEM activities are greatly reduced or eliminated when proper precautions and practices are followed. Youngstown State Universities' goal is to prevent injuries and illnesses, environmental incidents and property losses or damage. Safety is also essential in complying with all applicable health, safety and environmental regulations and requirements.

The appearance and organization of STEM facilities directly affects the safety and productivity as well as the university's reputation. There are two golden rules in developing a safe and productive environment:

1) Whenever you use an area, it is your responsibility to see that unsafe conditions are corrected immediately; and
2) Always leave an area in better condition than you found it.

Because of the wide variety of activities performed in STEM, it should **not** be assumed that the precautions and requirements in this manual are all-inclusive. More detailed safety training modules are available through the YSU online safety training software.

Questions, concerns, or additional safety and health training requests should be made to the EOHS Department at eohs@ysu.edu.

Emergency Response and Accident and Injury Reporting

In the event employees or students require emergency assistance (criminal activity, fire/smoke, medical emergencies or hazardous materials incidents) contact the Campus Police Dispatch by CALLING 9- 1-1 from a campus phone. Cell phone users should call 330-941-3527 and provide name, location (building/room) and a brief description of the emergency. Emergency response guidelines can be found at Campus Emergency Managemet Plan

Reporting Accidents/Incidents/Injuries

Safety and Health incidents must be investigated. The person(s) involved must provide a written Incident Report Form to EOHS in case of minor spills, fires, or hazardous material release regardless of whether an injury occurred. This form is available online from at Incident and Injury Report

EOHS may ask for assistance to investigate and prepare an investigation report. Investigations are made and reports written not only to satisfy certain laws but also to learn the cause of the problem and what changes in procedures, equipment, or training should be made to avoid other incidents/injuries.

EOHS will respond to chemical spills as reported. However, if the spilled material is not volatile and there is no immediate fire or toxic hazard, cleanup may be done by properly trained STEM faculty and staff. In situations involving a fire of unknown materials, research chemicals, or toxics, EOHS will advise on evacuation or other protective precautions for persons or property in the immediate area.

Puncture or Cut
If someone has a puncture wound or cut, wear personal protective equipment (gloves) to minimize exposure to human blood. Apply a pressure pad or clean cloth firmly to the wound. Raise the wounded area above the level of the heart to slow the bleeding. For severe bleeding or spurting call 911. Until medical personnel arrive, have the victim lie down and try to control any external bleeding. In a severe injury, keep the victim warm and do not move them.

Inhalation of hazard/toxic
A person exposed to smoke or fumes must be moved to fresh air. Any person overcome by smoke or fumes must be given medical treatment, call 911. NOTE: The air may be unsafe to enter. Do not enter without first confirming it is safe; this requires air sampling. Contact EOHS to perform entry sampling.

Skin contact with a chemical
If a chemical contacts a person's skin, remove the chemical from the skin as soon as possible. For chemicals that can cause burns, the stronger the chemical and the longer the contact, the worse the burn. For all chemicals except hydrofluoric (HF) acid, flush the skin under a safety shower for at least 15 minutes; call 911.

For limited skin exposure on a small area, a drench hose or sink may be adequate for flushing and 911 may not need called. Do not treat the burn. Do not puncture any blisters that may develop. Follow up medical treatment is recommended (doctor office or emergency room).

Eye contact with a chemical
Wash the eye(s) with water for at least 15 minutes, 911 may not need called. Follow up medical treatment is recommended (doctor office or emergency room).

Burn from a fire
If your clothing catches fire, immediately get under a safety shower or other water source. If a safety shower is not immediately available, stop, drop, and roll to extinguish the fire. Assess the condition of the skin's burn area. If skin is not broken, run water over the burn area to remove heat. Do not put ice on the burn. If skin is broken, apply a dry, sterile dressing over the wound and call 911. Until medical personnel arrive, keep the victim warm and do not move them.

Cryogenic Liquid Contact
Contact with cryogenic liquids may cause crystals to form in tissues under the spill area, either superficially or more deeply in the fluids and underlying soft tissues. The first aid procedure for contact with cryogenic liquids is identical to that for frostbite. Re-warm the affected area as quickly as possible by immersing it in warm, not hot, water (between 102° and 105° F). Do not rub the affected tissues. Do not apply heat lamps or hot water and do not break blisters. Cover the affected area with a sterile covering and seek assistance as you would for burns and call 911. Until medical personnel arrive, keep the victim warm and do not move them.

Shock
Shock is likely to develop in any serious illness or injury. Shock is a condition in which the circulatory system fails to deliver blood to all parts of the body. When the body's organs do not receive adequate blood supply, they fail to function properly. If a person appears to be in shock call 911. Until medical personnel arrive, have the victim lie down and elevate the victim's legs about 12 inches unless you suspect broken bones or possible head, neck, or back injuries. Help the victim maintain a normal body temperature and avoid moving them.

General Safety

<u>Housekeeping</u>
Poor housekeeping practices can cause a variety of hazards, which can lead to injuries, fires, and unhealthful working conditions.

Keeping things clean and organized helps provide a safer working space. Keep drawers and cabinet doors closed and electrical cords off the floor to avoid tripping hazards. Keep aisles clear of obstacles such as boxes, chemical containers, and other storage items that might be put there even temporarily. Avoid slipping hazards by cleaning up spilled liquids promptly and keeping the floor free of dirt and rocks or other small items. Never block or even partially block the path to an exit or to safety equipment, such as a fire extinguisher or safety shower.

Make sure that supplies and equipment on shelves provide sufficient clearance so that fire sprinkler heads operate correctly. There shall not be any storage within 18 inches of a sprinkler head.

Put ordinary trash in a trash can/container separate from chemical wastes. Broken glass and other sharp items must be disposed of in rigid, puncture-resistant containers to protect persons collecting the waste materials. Chemical wastes and unwanted chemicals must be disposed of promptly and not left to clutter a work space. Follow all procedures for Hazardous Waste Disposal found at Chemical Waste.

<u>Personal Hygiene</u>
Personal hygiene is extremely important in a work space. Contamination of food, beverages, or smoking materials is a potential route of exposure to toxic chemicals through ingestion. Therefore,

do not prepare, store, or consume food or drink, smoke, or apply lip balm in the work area.
Hand washing is a primary safeguard against inadvertent exposure to toxic materials. Always wash your hands before leaving the work space even if you were wearing gloves. Wash your hands after removing soiled protective clothing, and before eating, drinking, smoking, or using a rest room.

Wash your hands periodically during the day at intervals dictated by the nature of your work. Wash with soap and running water.

Confine long hair and loose clothing when in the work area to keep them from catching fire, dipping into chemicals, or becoming entangled in moving machinery. Avoid wearing finger rings, fingernail extensions and wrist watches which may become contaminated, or be caught in the moving parts of equipment.

Remove contaminated coats and gloves before you leave the work space. Keep a clean spare coat to wear outside the work space. Do not wear gloves outside the work space.

Working Alone or outside normal business hours

High risk work with chemical or physical hazards (high voltage, mechanical hazards) or any other work that might prove immediately dangerous must NOT be conducted alone. All high risk STEM work must be conducted with a partner or co-worker or in proximity to others.

High risk work on YSU campus outside of normal business hours (M-F 7:30am to 5pm) must be pre-approved in writing by the department chair and must include emergency contact information.

Experiments or other tasks that continue to operate while someone is not present (unattended) must be pre-approved in writing by the department chair and must include emergency contact information.

Visitors to the STEM work areas

Do not allow visitors, including children and pets, in work areas where high risk activities are in progress. Students from primary and secondary schools (minors) occasionally may enter these areas as part of educational programs under carefully controlled and supervised conditions. Colleagues, prospective students, and others may be invited into STEM work areas but must be escorted the entire time.

Equipment Safety Procedures

Vacuum work and apparatus

Vacuum work can result in an implosion and the possible hazards of flying glass, spattering chemicals, and fire. Set up and operate all vacuum operations with careful consideration of the potential risks.

Although a vacuum distillation apparatus may appear to provide some of its own protection in the form of heating mantles and column insulation, this is not sufficient because an implosion could scatter hot flammable liquid. Use an explosion shield and a full-face shield to protect personnel. Glassware under vacuum should be kept behind a shield or hood sash, taped, or resin (plastic) coated. Other items under vacuum must be rated for the pressure.

Equipment at reduced pressure is especially prone to rapid pressure changes, which can create large pressure differences within the apparatus. Such conditions can push liquids into unwanted locations, sometimes with undesirable consequences.

Do not allow water, solvents, and corrosive gases to be drawn into a building vacuum system. When the potential for such a problem exists, use a cold trap. Water aspirators are not recommended.

Precautions to be taken when working with vacuum lines and other glassware used at sub-ambient pressure are mainly concerned with the substantial danger of injury in the event of glass breakage. The degree of hazard does not depend significantly on the magnitude of the vacuum because the external pressure leading to implosion is always atmosphere. Thus, evacuated systems using aspirators merit as much respect as high-vacuum systems. Injury due to flying glass is not the only hazard in vacuum work. Additional dangers can result from the possible toxicity of the chemicals contained in the vacuum system, as well as from fire following breakage of a flask (e.g., of a solvent stored over sodium or potassium).

Because vacuum lines typically require cold traps (generally liquid nitrogen) between the pumps and the vacuum line, precautions regarding the use of cryogens should be observed also. Liquid nitrogen– cooled traps open to the atmosphere condense liquid air rapidly. When the coolant is removed, an explosive pressure buildup occurs, usually with enough force to shatter glass equipment if the system has been closed. Hence, only sealed or evacuated equipment should be so cooled. Vacuum traps must not be left under static vacuum; liquid nitrogen in Dewar flasks must be removed from these traps when the vacuum pumps are turned off.

Residues from vacuum distillations have been known to explode when the still was vented suddenly to the air before the residue was cool. To avoid such explosions, vent the still pot with nitrogen, cool it before venting, or restore pressure slowly. Sudden venting may produce a shock wave that explodes sensitive materials.

Vacuum Pumps

Distillation or similar operations requiring a vacuum must use a trapping device to protect the vacuum source, personnel, and the environment. This requirement also applies to oil-free Teflon-lined diaphragm pumps. Normally the vacuum source is a cold trap cooled with dry ice or liquid nitrogen. Even with the use of a trap, the oil in a mechanical vacuum trap can become contaminated and the waste oil must be treated as a hazardous waste.

Vent the output of each pump to a proper air exhaust system. This procedure is essential when the pump is being used to evacuate a system containing a volatile toxic or corrosive substance. Failure to observe this precaution results in pumping volatile substances into the laboratory atmosphere.

Scrubbing or absorbing the gases exiting the pump is also recommended. Even with these precautions, volatile toxic or corrosive substances may accumulate in the pump oil and thus be discharged into the laboratory atmosphere during future pump use. Avoid this hazard by draining and replacing the pump oil when it becomes contaminated. Vacuum pumps should carry tags indicating the date of the most recent oil change. Oil should be changed once a month or sooner if it is known that the oil has been unintentionally exposed to reactive gases. It may be desirable to maintain a log of pump usage as a guide to length of use and potential contaminants in the pump oil.

All pumps should be either vented into a hood or trapped. Vent lines may be Tygon, rubber, or copper. If Tygon or rubber lines are used, they should be supported so that they do not sag and cause a trap for condensed liquids.

Belt-driven mechanical pumps must have protective guards. Such guards are particularly important for pumps installed on portable carts or tops of benches where laboratory personnel might accidentally entangle clothing, hair, or fingers in the moving belt or wheels.

Distillation

Distillation of flammable and combustible solvents is dangerous due to the presence of heat and flammable vapors. At the completion of vacuum distillations, backfill the apparatus with inert gas. Stills in use should be attended at all times and should have an automatic high-temperature shutoff.

Certain common laboratory chemicals form peroxides on exposure to oxygen in air. Over time, some chemicals continue to build peroxides to potentially dangerous levels, whereas others accumulate a relatively low equilibrium concentration of peroxide, which becomes dangerous only after being concentrated by evaporation or distillation. Because distillation of a stabilized liquid removes the stabilizer, the distillate must be stored with care and monitored for peroxide formation.

Temperature Controls

Since the rates of most reactions accelerate as the temperature increases, highly exothermic reactions can become violent without adequate cooling. Viscous liquids transfer heat poorly and require special precautions. Apparatus shall be assembled so that either heating or cooling can be applied or withdrawn readily.

Whenever an electrical heating device is used, either a temperature controller or a temperature-sensing device must be used that will turn off the electric power if the temperature of the heating device exceeds some preset limit. Similar control devices are available that will turn off the electric power if the flow of cooling water through a condenser is stopped flowing to the loss of water pressure or loosening of the water supply hose to a condenser. Independent temperature sensors must be used for the temperature controller and shutoff devices.

Fail-safe devices, which can be either purchased or fabricated, can prevent the more serious problems of fires or explosions that may arise if the temperature of a reaction increases significantly because of a change in line voltage, the accidental loss of reaction solvent, or loss of cooling. Temperature-sensing devices absolutely must be securely clamped or firmly fixed in place, maintaining contact with the object or medium being heated at all times. If the temperature sensor for the controller is not properly located or has fallen out of place, the controller will continue to supply power until the sensor reaches the temperature setting, creating an extremely hazardous situation. Insert a thermometer in heated liquids if dangerous exothermic decomposition is possible. This will provide a warning and may allow time to remove the heat and apply external cooling.

Drying Ovens and Furnaces

Volatile organics must not be dried in ovens that vent to the room air. Glassware rinsed with organics should not be oven dried unless it is first re-rinsed with water. Bimetallic strip thermometers rather than mercury thermometers are recommended for measuring oven temperatures.

Wear heat- resistant gloves and appropriate eye protection when working at ovens or furnaces. ANSI- approved eyewear (i.e., heat-absorbing, reflective goggles) offers protection against projectiles and infrared radiation.

Heat Blocks, Oil and Sand Baths

Improper use of a hot oil or sand bath may create serious hazards such as spatter from water falling into the bath, smoke caused by decomposition of the oil or organic materials in the oil, and fire from overheating the oil. Baths shall not be left unattended without a high-temperature shutoff. The oil shall be properly labeled, including information on its safe working temperature.

Fresh silicone oils have higher auto ignition temperatures and are recommended over the use of paraffin oil. Contact with oxygen and long exposure to temperature at the upper end of their application range accelerates the degradation of silicone oils and will lower the auto ignition temperature. Replace the silicone oil in openly heated oil baths at least annually.

Contain heated oil in either a metal pan or a heavy-walled porcelain dish; a Pyrex dish or beaker can break and spill hot oil if struck accidentally with a hard object. Mount the oil bath carefully on a stable horizontal support such as a laboratory jack that can be raised or lowered easily without danger of the bath tipping over. Always clamp equipment high enough above a hot plate or oil bath so if the reaction begins to overheat, the heater can be lowered immediately and replaced with a cooling bath without having to readjust the clamps holding the equipment setup. Provide secondary containment in the event of a spill of hot oil. Wear proper protective gloves when handling a hot bath.

Cooling Baths

The preferred liquids for dry-ice cooling baths are isopropyl alcohol or glycols; add dry ice slowly to the liquid portion of the cooling bath to avoid foaming. Avoid the common practice of using acetone–dry ice as a coolant; the alternatives are less flammable, less prone to foaming and splattering with dry ice, and less likely to damage some trap components (O-rings, plastic). Dry ice and liquefied gases used in refrigerant baths should always be open to the atmosphere. Never use them in closed systems, where they may develop uncontrolled and dangerously high pressures.

Use extreme caution in using liquid nitrogen as a coolant for a cold trap. If such a system is opened while the cooling bath is still in contact with the trap, oxygen may condense from the atmosphere. The oxygen could then combine with any organic material in the trap to create a highly explosive mixture. Therefore, do not open a system that is connected to a liquid nitrogen trap to the atmosphere until the liquid nitrogen Dewar flask or container has been removed. A liquid nitrogen–cooled trap must never be left under static vacuum. In addition, if the system is closed after even a brief exposure to the atmosphere, some oxygen may have already condensed. Then, when the liquid nitrogen bath is removed or when it evaporates, the condensed gases will vaporize, producing a pressure buildup and the potential for explosion. The same explosion hazard can be created if liquid nitrogen is used to cool a flammable mixture that is exposed to air. Caution must be applied when using argon, for instance as an inert gas for Schlenk or vacuum lines, because it condenses as a colorless solid at liquid nitrogen temperature. A trap containing frozen argon is indistinguishable from one containing condensed solvent or other volatiles and presents an explosion hazard if allowed to warm without venting.

Cold Traps

Cryogenic liquids are materials with boiling points of less than −73 °C (−100 °F). Liquid nitrogen, helium, argon, and slush mixtures of dry ice with isopropyl alcohol are the materials most commonly used in cold traps to condense volatile vapors from a gas or vapor stream. Cold traps used in reduced- pressure systems should be placed in vermiculite-filled metal cans. If this option is not possible, the cold traps should be coated with plastic resin or wrapped with cloth-backed friction or duct tape. In the event of an implosion, the coating will reduce the amount of flying glass.

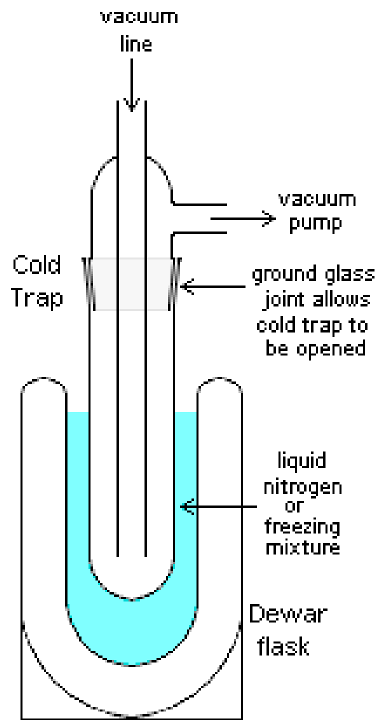


Figure 1: Cold Trap

Users of cold traps should be aware of the boiling points of the components and the possible materials that can condense in the reduced-pressure system. After completion of an operation in which a cold trap has been used, isolate the trap from the source, remove from the coolant, and vent to atmospheric pressure in a safe and environmentally acceptable way. Otherwise, pressure could build up, creating a possible explosion or sucking pump oil into a vacuum system. Dry ice and liquefied gases used in refrigerant baths should always be open to the atmosphere. Never use them in closed systems, where they may develop uncontrolled and dangerously high pressures.

Exercise extreme caution in using liquid nitrogen as a coolant for a cold trap. If such a system is opened while the cooling bath is still in contact with the trap, oxygen may condense from the atmosphere. Caution must be applied when using argon as an inert gas for Schlenk or vacuum lines, because it condenses as a colorless solid at liquid nitrogen temperature. A trap containing frozen argon is indistinguishable from one containing condensed solvent or other volatiles and presents an explosion hazard if allowed to warm without venting.

Experimental Reactor Pressure Vessels

Experimental reactor pressure vessels may also be referred to as sample preparation bombs, acid digestion bombs, hydrothermal reactors or chemical digestion autoclaves. As part of a experimental reactor pressure vessel safety program, write detailed standard operating procedures, including intended operating pressures and temperatures and keep them available at the work site. Heating chemicals inside a closed vessel can result in some of the highest gas or super critical fluid pressures encountered in a laboratory. People that are inexperienced must be directly supervised by an experienced faculty or staff member during design, vessel assembly and heating mode selection until they exhibit full understanding and proficiency.

If you use laboratory experimental pressure vessels in, it is important to understand what conditions increase the hazards associated with use so you can prevent dangerous ruptures or explosions from occurring. All laboratory reactor pressure vessels must be equipped with a form of overpressure relief to protect the vessel from the hazards of unexpected or dangerously high internal pressures. Appropriate over pressure relief through a safety rupture disk or safety relief valve must be part of the experimental reactor pressure vessel design.

- DO NOT use a experimental reactor pressure vessel without overpressure relief.
- DO NOT use experimental reactor pressure vessels without manufacturer’s documentation of maximum pressure and temperature.
- DO NOT assemble or maintain pressure vessels without manufacturer’s literature.
- DO NOT exceed temperature limits for reactions or pressure vessels specifications.
- DO NOT exceed vessel-loading limits.
- DO NOT form explosive materials inside a pressure vessel. Some chemicals and mixtures are prohibited in laboratory reactor pressure vessels.
- DO NOT treat fats, fatty acids, glycerin and similar materials with nitric acid in pressure vessels.
- DO NOT treat cellulosic materials with mixed nitric and sulfuric acids.
- DO NOT use perchloric acid, picric acid or concentrated hydrazine in these vessels.
- AVOID reactions which are highly exothermic or which may be expected to release large volumes of gas.

Overloading of a pressure vessel is a significant hazard. Where available, identify the charging limits for each chemical and vessel size in the manufacturer’s literature.

Always evaluate the stoichiometry and chemistry that you are trying to achieve with special considerations for catalysts and gaseous by-products that may affect pressure build up inside the vessel. Assess any intermediates, side-products and products that may form and their behavior within the vessel, including their corrosive nature and their tendency to violently decompose at elevated temperature and pressure. Determine maximum temperature and pressure limits expected, taking into account the energetics of the reaction being conducted and any pathways that might cause the reaction to run out of control.

In order to prevent dangerous overheating, the best practice is to:

- Use ovens or heating devices with high temperature limit controllers.
- Heat general-purpose metal body laboratory reactor pressure vessels only in an oven.
- Heat polymer body laboratory reactor pressure vessels only in a microwave oven.
- Heat other laboratory reactor pressure apparatus behind a blast shield or suitable barrier.
- Post caution signs or an Unattended Experiment Notice when heating pressure vessels unattended

Some pressure vessels are equipped with a polytetrafluoroethylene (PTFE) cup and lid liner. Due to PTFE flow, once a PTFE cup and lid is pressurized it becomes a uniquely matching pair. Using unmatched pairs of cups and lids will cause leaks. Store all the parts of a pressure vessel together to avoid mismatches. Periodically conduct a leak check in accordance with the manufacturer's literature.

Not all pressure vessels use a PTFE insert. Internal wetted parts of a pressure vessel have to be constructed resistant to corrosive materials at the expected operating pressure. Each alloy has its own physical strength and temperature characteristics as well as its own unique resistance to certain corrosive materials. All of these factors must be considered when making a selection. Dedicate pressure vessels for either acid or base service. Do not interchange the use of acids and bases in the same pressure vessel.

Regulators

Regulators are gas-specific which limits interchange and adds safety. Special installation processes, not mentioned here, are used for toxic or high purity gases. Always make sure that the regulator and valve fittings are compatible.

To select the appropriate regulator:

- Determine the gas pressure needed.
- Determine the maximum pressure the system might require.
- Select a delivery pressure range so the required pressures are in the 25%-90% range of the regulator delivery pressure.
- Check with the gas supplier about compatible connections and regulators.

Check cylinder outlet and regulator inlet connections for debris or contamination before connecting. Some gases, such as carbon dioxide, require a gasket. Ensure that a required gasket is in place before assembling the regulator onto the cylinder.

Tighten connecting nut with a smooth jaw wrench. Back out the adjusting knob or key on the regulator. Open the cylinder valve just enough to indicate pressure on the regulator gauge (no more than one full turn). Check connections with a soap solution for leaks. Never use oil or grease on the regulator of a cylinder valve.

All compressed gas regulators should, at a minimum, be checked for external leakage and internal leakage (creep or crawl) regularly. Regulators should be removed from service at least every five years (more frequent in some cases) and returned to the manufacturer, or a competent agent to be inspected and/or refurbished as necessary. Regulators should also be tagged or labeled to identify the last date of inspection. Users should consult the manufacturer for specific procedures on how to check for external and internal leakage as well as the recommended frequency of the tests. Regulators are continuously exposed to high stresses due to cylinder pressures. In addition, the materials of construction are attacked internally by both mildly and severely corrosive gases. External corrosive environments can cause gauges and springs to corrode. Argon, helium and nitrogen regulators (CGA 580) will, under a given set of conditions, have a longer service life than regulators used for hydrogen chloride and hydrogen sulfide (CGA 330) simply because the gas service is more severe (corrosive).

The most common type of regulator failure is the internal leak, sometimes called creep or crawl. This can occur when the seat becomes damaged or displaced due to a foreign particle such as a metal chip or other material. When the seat cannot close completely, delivery pressure will not be maintained and regulator pressure cannot reach a state of equilibrium. Downstream or delivery pressure will continue to climb until the safety relief mechanism on the regulator is activated (usually a relief valve or a diaphragm burst hole). Checking for this type of failure is relatively easy if the device has a gauge that reads regulated pressure. The gauge pressure will start to rise above the set point and continue upward. This creates a potentially hazardous condition where any downstream equipment would be subjected to pressures beyond the rated limit. Regulators should be visually checked for this type of failure. Excessive flexing of metal regulator diaphragms can cause a radial crack, which allows gas to escape to the atmosphere through the vent hole in the bonnet.

Electricity and Electrical Equipment

Electrical currents of very low amperage and voltage may result in fatal shock under certain circumstances. Voltages as low as 24 volts AC can be dangerous and present a lethal threat. Low-voltage DC circuits do not normally present a hazard to human life, although severe burns are possible. The duration of contact with a live circuit affects the degree of damage, especially with regard to burns.

All electrical switches shall be labeled, including circuit breakers in the service panels, and all laboratory personnel shall know where these controls are and how to shut off circuits or equipment in case of fire or other accident. Any electrical equipment that is not operating properly or seems to be overheating shall be turned off immediately and inspected by a qualified technician.

Electrical equipment should be inspected periodically to confirm that the cords and plugs are in safe condition. Circuit diagrams, operating instructions, descriptions of hazards, and safety devices are usually provided by the manufacturer and should be kept on file for reference.

Only three-wire grounded, double-insulated or isolated wiring and equipment shall be used in 110V- 115V AC applications. All wiring and equipment shall comply with the National Electrical Code. In specifically designated laboratories, cold rooms, or storage rooms or other locations where concentrations of flammable vapor-air mixtures are likely to occur, certified explosion-proof wiring and equipment, including light fixtures, switches, refrigerators, and telephones, shall be used.

Series-wound motors with carbon brushes, typically found in household appliances such as blenders and mixers, are not spark-free and shall not be used in laboratories where flammable vapors accumulate. Equipment manufactured for use in laboratories generally contains induction motors.

Electrical extension cords should be avoided, where practical, by installing additional electrical outlets. Only electricians from Facilities are permitted to make electrical modifications in University properties. When extension cords are used, the current carrying capacity shall be larger than the current requirement of the equipment connected to it. Electrical cords on equipment shall be discarded or repaired if frayed or damaged. Cords should be kept as short as practical to avoid tripping hazards and tangles. In wet locations, ground fault circuit interrupters (GFCI) must be used.

Place electrical equipment to minimize the possibility that water or chemicals could spill on it or that water could condense and enter the motor or controls. In particular, place such equipment away from safety showers. In cold rooms, condensation can be minimized by mounting electrical equipment on walls or vertical panels.

Only qualified individuals are permitted to make electrical repairs to any kind of electrical equipment. All electrical equipment must be de-energized and locked out according to the YSU Lockout Tagout Program before repairs are made.

If a worker receives an electrical shock and is in contact with the energized device, use nonconductive gloves or a non-conducting device to pull or push the victim free from the electrical source. Help victims only if you are certain that you will not endanger your own safety. Turn off or disconnect the power source if possible. Call Campus Police at 911. If a trained person is available, start CPR if necessary. Get medical assistance at once.

Ultraviolet, Visible, and Near-Infrared Radiation

Ultraviolet, visible, and infrared radiation from lamps and lasers in the laboratory can produce a number of hazards. Medium-pressure Hanovia 450 Hg lamps are commonly used for ultraviolet irradiation in photochemical experiments. Ultraviolet lights used in biosafety cabinets, as decontamination devices, or in light boxes to visualize DNA can cause serious skin and corneal burns. Powerful arc lamps can cause eye damage and blindness within seconds.

When incorrectly used, the light from lasers poses a hazard to the eyes of the operators and other people present in the room and is a potential fire hazard. See the Laser Safety Handbook for further details about laser registration and hazard control. Glassblowing and the use of laser or ultraviolet light sources require special eye protective glasses or goggles.

Electromagnetic Radiation and Magnetic Fields

Increasingly, instruments that generate large static magnetic fields (e.g., NMR spectrometers, MRI) are present in research laboratories. Such magnets typically have fields of 14,000 to 235,000 G (1.4 to 23.5 T), far above that of Earth's magnetic field, which is approximately 0.5 G. The magnitude of these large static magnetic fields falls off rapidly with distance. Many instruments now have internal shielding, which reduces the strength of the magnetic field outside of the instrument. Strong attraction occurs when the magnetic field is greater than 50 to 100 G and increases by the seventh power as the separation is reduced. However, this highly nonlinear falloff of magnetic field with distance results in an insidious hazard

The health effects of exposure to static magnetic fields are an area of active research. Currently, there is no clear evidence of a negative health impact from exposure to static magnetic fields, although biological effects have been observed (Schenck, 2000), and recently, guidelines on limits of exposure to static magnetic fields have been issued by the International Commission on Non-ionizing Radiation (ICNIRP, 2009), which is a collaborating organization with the World Health Organization's International Electromagnetic Field Project.

An object that moves into the attractive field of a strong magnet system, such as a nuclear magnetic resonance (NMR) system or any other instrument system requiring a superconducting magnet, can become a projectile that is pulled rapidly toward the magnet. For example, the large attractive force of an NMR requires that objects ranging from keys, scissors, knives, wrenches, other tools, oxygen cylinders, buffing machines, wheelchairs, and other ferromagnetic objects are excluded from the immediate vicinity of the magnet to protect safety and data quality.

Magnetic fields of ~10 G can adversely affect credit cards, watches, and other magnetic objects. Computer and television screens in neighboring areas may be affected by shifts in small, peripheral magnetic fields as magnets are brought up to field or decommissioned. Prudent practices require posting warnings, cordoning off the area at the 5-G line, and limiting access to areas with more than 10 to 20 G to knowledgeable staff. Keep people wearing heart pacemakers and other electronic or electromagnetic prosthetic devices or other potentially magnetic surgical implants, such as aneurysm clips, away from strong magnetic sources. Repairs done near a strong magnet should be performed with non-ferromagnetic tools.

Magnetic fields operate in three dimensions, and when considering the impact of an instrument, field strength should be checked on the floors above and below the floor where a superconducting magnet is installed. The 5-G line should be identified in all affected rooms, and appropriate warnings should be posted.

Because superconducting magnets use liquid nitrogen and liquid helium coolants, the precautions associated with the use of cryogenic liquids must be observed as well. If the superconducting magnet loses superconductivity because of damage, physical shock, or for any other reason, the coil will heat the cryogenic liquid that surrounds it, the magnet will quench (lose field), and the helium will boil off rapidly into the surrounding space. Low-oxygen alarms are recommended in rooms where instruments with superconducting magnets are located. In the event of a quench, all personnel should leave the area and not return until oxygen levels return to normal. If emergency personnel must enter the area before the oxygen levels have been verified, they should wear a self-contained breathing apparatus (SCBA).

If an object becomes stuck to a superconducting magnet, do not attempt to remove it, but call the vendor of the magnet for guidance. Attempting to remove the object could result in injury to personnel and damage to the magnet. It may also cause the magnet to quench, releasing dangerous quantities of gaseous helium into the area.

Effects	Field Strength at Which Effects Occur (G)
Effects on sensitive equipment such as electron microscopes, image intensifiers, and nuclear cameras	1
Disturbance of cathode ray tubes; possible detrimental effects on medical equipment, such as pacemakers, implants, surgical clips, or neurostimulators	5
Erasure of credit card and bank cards; disruption of small mechanical devices, such as analog watches and clocks; and disturbance of X-ray tubes	10
Destruction or corruption of magnetic storage material	20
Saturation of transformers and amplifiers	50

Table 1: Summary of magnetic field effects

<u>Radio Frequency</u>

Hazards Radio frequency (rf) and microwaves occur within the range 10 kHz to 300,000 MHz and are used in rf ovens and furnaces, induction heaters, and microwave ovens. Extreme overexposure to microwaves can result in the development of cataracts, sterility or both. Microwave ovens are increasingly being used in laboratories for organic synthesis and digestion of analytical samples. Only microwave ovens designed for laboratory or industrial use should be used in a laboratory. Use of metal in microwave ovens can result in arcing and, if a flammable solvent is present, in fire or explosion. Superheating of liquids can occur. Capping of vials and other containers used in the oven can result in explosion from pressure buildup within the vial. Inappropriately selected plastic containers may melt.

Microwave Ovens

Use microwave ovens specifically designed for laboratory use. Domestic microwave ovens are not appropriate. Microwave heating presents several potential hazards not commonly encountered with other heating methods: extremely rapid temperature and pressure rise, liquid superheating, arcing, and microwave leakage. Microwave ovens designed for the laboratory have built-in safety features and operation procedures to mitigate or eliminate these hazards. Users of such equipment must be thoroughly knowledgeable of operation procedures and safety devices and protocols before beginning experiments, especially when there is a possibility of fire (flammable solvents), over-pressurization, or arcing (Foster and Cournoyer, 2005).

To avoid exposure to microwaves, never operate ovens with the doors open. Do not place wires and other objects between the sealing surface and the door on the oven's front face. Keep the sealing surfaces clean. To avoid electrical hazards, the oven must be grounded. If use of an extension cord is necessary, use only a three-wire cord with a rating equal to or greater than that for the oven. To reduce the risk of fire in the oven, do not overheat samples. The oven must be closely watched when combustible materials are in it. Do not use metal containers or metal-containing objects (e.g., stir bars) in the microwave, because they can cause arcing.

In general, do not use heat-sealed containers in a microwave oven because of the danger of explosion. If sealed containers must be used, select their materials carefully and ensure the containers are properly designed. Commercially available microwave acid digestion bombs, for example, incorporate a Teflon sample cup, a self-sealing Teflon O-ring and a compressible pressure-relief valve. Do not exceed the manufacturer's loading limits. For such applications, properly vent the microwave oven using an exhaust system. Placing a large item, such as a laboratory microwave or an oven, inside a chemical fume hood is not recommended.

Heating a container with a loosened cap or lid poses a significant risk. Microwave ovens can heat material (e.g., solidified agar) so quickly that, even though the container lid is loosened to accommodate expansion, the lid can seat upward against the threads and the container can explode. Screw caps must be removed from containers being microwaved. If the sterility of the contents must be preserved, screw caps may be replaced with cotton or foam plugs.

Ionizing Radiation

Ionizing radiation is a classification for high-energy radiation capable of breaking chemical bonds. This class of radiation encompasses both photonic (high ultraviolet radiation, x-rays, and gamma rays) and particulate (alpha particles, beta particles, positrons, and neutrons) forms of emissions. Before dealing with these sources, training must be completed under the Radiation Safety

Officer. Contact EOHS at ext. 3700. For more specific information on ionizing radiation hazards, please consult the Radiation Safety Program.

STEM Work Space Infrastructure

Ventilation

STEM work spaces must be provided with general ventilation adequate for employee comfort and sufficient to supply air for chemical fume hoods and other local ventilation devices. Because the general air supply is not adequate for manipulating hazardous materials on an open lab bench, volatile or toxic chemicals shall be handled in a chemical fume hood or other appropriate containment device.

STEM work space ventilation should change the air at least six times per hour. Higher air exchange rates may be required depending on the nature of the work. Except in special circumstances approved by EOHS, air in laboratories shall be at a negative pressure with respect to the rest of the building. Air diffusers or grilles must be so designed and located as to direct the air over the laboratory personnel and sweep the contaminated air away from their breathing zone. To promote uniform distribution and mixing of air in large spaces, the supply registers must deliver the air in all directions, at a typical velocity of 20 linear feet per minute.

Problems with general ventilation must be reported promptly to Facilities. Adjustments or alterations to the general ventilation equipment must be performed only under the supervision of Facilities.

On occasion, Facilities will issue notices of intent to perform maintenance work on the ventilation system. These notices must be heeded and chemical fume hoods must not be used when Facilities is involved in repairing or adjusting the ventilation system. The supervisor of the work space is responsible for ensuring that the Facilities crew is informed of the hazards in the area. The chemical fume hood must be cleared of toxic materials and properly decontaminated before such work begins. Facilities may request EOHS to inspect the chemical fume hood prior to maintenance or repair work. Be prepared to supply a detailed history of chemical and biological agent use in the chemical fume hood for safety evaluation purposes.

Chemical Fume Hood

A chemical fume hood is an important engineering control for preventing exposure to hazardous materials. It serves as an effective means for capturing toxic, carcinogenic, offensive, flammable vapors or other airborne contaminants. A chemical fume hood is an important engineering control for preventing exposure to hazardous materials. With the sash lowered, the chemical fume hood also forms a physical barrier to protect workers from hazards such as chemical splashes or sprays, fires and minor explosions. Chemical fume hoods may also provide effective containment for accidental spills of chemicals although this is not their primary purpose. Turbulence is the biggest issue with proper chemical fume hood operation. It can lead to back spill of contaminants out of the chemical fume hood. The operator has significant control over the factors that cause turbulence and consequently, the chemical fume hood's capture efficiency. Turbulence is also created at the face of the chemical fume hood when obstacles to airflow such as containers and equipment are too close to the sash. Chemical fume hood performance is also dependent on the room's airflow pattern, including airflow generated by drafts and persons walking by. Minimize traffic, opening and closing of doors near the chemical fume hood. When the chemical fume hood is in use, the sashes should be pulled down as far as workable for minimal external airflow interference and maximum barrier protection. Chemical fume hoods must be evaluated for performance upon installation and following any alterations. EOHS monitors chemical fume hoods annually. The fan and duct systems are maintained and inspected by Facilities Management. Any problems with hood ventilation or airflow should be reported to EOHS or Facilities for inspection and evaluation.

Safety Showers

Safety showers must be installed in all areas where employees may be exposed to splashes or spills of corrosive materials that may be injurious to the eyes and body. As a rule, new shower installations shall adhere to the recommendations for shower location and minimum performance requirements established in American National Standard Z-358.1 (2009). Showers shall be placed as close to the hazard as possible, but in no case more than 10 seconds' travel time from the hazard. Department heads shall ensure that safety showers are installed in the department where needed. Drench hoses substitute for showers in some locations on campus.

Every STEM employee must be instructed in the location(s) and use of a safety shower. Safety showers must be inspected at least annually including a visual check of visible plumbing and verification of proper operation. EOHS conducts the annual tests and maintains related records.

Eyewash Stations

An eyewash providing a continuous, low-pressure stream of aerated water must be provided in each laboratory in which corrosive chemicals are stored and used. The designated eyewash(es) must be easily accessible from any part of the work area and labeled. If possible, the eyewash should be located near the safety shower so that, if necessary, the eyes can be washed while the body is showered.

Faculty and area supervisors are responsible for ensuring that the labeled eyewash fountains in their areas are flushed weekly. Operate the valve, visually observe availability of the aerated water stream, and flush the pipes or hose of sediment that may have collected. Issue a work order to Facilities if an eyewash station does not provide a clean water stream of sufficient pressure and attach an Out-of-order sign as documentation for your maintenance action. Fend All units should be checked monthly.

Sinks and Drain Traps

Every laboratory using chemical or biological agents must have at least one sink, preferably located near the exit, available for handwashing. The sink must be cleaned regularly to eliminate contamination, and soap must be supplied for handwashing. Antimicrobial soaps are not necessary. Drain traps in sinks, floors and other places will dry out if they are not used regularly allowing odors and contamination to back up into the room. Drain traps must be kept filled with water to prevent backup.

Fire Extinguisher

Fire extinguishers are provided by the University in corridors, public areas, STEM work spaces, and other locations where required by building and life safety code. EOHS provides fire extinguishers in new and renovated laboratories during the construction phase. All existing STEM work space are equipped with extinguishers. Missing extinguishers should be reported to EOHS. Extinguishers in individual STEM work space are ordered through EOHS at no cost to the faculty. EOHS will inspect and maintain all fire extinguishers,

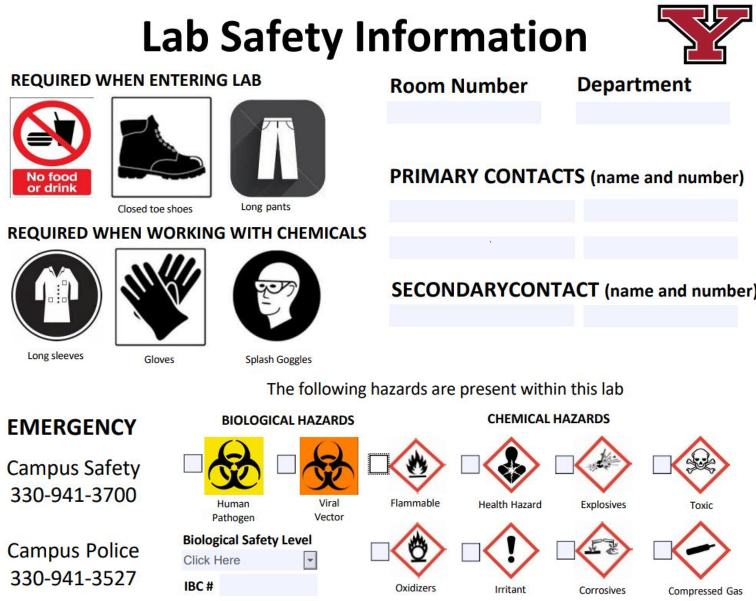
Laboratory Doors

Fire and life safety codes may require that corridor doors be fire rated and equipped with door closers. Doors with door closers are generally kept closed at all times, unless the door release is tied into the building's fire alarm system. Keeping laboratory doors to corridors closed helps ensure that ventilation systems work properly and maintain contaminant-containing pressure differentials between labs and corridors. Doors in internal laboratory suites may have less stringent door closing requirements.

Hazardous Chemicals

Classes of Chemicals

Chemicals can be divided into several different hazard classes. The hazard class will determine how these materials should be stored and handled and what special equipment and procedures are needed to use them safely. Each chemical container, whether supplied by a vendor or produced in the laboratory, must include labels that clearly identify the hazards associated with that chemical. In addition to specific chemical labels, hazard information for specific chemicals can be found by referencing the Safety Data Sheet (SDS) for that chemical. Rooms containing hazardous chemicals must be labeled properly with the appropriate globally harmonized system pictogram shown below.



It is essential that all STEM work space workers understand the types of hazards, recognize the routes of exposure, and are familiar with the major hazard classes of chemicals. In many cases, the specific hazards associated with new compounds and mixtures will not be known, so it is recommended that new chemical compounds be treated as if they were potentially harmful and to use appropriate eye, inhalation and skin protection equipment.

<u>Flammable</u>

A number of highly flammable substances are in common use on campus. Flammable liquids include those chemicals that have a flashpoint of less than 100 degrees Fahrenheit. These materials must be stored in flammable storage cabinets if aggregate quantities of 10 gallons/room or more are stored in the STEM work space and if the container size is greater than 1 gallon (4 L). Flame-resistant laboratory coats must be worn when working with flammable materials and/or with procedures where a significant fire risk is present (e.g., when working with open flame, etc.). These materials can constitute a significant immediate threat and should be treated with particular care, even though the use of these materials is fairly common in the work space setting. Particular attention should be given to preventing static electricity and sparks when handling flammable liquids.

<u>Reactive</u>

Reactive and explosive substances are materials that decompose under conditions of mechanical shock, elevated temperature, or chemical action, and release of large volumes of gases and heat. Some materials, such as peroxide formers, may not be explosive, but may form explosive substances over time. These substances pose an immediate potential hazard and procedures that use them must be carefully reviewed. These materials must also be stored in a separate flame-resistant storage cabinet or, in many cases, in a laboratory grade refrigerator or freezer that is designed for storing flammable and reactive chemicals. Pyrophoric chemicals are a special classification of reactive materials that spontaneously combust when in contact with air and require laboratory-specific training. Flame- resistant laboratory coats must always be worn when working with pyrophoric chemicals. Pyrophorics must also always be handled in laboratories equipped with emergency sprinkler systems.

Health Hazards

OSHA uses the following definition for health hazards: The term 'health hazard' includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes.

Irritant

Irritants are defined as non-corrosive chemicals that cause reversible inflammatory effects on living tissue by chemical action at the site of contact. Wide varieties of organic and inorganic compounds, including many chemicals that are in a powder or crystalline form, are irritants. The most common example of an irritant may be ordinary smoke that can irritate the nasal passages and respiratory system. Consequently, eye and skin contact with all laboratory chemicals should always be avoided. Symptoms of exposure can include reddening or discomfort of the skin and irritation to respiratory systems.

Sensitizer

A sensitizer (allergen) is a substance that causes exposed people to develop an allergic reaction in normal tissue after repeated exposure to the substance. Examples of sensitizers include diazomethane, chromium, nickel, formaldehyde, isocyanates, arylhydrazines, benzylic and allylic halides, and many phenol derivatives. Sensitizer exposure can lead to all of the symptoms associated with allergic reactions, or can increase an individual's existing allergies.

Target Organ Hazard

Substances included in this category include:

- Hepatotoxins – i.e., substances that produce liver damage, such as nitrosamines and carbon tetrachloride.
- Nephrotoxins – i.e., agents causing damage to the kidneys, such as certain halogenated hydrocarbons
- Neurotoxins – i.e., substances that produce their primary toxic effects on the nervous system, such as mercury, acrylamide and carbon disulfide.
- Agents that act on the hematopoietic system – e.g., carbon monoxide and cyanides that decrease hemoglobin function and deprive the body tissues of oxygen.
- Agents that damage lung tissue – e.g., asbestos and silica. Symptoms of exposure to these materials vary. Staff working with these materials should review the SDS for the specific

material being used and should take special note of the associated symptoms of exposure.

Acute Toxins

Substances that have a high degree of acute toxicity are interpreted by OSHA as being substances that "may be fatal or cause damage to target organs as the result of a single exposure or exposures of short duration." These chemicals, associated chemical waste, and storage containers must be handled with care to prevent cross contamination of work areas and unexpected contact. Empty containers of these substances must be packaged and disposed of as hazardous waste without rinsing trace amounts into the sanitary sewer system.

Reproductive Toxins

Reproductive toxins include any chemical that may affect the reproductive capabilities, including chromosomal damage (mutations) and effects on fetuses (teratogenesis). Reproductive toxins can affect the reproductive health of both men and women if proper procedures and controls are not used. For women, exposure to reproductive toxins during pregnancy can cause adverse effects on the fetus; these effects include embryolethality (death of the fertilized egg, embryo or fetus), malformations (teratogenic effects), and postnatal functional defects. For men, exposure can lead to sterility. Pregnant women and women intending to become pregnant should consult with their supervisor and EOHS before working with substances that are suspected to be reproductive toxins.

Carcinogens

Carcinogens are chemical or physical agents that cause cancer. Generally, they are chronically toxic substances; that is, they cause damage after repeated or long-duration exposure, and their effects may only become evident after a long latency period. Chronic toxins are particularly insidious because they may have no immediately apparent harmful effects. These materials are separated into two classes: select carcinogens and regulated carcinogens.

The use of carcinogens may require personal exposure sampling based on usage. When working with carcinogens, it is particularly important to review and effectively apply engineering and administrative safety controls as the regulatory requirements for work spaces that may exceed long-term (8 hour) or short-term (15 minutes) threshold values for these chemicals are very extensive.

<u>Corrosive</u>

As a health hazard, corrosive substances cause destruction of, or alterations in, living tissue by chemical action at the site of contact. Major classes of corrosive substances include:

- Strong acids – e.g., sulfuric, nitric, hydrochloric and hydrofluoric acids
- Strong bases – e.g., sodium hydroxide, potassium hydroxide and ammonium hydroxide
- Dehydrating agents – e.g., sulfuric acid, sodium hydroxide, phosphorus pentoxide
- Oxidizing agents – e.g., hydrogen peroxide, chlorine and bromine.

Symptoms of exposure for inhalation include a burning sensation, coughing, wheezing, laryngitis, shortness of breath, nausea, and vomiting. For eyes, symptoms include pain, blood shot eyes, tearing, and blurring of vision. For skin, symptoms may include reddening, pain, inflammation, bleeding, blistering and burns. As a physical hazard, corrosive substances may corrode materials they come in contact with and may be highly reactive with other substances. It is important to review information regarding the materials they may corrode, and their reactivity with other substances, as well as information on health effects. In most cases, these materials should be segregated from other chemicals and require secondary containment when in storage.

Nanomaterials

The increasing use of nanomaterials in research labs warrants consideration of the hazards they may pose. As is the case with many new technologies, the health effects of nanomaterials have not been thoroughly investigated. Consequently, the uncertainty surrounding the toxicity of nanomaterials merits a cautious approach when working with them.

Nanomaterials include any materials or particles that have an external dimension in the nanoscale (~1 – 100 nm). Nanomaterials are both naturally occurring in the environment and intentionally produced. Intentionally produced nanomaterials are referred to as Engineered

Nanomaterials (ENMs). The most common types of ENMs are carbon-based materials such as nanotubes, metals and metal oxides such as silver and zinc oxide, and quantum dots made of compounds such as zinc selenide

Nanomaterials can be categorized by the potential risk of exposure they pose to personnel based on the physical state of the materials and the conditions in which they are used. In general, the risk of exposure is lowest when nanomaterials are bound in a solid matrix with little potential to create airborne dust or when in a non-volatile liquid suspension. The risk of exposure increases when nanomaterials are used as fine powders or are suspended in volatile solvents or gases. The parent compound of the nanomaterial should also be taken into consideration when evaluating the potential hazards associated with exposure. For more information, see the National Institute of Occupational Safety & Health's (NIOSH)

Safety Practices for Working with Engineered Nanomaterials

Exposure Reduction to Hazardous Chemicals

Hazardous chemicals require a carefully considered, multi-tiered approach to ensure safety. There are four primary routes of exposure for chemicals that have associated health hazards inhalation, absorption (through the skin or eyes). Ingestion, and injection (skin being punctured by a contaminated sharp object or uptake through an existing open wound). Of these, the most likely route of exposure in the laboratory is by inhalation. Many hazardous chemicals may affect people through more than one of these exposure modes, so it is critical that protective measures are in place for each of these uptake mechanisms.

Safety Controls

Engineering Controls

Engineering controls include all “built in” safety systems. These controls offer the first line of protection and are highly effective in that they generally require minimal special procedures or actions on the part of the user except in emergencies. Additionally, engineering controls often involve the replacement or elimination of hazards for a work environment. A fundamental and very common example is the laboratory fume hood, which is very effective at containing chemical hazards and protecting users from inhalation hazards. Other examples of engineering controls include general room ventilation, flammable material storage units, and secondary containment.

Administrative Controls

These controls consist of policies and procedures; they are not generally as reliable as engineering controls in that the user has to carefully follow the appropriate procedures and must be fully trained and aware in order to do so. EOHS requires that each lab or work space have safety procedures, which include safety practices, for any space that involves hazardous materials. These safety procedures must be area specific, communicated via area specific trainings, Standard Operating Procedures and properly documented.

Personal Protective Equipment

Personal protective equipment serves as a person’s last line of defense against exposures and is required by everyone entering a STEM work space containing hazards. The PPE policy outlines the basic PPE requirements, which include but are not limited to:

- Full length pants and close-toed shoes, or equivalent
- Protective gloves, laboratory coats, & eye protection when working with, or adjacent to, hazardous chemicals
- Flame resistant laboratory coats for high hazard materials, pyrophorics, and flammables.

The primary goal of PPE is to mitigate, at a minimum, the hazard associated with exposure to hazardous substances. The SDS for a chemical or material should always be consulted to determine the appropriate required PPE. In some cases, additional, or more protective, equipment must be used. If a project involves a chemical splash hazard, chemical goggles are required; face shields may also be required when working with chemicals that may cause immediate skin damage.

Types of Personal Protective Equipment

Clothing

Cover unprotected skin whenever possible. Suitable clothing must be worn in the STEM work space; shorts are not appropriate. Clothing may absorb liquid spills that would otherwise be exposed to your skin. Long sleeves protect arms and shall fit snugly, especially when you are working around machinery.

Wear closed-toed shoes in the STEM work space to protect against chemical and physical hazards. Do not wear sandals, cloth sport shoes, perforated shoes, or open-toed shoes. If you clean up a spill from the floor, you may need the added protection of rubber boots or plastic shoe covers. Safety- toed shoes may be required for handling heavy items, such as gas cylinders or heavy equipment components.

Aprons, laboratory coats, gloves, and other protective clothing, preferably made of chemically inert material, must be readily available and used. Laboratory coats are essential to protect street clothing from biological agent aerosols or chemical and radioactive material splashes and spills, vapors, or dusts. For work involving carcinogens, disposable coats may be preferred.

When the potential for fire exists, consider wearing clothing specifically designed to be flame retardant. Several types of flame-resistant clothes are available from safety suppliers. A low-cost option is a disposable cotton coat that has been treated with a flame-resistant material.

Eye Protection

Eye protection is mandatory in STEM work spaces where there are hazards of flying objects or splashing chemicals.

Regulations require protective eye and face equipment where there is a reasonable probability that using them can prevent injury. Eye protection is not interchangeable among employees and must be provided for each individual unless disinfected after use.

Safety glasses with clear side shields are adequate protection for general use. Goggles must be worn when there is danger of splashing chemicals or flying particles, such as when chemicals are poured or glassware is used under elevated or reduced pressure. Safety goggles differ from safety glasses in that they form a seal with the face, which completely isolates the eyes from the hazard. A face shield with goggles offers maximum protection (for example, with vacuum systems that may implode).

Normal glasses do not provide sufficient protection; people whose vision requires corrective lenses, and who are required to wear eye protection, must wear goggles over their eyeglasses, or prescription safety glasses. If contact lenses are worn, they should not be handled in the STEM work spaces and must be worn with regularly required eye protection, such as plastic goggles.

Gloves

Gloves are worn to prevent skin contact with toxic, radioactive or biological agents, burns from hot or extremely cold surfaces or corrosives, or cuts from sharp objects. Many gloves are made for specific uses. For adequate protection, select the correct glove for the hazard in question.

Leather and Kevlar gloves provide good protection for picking up broken glass, handling objects with sharp edges. However, because they absorb liquid, these gloves do not provide protection from chemicals, nor are they adequate for handling extremely hot or cold surfaces.

Select glove materials resistant to the chemical being used, and change gloves periodically to minimize penetration. The chemical resistance of common glove materials varies according to the glove manufacturer, as manufacturers may vary the thicknesses and formulations of material

Respiratory Protection
Typically, respiratory protection is not needed in a work space where there is adequate ventilation. Under most circumstances, safe work practices, small-scale usage, and engineering controls adequately protect workers from airborne hazards.

Under certain circumstances respiratory protection may be needed. These can include:

- An accidental spill of a hazardous chemical outside a fume hood
- An unusual operation that cannot be conducted under local ventilation
- Weighing hazardous powders.
- When exposure monitoring indicates that exposures exist that cannot be controlled by engineering or administrative controls.
- As required by a specific protocol or as defined by applicable regulations (ie welding on stainless steel)

Because there are numerous types of respirators available, and each has specific limitations and applications, respirator selection and use require pre-approval by EOHS. For either required or voluntary use of a respirator, the employee must fill out a Respirator Protection Request form; review it with his/her supervisor, and return the completed form to EOHS. EOHS will then contact the employee to evaluate the potential exposure. Tasks with potential airborne hazards that cannot be eliminated by engineering or administrative controls will not be authorized by EOHS until affected employees can be incorporated into the Respirator Protection Program.

Training and Maintaining PPE
Personal protective equipment (PPE) should be kept clean and stored in an area where it will not become contaminated. PPE should be inspected prior to use to ensure it is in good condition. It should fit properly and be worn properly. If it becomes contaminated or damaged, it should be cleaned or repaired when possible, or discarded and replaced.

Contaminated PPE
In cases where spills or splashes of hazardous chemicals on clothing or PPE occur, the clothing/PPE should immediately be removed and placed in a closed container that prevents release of the chemical. Heavily contaminated clothing/PPE resulting from an accidental spill should be disposed of as hazardous waste. Non-heavily contaminated PPE should be cleaned

and, as appropriate. STEM personnel should never take contaminated items home for cleaning or laundering. Persons or companies hired to clean contaminated items must be informed of potentially harmful effects of exposure to hazardous chemicals and must be provided with information to protect themselves.

Exposure Assessment

All University employees require protection from exposure to hazardous chemicals above PELs, STELs and Ceiling concentrations. OSHA requires the person supervising, directing, or evaluating the exposure assessment monitoring be competent in the practice of industrial hygiene. Thus, only representatives of EOHS and not the Supervisor should perform exposure assessment.

The EOHS Department will promptly notify the employee and his/her supervisor of the results in writing (within 15 working days or less when required by regulation) after receipt of the monitoring results. The EOHS Department will establish and maintain an accurate record of any measurements taken to monitor exposures for each employee.

Chemical Inventory and Hazard Communication

Youngstown State University has an established Hazard Communication Program that complies with the OSHA Hazard Communication Standard. The purpose of the Hazard Communication Program is to ensure that all employees and, upon request, their personal physicians, have the right to receive information regarding the hazardous substances to which they may have been exposed at work. The university is responsible for providing information about the hazardous substances in the workplace, the associated hazards, and the control of these hazards, through a comprehensive hazard communication program that is summarized briefly below.

The requirements of the Hazard Communication Program apply to STEM work spaces due to the potential for large-scale experiments and for activities that may occur outside of areas where engineering controls are available.

Chemical Inventories

The chemical database is maintained by the CMC at www.chemicalsafety.com. For login information, please contact EOHS at eohs@ysu.edu or 330-941-3700.
The chemical inventory list should be reviewed prior to ordering new chemicals and only the minimum quantities of chemicals necessary for the research and teaching labs should be purchased. As new chemicals are added to the inventory, each laboratory group must confirm that they have access to the Safety Data Sheets (SDS) for those chemicals. Where practical, each chemical should be dated so that expired chemicals can be easily identified for disposal.

Inventory the materials in your STEM work space frequently (at least annually) to avoid overcrowding with materials that are no longer useful and note the items that should be replaced, have deteriorated, or show container deterioration. Unneeded items should be returned to the storeroom/stockroom and compromised items should be discarded as chemical waste.

Access to hazardous chemicals, including toxic and corrosive substances, should be restricted at all times. These materials must be stored in STEM work spaces or storerooms that are kept locked when personnel are not present. Locked storage cabinets or other precautions are always recommended, and in some cases may be required in the case of unusually toxic or hazardous chemicals. For guidance on locked storage requirements, please contact EOHS. On termination or transfer of STEM work space personnel, all related hazardous materials must be properly disposed of, or transferred to the STEM work space supervisor or a designee.

STEM work space supervisors are responsible for verifying if any items on their chemical inventory are subject to the requirements of the hazard communication regulation. An SDS must be available for each hazardous substance in a laboratory's chemical inventory. SDSs are available from the Chemical Management Center SDS Website .

Chemical Labels and Warnings

Every chemical found in the STEM work space must be properly labeled. Most chemicals come with a manufacturer's label that contains the necessary information, so care should be taken to not damage or remove these labels. Each chemical bottle, including diluted chemical solutions, must be labeled with its contents and the hazards associated with this chemical. It is recommended that each bottle also be dated when received and when opened to assist in determining which chemicals are expired and require disposal. New chemicals and compounds generated by STEM work space operations must be labeled with the name, date, and hazard information; the person(s) responsible for this chemical should be named on the container so that they can be contacted if questions arise about the container's contents.

Chemical Storage

Establish and follow safe chemical storage & segregation procedures for your STEM work space. Acceptable chemical storage locations may include corrosive cabinets, flammable cabinets, shelves, or appropriate refrigerators or freezers. Fume hoods should not be used as general storage areas for chemicals, as this may seriously impair the ventilating capacity of the hood. Chemicals should not be routinely stored on bench tops or stored on the floor.

STEM work space refrigerators and freezers must be labeled appropriately with "No Food/Drink" and must never be used for the storage of consumables.

Shelving units should have a raised lip along the outer edge to prevent containers from falling. Hazardous liquids or corrosive chemicals must not be stored on shelves above eye-level and chemicals that are highly toxic or corrosive must be in unbreakable secondary containers.

Chemicals must be stored at an appropriate temperature and humidity level and should never be stored in direct sunlight or near heat sources, such as laboratory ovens. Incompatible materials should be stored in separate cabinets, whenever possible.

Chemical Segregation

Figure 13 contains information regarding the general hazard class segregation that should be followed. These chemicals require separation by at least an appropriate secondary container and in some cases should be located in different cabinets or locations completely. Such circumstance includes flammable and oxidizing gases.

Hazard Class	***Keep out of contact with:***
Flammables	*Oxidizers*
Acids	*Bases*
Organic Acids	*Inorganic Acids*
Water Reactive Chemicals	*Water and Aqueous Solutions*

Figure 13: Hazard Class Segregation

Compressed and Liquified Gases

- Never drop cylinders or permit them to strike each other violently.
- Do not expose cylinders to temperatures higher than 50° C. Some rupture devices on cylinders release at about 65° C.
- Never tamper with pressure relief devices in valves or cylinders.
- Before using cylinders, read all label information and Safety Data Sheet associated with the gas being used.

Maximum allowable storage quantities vary depending on campus, building, floor, control area, fire rated design and type of gas. Only cylinders that are in use can be kept in the STEM work space. When the cylinder is not in use, close the main cylinder valve tightly and add the protective cap. Promptly remove the regulator from an empty cylinder, replace the protective cap, and label the cylinder by using an "empty" tag or writing on the side of the cylinder with chalk. Never bleed cylinders completely empty; leave a slight pressure to keep contaminants out. Empty cylinders must be promptly removed to the CMC.

Toxic Gases

Flow-restricting orifices are recommended on cylinders of toxic gases. All portable tanks and cylinders must be marked to indicate the orifice (inches) on the certification tags and the vessel themselves. Toxic-gas cylinders must be stored in continuously mechanically ventilated enclosures with an extinguishing system (IFC 2012 – Section 6004.1.2). If the net toxic gas content exceeds one pound per cylinder no more than three cylinders of toxic gas are allowed per enclosure (gas cabinet). Any new STEM work space construction must require vented gas cabinets for storage of highly toxic gases. Gas cylinder cabinets for toxic gases must have a fire extinguishing system (IFC 2012 – 6004.1.2). Waste toxic gases must be treated by absorption, wet or dry scrubbing, combustion, or condensation via refrigeration, before being vented to chemical fume hoods or other local exhaust arrangements. The safe venting of pressure-relief devices should be considered. (IFC 2012 – Section 6003.1.3 Treatment Systems) If the physiological warning properties for the toxic or highly toxic gas(es) are above the PEL an emergency alarm system is required (IFC 2012 – 6004.2.2.10); consult EOHS regarding this determination.

Flammable Gases

Flammable gas cylinders must be stored 20ft away from oxidizers and oxygen gas cylinders or separated by a fire rated wall.

Acetylene

The in house transfer, handling, storage, and utilization of acetylene in cylinders shall be in accordance with Compressed Gas Association Pamphlet G-1-2015. Acetylene cylinders have a porous filler material filled with acetone and dissolved acetylene. The cylinder must only be used in the upright position. If a cylinder has been handled in a non-upright position, do not use it until it has sat upright for at least 30 minutes. Some tubing materials, such as copper and lead solder, form explosive acetylides. Never exceed the delivery pressure limit of 15psig indicated by the warning red line of an acetylene pressure gauge. The use of an excess flow control valve is not recommended. Install a flash arrestor downstream from the regulator and check valves wherever backflow needs to be prevented.

Hydrogen

Individual hydrogen gas cylinders should contain less than 400scf. Larger hydrogen gas vessels may require a laboratory designed with explosion control and other safety measures. The installation of a flash arrestor is required and the installation of an excess flow control valve is recommended.

Cryogenic Liquids

The hazards of cryogenic liquids include fire or explosion, pressure buildup, embrittlement of structural materials, asphyxiation, and destruction of living tissue on contact. Portable cylinders of cryogens must only be stored in well-ventilated areas. Storage of cryogenic liquids or liquefied gases in cold rooms or other rooms without external ventilation is prohibited.

Because liquid nitrogen containers are at low pressure and have protective rings mounted around the regulator, they are not required to be affixed to a permanent fixture such as a wall. However, additional protection considerations should be addressed when storing liquid nitrogen in a STEM work space. The primary risk to personnel from liquid nitrogen is skin or eye thermal damage caused by contact with the material. The gases usually are not toxic, but if too much oxygen is displaced, asphyxiation is a possibility. Always use appropriate thermally insulated gloves when handling liquid nitrogen. Face shields may be needed in cases where splashing can occur.

Inert Gases

Indoor areas where bulk inert gas systems are newly installed shall be continuously monitored with an atmosphere monitoring system. The system shall provide an audible and visual alarm (red light) when the oxygen level drops to 19.5%. The audible and visual alarm shall be located inside the area and immediately outside of all entrances to the indoor area. A blue indicator light shall indicate a detection system malfunction.

Chemical Security

It is critical that chemicals be secured to prevent theft from campus laboratories. Numerous federal agencies are involved in the maintenance of laboratory security, including the Drug Enforcement Agency , Federal Bureau of Investigations , and Department of Homeland Security.

It is each supervisors responsibility to prevent and report any theft of chemicals from their work space to the Chemical Management Center. Areas can increase their security by simply keeping doors closed and locked when unoccupied, maintaining a current and accurate chemical inventory, training personnel on security procedures, and controlling access to keys. Areas should report any suspicious activity to Campus Police.

Training

Effective training is critical to facilitate a safe and healthy work environment and prevent shop accidents. All Faculty/ Supervisors must participate in formal safety training and ensure that all their employees and students have appropriate safety training before working in a shop area. Contact EOHS at extension 3700 or eohs@ysu.edu to arrange training.

All STEM lab and shop area personnel must complete general safety training before working in a new shop area and if new equipment or situations arise.

Annual refresher training is also required for all laboratory personnel. EOHS offers online training, plus resource materials to assist shop areas in implementing site- specific training. Additional face-to-face training can be requested from EOHS.

Anyone working in a STEM lab or shop area are required to complete online STEM Lab Safety training, which includes:

- Review of STEM Safety Plan (this document)
- Hand and Power Tools
- Hazard Communication GHS
- Machine Guarding
- Shop Safety
- Slips, Trips, and Falls

Documentation of Training

Accurate recordkeeping is a critical component of health and safety training and required according to regulations. Online training records are kept by EOHS. Face-to-face training (including safety meetings, one-on-one training, in-class) conducted by the department is the responsibility of each department. Electronic copies are encouraged, however if hard copies are maintained documentation should be located in the physical shop or lab. For shop/lab specific trainings please include a sign in sheet with sufficient details such as date, topics discussed, and who lead the training.

Waste Management

The EOHS Hazardous Materials Program manages the shipment and disposal of all hazardous waste generated on campus. Each laboratory employee must comply with the campus Hazardous Waste Management Program requirements and all applicable regulations. A regular pickup service is provided to most research buildings equipped with wet labs, and a pick-up is available upon request to other locations where hazardous waste is generated.

Shop/lab personnel are responsible for identifying waste, labeling it, storing it properly in the laboratory and transporting waste to their designated pick-up location on time. Shop/lab clean-outs and disposal of high hazard compounds (e.g. expired peroxide forming chemicals, dried picric acid, or abandoned unknown chemicals) must be scheduled in advance, and fees for these services are sometimes applied. The employee, faculty or supervisor of the work area is responsible for coordinating the disposal of all chemicals from his/her area prior to closing down operations.

APPENDIX A: References and Source Material

1.) Northwestern Laboratory Manual and Chemical Hygiene Plan
2.) UCLA Laboratory Manual and Chemical Hygiene Plan
3.) The Ohio State University Laboratory Manual
4.) Virginia Tech Laboratory Manual and Chemical Hygiene Plan
5.) Prudent Practices in the Laboratory. National Research Council. 2011
6.) Leggett, D. Chemical Reactivity Assessments in R&D. MRSC
7.) Parr No.230M Safety in the Operation of Laboratory Reactors and Pressure Vessels
8.) Pressure Classification of Reactions, NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals (2011 Edition) Annex C 45-39
9.) Safety in Academic Chemistry Laboratories. American Chemical Society (https://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsaf ety/publications/safety-in-academic-chemistry-laboratories-faculty.pdf)

APPENDIX B: Glossary

ACGIH - The American Conference of Governmental Industrial Hygienists is a voluntary membership organization of professional industrial hygiene personnel in governmental or educational institutions. The ACGIH develops and publishes recommended occupational exposure limits each year called Threshold Limit Values (TLVs) for hundreds of chemicals, physical agents, and biological exposure indices. AEROSOL - Liquid droplets or solid particles dispersed in air that are of fine enough size (less than 100 micrometers) to remain dispersed for a period of time.

ASPHYXIANT - A chemical (gas or vapor) that can cause death or unconsciousness by suffocation. Simple asphyxiants, such as nitrogen, either use up or displace oxygen in the air. They become especially dangerous in confined or enclosed spaces. Chemical asphyxiants, such as carbon monoxide and hydrogen sulfide, interfere with the body's ability to absorb or transport oxygen to the tissues.

"C" OR CEILING - A description usually seen in connection with a published exposure limit. It refers to the concentration that should not be exceeded, even for an instant. It may be written as TLV-C or Threshold Limit Value - Ceiling. (See also Threshold Limit Value).

CARCINOGEN - A cancer-producing substance or physical agent in animals or humans. A chemical is considered a carcinogen or potential carcinogen if it is so identified in any of the following:

- National Toxicology Program, "Annual Report of Carcinogens" (latest edition)
- International Agency for Research on Cancer, "Monographs"(latest edition)
- OSHA, 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances

CHEMICAL HYGIENE OFFICER - An employee who is designated by the employer and who is qualified by training or experience to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan.

CHEMICAL HYGIENE PLAN - A written program developed and implemented by the employer which sets forth procedures, equipment, personal protective equipment, and work practices that are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace and (2) meets the requirements of OSHA regulation 29 CFR 1910.1450.

COMBUSTIBLE LIQUID - Any liquid having a flashpoint at or above 100°F (37.8°C) but below 200°F (93.3°C) except any mixture having components with flashpoints of 200°F or higher, the total volume of which make up 99% or more of the total volume of the mixture.

COMPRESSED GAS - A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70°F (21.1°C), or; a gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130°F (54.4°C) regardless of the pressure at 70°F (21.1°C), or; a liquid having a vapor pressure exceeding 40psi at 100°F(37.8°C)as determined by ASTMD-323-72.

CORROSIVE - A substance that, according to the DOT, causes visible destruction or permanent changes in human skin tissue at the site of contact or is highly corrosive to steel.

DESIGNATED AREA - An area which has been established and posted with signage for work involving hazards (e.g., "select carcinogens," reproductive toxins, or substances which have a high degree of acute toxicity). A designated area may be the entire laboratory, an area of a laboratory, or a device such as a laboratory hood.

EMERGENCY - Any potential occurrence, such as, but not limited to, equipment failure, rupture of containers, or failure of control equipment which could result in an uncontrolled release of a hazardous chemical into the workplace.

EXPLOSIVE - A chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to a sudden shock, pressure, or high temperature.

FLAMMABLE - A chemical that falls into one of the following categories:

1. Flammable aerosol - an aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening, or a flashback (a flame extending back to the valve) at any degree of valve opening;

2. Flammable gas - a gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13% by volume or less; or a gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12% by volume, regardless of the lower limit;

3. Flammable liquid - any liquid having a flashpoint below 100°F (37.8°C), except any mixture having components with flashpoints of 100°F (37.8°C) or higher, the total of which make up 99% or more of the total volume of the mixture; or

4. Flammable solid - a solid, other than a blasting agent or explosive as defined in1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and, when ignited, burns so vigorously and persistently as to create a serious hazard. A chemical shall be considered to be a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a greater than one-tenth of an inch per second along its major axis.

FLASHPOINT - The minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite in the presence of an ignition source or when tested as follows:

1. Tagliabue Closed Tester (See American National Standard Method of Test for Flashpoint by Tag Closed Tested, Z11.24-1979 (ASTM D-56-79) for liquids with a viscosity of less than 45 Saybolt Universal Seconds (SUS) at 100°F (37.8°C) or that contain suspended solids and do not have a tendency to form a surface film;
2. Pensky-Martens Closed Tester (See American National Standard Method of Test for Flashpoint by Pensky-Martens Closed Tester, Z11.7-1979 (ASTM D-73-79) for liquids with a viscosity equal to or greater than 45 SUS at 100°F (37.8°C), or that contain suspended solids, or that have a tendency to form a surface film under test; or,
3. Setaflash Closed Tester (See American National Standard Method of Test for Flashpoint of Set a flash Closed Tester (ASTM D-3278-78)). Organic peroxides, which undergo auto accelerating thermal decomposition, are excluded from any flashpoint determination methods specified above.

GENERAL VENTILATION - Also known as general exhaust ventilation, this is a system of ventilation consisting of either natural or mechanically induced fresh air movements to mix with and dilute contaminants in the workroom air. This is not the recommended type of ventilation to control contaminants that are highly toxic, when there may be corrosion problems from the contaminant, when the worker is close to where the contaminant is being generated, and where fire or explosion hazards are generated close to sources of ignition. (See Local Exhaust Ventilation)

GLOBALLY HARMONIZED SYSTEM (GHS) - The GHS is a system for standardizing and harmonizing the classification and labeling of chemicals. It is a logical and comprehensive approach to defining health, physical and environmental hazards of chemicals; creating classification processes that use available data on chemicals for comparison with the defined hazard criteria; and communicating hazard information, as well as protective measures, on labels and Safety Data Sheets (SDS).

HAZARD ASSESSMENT - A formal procedure undertaken by the supervisor in which occupational hazards for all employees are described per procedure or task, and by affected body part(s) or organ(s), and which is documented and posted in the workplace with all personal protective equipment requirements.

HAZARD WARNING - Any words, pictures, symbols or combination thereof appearing on a label or other appropriate form of warning that convey the hazards of the chemical(s) in the container(s).

HAZARDOUS MATERIAL - Any material that is a potential/actual physical or health hazard to humans.

HAZARDOUS MATERIAL (DOT) - A substance or material capable of posing an unreasonable risk to health, safety, and property when transported including, but not limited to, compressed gas, combustible liquid, corrosive material, cryogenic liquid, flammable solid, irritating material, material poisonous by inhalation, magnetic material, organic peroxide, oxidizer, poisonous material, pyrophoric liquid, radioactive material, spontaneously combustible material, and water reactive material.

HAZARDOUS CHEMICAL - A chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals that are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic system, and agents which damage the lungs, skin, eyes or mucous membranes. A chemical is also considered hazardous if it is listed in any of the following:

1. OSHA, 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances
2. “Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment,” ACGIH (latest edition)
3. “The Registry of Toxic Effects of Chemical Substances,” NIOSH (latest edition)

HIGHLY TOXIC - A substance falling within any of the following categories:

1. A substance that has a median lethal dose (LD50) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

2. A substance that has a median lethal dose (LD50) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.
3. A substance that has a median lethal concentration (LC50) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

IGNITABLE - A solid, liquid or compressed gas waste that has a flashpoint of less than 140°F. Ignitable material may be regulated by the EPA as a hazardous waste as well.
INCOMPATIBLE - The term applies to two substances to indicate that one material cannot be mixed with the other without the possibility of a dangerous reaction.
IRRITANT - A substance which, by contact in sufficient concentration for a sufficient period of time, will cause an inflammatory response or reaction of the eye, skin, nose or respiratory system. The contact may be a single exposure or multiple exposures. Some primary irritants: chromic acid, nitric acid, sodium hydroxide, calcium chloride, amines, metallic salts, chlorinated hydrocarbons, ketones and alcohols.
LABEL - Any written, printed or graphic material displayed on or affixed to containers of chemicals, both hazardous and non-hazardous.
LABORATORY TYPE HOOD - A device located in a laboratory, enclosed on five sides with a movable sash or fixed partial enclosure on the remaining side; constructed and maintained to draw air from the lab- oratory and to prevent or minimize the escape of air contaminants into the laboratory; and allows chemical manipulations to be conducted in the enclosure without insertion of any portion of the employee's body other than hands and arms.
LABORATORY USE OF HAZARDOUS CHEMICALS - Handling or use of such chemicals in which all of the following conditions are met:

1. Chemical manipulations are carried out on a "laboratory scale".
2. Multiple chemical procedures or chemicals are used.
3. The procedures involved are not part of a production process nor in any way simulate a production process.
4. "Protective laboratory practices and equipment" are available and in common use to minimize the potential for employee exposure to hazardous chemicals.

LOCAL EXHAUST VENTILATION (Also known as exhaust ventilation) – A ventilation system that captures and removes the contaminants at the point they are being produced before they escape into the workroom air. The system consists of hoods, ductwork, a fan, and possibly an air-cleaning device. Advantages of local exhaust ventilation over general ventilation include: it removes the contaminant rather than dilutes it, requires less airflow and, thus, is more economical over the long term; and the system can be used to conserve or reclaim valuable materials; however, the system must be properly designed with the correctly shaped and placed hoods, and correctly sized fans and ductwork.

MEDICAL CONSULTATION -A consultation that takes place between an employee and a licensed physician for the purpose of determining what medical examinations or procedures, if any, are appropriate in cases where a significant exposure to a hazardous chemical may have taken place.
MIXTURE - Any combination of two or more chemicals if the combination is not, in whole or in part, the result of a chemical reaction.
MUTAGEN - Anything that can cause a change (or mutation) in the genetic material of a living cell.
NFPA - The National Fire Protection Association; a voluntary membership organization whose aims are to promote and improve fire protection and prevention. NFPA has published 16 volumes of codes known as the National Fire Codes. Within these codes is Standard No. 705, "Identification of the Fire Hazards of Materials". This is a system that rates the hazard of a material during a fire. These hazards are divided into health, flammability, and reactivity hazards and appear in a well-known diamond system using from zero through four to indicate severity of the hazard. Zero indicates no special hazard and four indicates severe hazard.
NIOSH - The National Institute for Occupational Safety and Health; a federal agency that among its various responsibilities trains occupational health and safety professionals, conducts research on health and safety concerns, and tests and certifies respirators for workplace use.
ODOR THRESHOLD - The minimum concentration of a substance at which a majority of test subjects can detect and identify the substance's characteristic odor.
OXIDIZER - Is a substance that gives up oxygen easily to stimulate combustion of organic material.
PERMISSIBLE EXPOSURE LIMIT (PEL) - An exposure, inhalation or dermal permissible exposure limit specified in 8 CCR 5155. PELs may be either a time-weighted average (TWA) exposure limit (8-hour), a 15-minute short-term limit (STEL), or a ceiling (C).
PERSONAL PROTECTIVE EQUIPMENT -Any devices or clothing worn by the worker to protect against hazards in the environment. Examples are respirators, gloves, and chemical splash goggles.
PHYSICAL HAZARD - A chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive), or water-reactive.
PYROPHORIC - A chemical that will spontaneously ignite in the air at a temperature of 130°F (54.4o C) or below.
REACTIVITY - A substance's susceptibility to undergoing a chemical reaction or change that may result in dangerous side effects, such as explosion, burning, and corrosive or toxic emissions. Conditions that cause the reaction, (ex: heat, other chemicals, dropping), will usually be specified as "Conditions to Avoid" when a chemical's reactivity is discussed on an SDS.
REPRODUCTIVE TOXINS - Chemicals that affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis).
RESPIRATOR - A device that is designed to protect the wearer from inhaling harmful contaminants.
RESPIRATORY HAZARD - A particular concentration of an airborne contaminant that, when it

enters the body by way of the respiratory system or by being breathed into the lungs, results in some body function impairment.
SAFETY DATA SHEET (SDS) - Written or printed material concerning a hazardous chemical which is prepared in accordance with paragraph (g) of 29 CFR 1910.1200 SELECT CARCINOGENS - Any substance which meets one of the following: 1. It is regulated by OSHA as a carcinogen; or 2. It is listed under the category, "known to be carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition); or 3. It is listed under Group 1 ("carcinogen to humans") by the International Agency for Research on Cancer Monographs (IARC) (latest editions); or 4. It is listed in either Group 2A or 2B by IARC or under the category, "reasonably anticipated to be carcinogens" by NTP.
SENSITIZER - A substance that may cause no reaction in a person during initial exposures, but afterwards, further exposures will cause an allergic response to the substance.
SHORT-TERM EXPOSURE LIMIT - Represented as STEL or TLV-STEL, this is the maximum concentration to which workers can be exposed for a short period of time (15 minutes) for only four times throughout the day with at least one hour between exposures. In addition, the daily TLV/TWA must not be exceeded.
SOLVENT - A substance, commonly water, but in industry often an organic compound, which dissolves another substance.
THRESHOLD LIMITVALUE (TLV) -Airborne concentration of substances devised by the ACGIH that represents conditions under which it is believed that nearly all workers may be exposed day after day with no adverse effect. TLVs are advisory exposure guidelines, not legal standards that are based on evidence from industrial experience, animal studies, or human studies when they exist. There are three different types of TLVs: Time-Weighted Average (TLV-TWA), Short-Term Exposure Limit (TLV-STEL), and Ceiling (TLV-C). (See also PEL).
TOXICITY - A relative property of a material to exert a poisonous effect on humans or animals and a description of the effect and the conditions or concentration under which the effect takes place.
VAPOR - The gaseous form of substances which are normally in the liquid or solid state (at normal room temperature and pressure). Vapors evaporate into the air from liquids such as solvents. Solvents with lower boiling points will evaporate faster.

APPENDIX C:

STEM Area Audit Form

APPENDIX D:
STEM Area Door Signage