

Introduction

Part I: Equipment Related Hazards

- A. Autoclaves
- B. Battery Charging
- C. Centrifuges
 - 1. General Guidelines
 - 2. Rotor Care
- D. Electrical Safety
 - 1. Shock Hazards
 - 2. Common Laboratory Electrical Hazards and Preventative Steps
 - 3. Safe Use of Electrophoresis Equipment
- E. Extraction, Distillation, and Evaporation
 - 1. Extractions Using a Separatory Funnel
 - 2. Distillations
 - 3. Reduced Pressure Distillations and Rotary Evaporation
- F. General Equipment Set Up
 - 1. Assembling Apparatus
 - 2. Apparatus in Hoods
- G. Glassware Handling, Cleaning and Disposal
 - 1. Glassware and Plasticware
 - 2. Handling
 - 3. Preparation of Glass Tubing and Stoppers
 - 4. Cleaning
 - 5. Disposal
- H. Heat and Heating Devices
 - 1. General Guidelines
 - 2. Ovens
 - 3. Heating Baths
- I. Mechanical Hazards
- J. Vacuum Hazards
 - 1. General Guidelines for Glass under Vacuum
 - 2. Vacuum Systems

Part II: Laboratory Environment Hazards

- K. Ergonomics
- L. Hot or Cold Environments
 - 1. Heat Stress
 - 2. Hypothermia
- M. Lighting
- N. Noise
- O. Recirculating Air and Confined Spaces
- P. Radiation
 - 1. Ionizing
 - Radioactive Materials
 - Radiation Generating Equipment
 - 2. Non-ionizing
 - Radio Frequency Devices
 - Lasers
 - Ultraviolet Light Source

Part III: Cryogenics, Compressed Gases, and Pressure Hazards

- Q. Cryogenic Liquid and Dry Ice Safety
 - 1. Cryogenic Liquids
 - 2. Dry Ice
- R. Cold Traps
- S. Compressed Gases
- T. Pressurized Systems
 - 1. General Hazards
 - 2. Guidelines Applicable to DRI

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

Introduction

Numerous physical hazards may be present in the laboratory. While not as exotic as chemical and biological hazards, physical hazards are responsible for the majority of workplace injuries. It is important to be aware of these hazards, preplan, use personal protective equipment and follow basic safety rules in order to prevent accidents involving physical hazards.

This document describes physical hazards that may be found in DRI laboratories. Some sections/information may also be applicable to the field work and non-laboratory tasks. The basic template for this appendix was obtained from Cornell University and is used with their permission.

Part I: Equipment Related Hazards

A. Autoclaves

Autoclaves present a number of physical hazards such as:

- Heat, steam, and pressure.
- Thermal burns from steam and hot liquids.
- Cuts from broken or exploding glass.

Please refer to [DRI Guidelines for Autoclave Use](#) for details.

B. Batteries

Batteries present a number of potential hazards. Charged batteries are “always on.” Care must be taken to ensure that electrodes of batteries in storage do not contact each other leading to fire.

Lead acid batteries contain corrosive liquids and also generate hydrogen gas during charging which poses an explosion hazard. OSHA requires adequate ventilation to prevent hydrogen build up and an eyewash/safety shower in battery charging locations.

Lithium batteries may burst into flames if overcharged, and nickel cadmium and lead acid types contain heavy metals. Almost all rechargeable batteries are capable of sufficient output current to start fires if short-circuited. Because of these sorts of hazards, and disposal considerations, a more detailed document has been developed.

For uses of batteries in applications beyond consumer products, please see the [DRI Battery Use Guidelines](#),

C. Centrifuges

1. Some general safety guidelines to follow when using centrifuges:
 - Be familiar with the operating procedures written by the manufacturer. Keep the operating manual near the unit for easy reference. If necessary contact the manufacturer to replace lost manuals.
 - Handle, load, clean, and inspect rotors as recommended by the manufacturer.
 - Pay careful attention to instructions on balancing samples -- tolerances for balancing are often very restricted. Check the condition of tubes and bottles. Make sure you have secured the lid to the rotor and the rotor to the centrifuge.
 - For ultracentrifuges, maintain a logbook of rotor use for each rotor, recording the speed and length of time for each use.
 - To avoid catastrophic rotor failure, some types of rotors must be "de-rated" (limited to a maximum rotation speed that is less than the maximum rotation speed specified for the rotor when it is new) after a specified amount of use, and eventually taken out of service and discarded.
 - Use only the types of rotors that are specifically approved for use in a given centrifuge unit.
 - Maintain the centrifuge in good condition. Broken door latches and other problems should be repaired before using the centrifuge.
 - Whenever centrifuging biohazardous material, always load and unload the centrifuge rotor in a biological safety cabinet. Avoid pop-top tubes which can create aerosols upon opening. Use screw capped tubes instead.

2. Centrifuge Rotor Care

Basic centrifuge rotor care includes:

- Keep the rotor clean and dry, to prevent corrosion.
- Remove adapters after use and inspect for corrosion.
- Store the rotor upside down, in a warm, dry place to prevent condensation in the tubes.
- Read and follow the recommendations in the manual regarding:
 - Regular cleaning
 - Routine inspections
 - Regular polishing
 - Lubricating O-rings
 - Decontaminating the rotor after use with radioactive or biological materials
- Remove any rotor from use that has been dropped or shows any sign of defect, and return it to a manufacturer's representative for inspection.

D. Electrical Safety

1. Shock Hazards

Electricity travels in closed circuits, and its normal route is through a conductor. Shock occurs when the body becomes a part of the electric circuit. Electric shock can cause direct injuries such as electrical burns, arc burns, and thermal contact burns. It can also cause injuries of an indirect or secondary nature from involuntary muscle contractions from the electric shock. These injuries can include bruises, bone fractures, and even death resulting from collisions or falls. Death may also occur from damage to internal organs and cardiac arrest. Electrical shock generally occurs from contact in one of three ways:

- Both wires of the electric circuit, or
- One wire of the energized circuit and the ground, or
- A metallic part that has become energized by being in contact with an energized wire, and another part or ground.

The severity of the shock received when a person becomes a part of an electric circuit is affected by three primary factors:

- The amount of current flowing through the body (measured in amperes).
- The path of the current through the body.
- The length of time the body is in the circuit.

Other factors that may affect the severity of shock are the frequency of the current, the phase of the heart cycle when shock occurs, and the general health of the person prior to shock.

2. Common Laboratory Electrical Hazards and Preventative Steps

Laboratories are unique environments with many potential electrical hazards. Fortunately, simple precautions can be taken to reduce the risk:

- **New equipment may have different hazards** than those you are familiar with. Before operating new equipment read and follow all equipment operating instructions for proper use.
- **Access panels and covers may shield high voltages.** Do not take apart laboratory instruments or attempt electrical repairs unless you are a qualified technician assigned to perform electrical work by your supervisor. Fixed wiring may only be repaired or modified by Facilities personnel or an approved outside repair service vendor.

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

- **Wet hands, salt solutions, and some anti-static devices may enhance electrical contact with the body.** Use extra caution and ground fault circuit interrupter (GFCI) devices when these conditions exist.
- **Remove rings, watches and other jewelry, which may become part of an electrical circuit when working around electricity.**
- **The accidental or unexpected starting of electrical equipment can cause severe injury or death.** Common laboratory equipment that may automatically start includes:
 - Vacuum Pumps (may start from remote pressure transducer or instrument controller)
 - Air compressors (may start on demand from pressure set point)
 - Auto samplers (may move under computer or instrument control)
 - Ovens (thermostat controlled)
 - Cryostats (thermostat controlled)
 - Chillers (thermostat controlled)
 - Air Conditioners (thermostat controlled)
 - Lasers (many have a safety delay in producing a beam, or warm up time for tubes or cavities)
 - Sump or feed pumps (actuated by fluid level)Employees must follow the [DRI Energy Control \(lock-out/tagout\) Program](#).
- **Unplugging something does not necessarily make it safe.** Capacitors may store a lethal charge and battery circuits, such as those found in Uninterruptible Power Supplies, also remain live. Be extra cautious with these types of devices and apply the applicable energy controls techniques to mitigate the hazard.
- **Instruments in breadboard (developmental) form** must be energized only under the direct supervision of the technician, and not left unattended while live unless protective measures are taken to exclude accidental contact with any exposed hazards. Finished devices fabricated for experimental purposes must be sufficiently enclosed to preclude contact with any exposed hazards and be properly grounded.
- **Improper use of extension cords is hazardous.** If you need additional power supply, the best solution is to have additional outlets installed by Facilities. Do not use extension cords or power strips ("power taps") as a substitute for permanent wiring. Never daisy chain extension cords or power strips to get power where it is needed.
- **Corrosives found in the laboratory environment may deteriorate wiring or insulation.** Common causes of cracked insulation are the mineral acids and bases, ozone, heat, and ultraviolet light. Inspect all electrical and extension cords for wear and tear. Pay particular attention near the plug and where the cord connects to the piece of equipment. If you discover a frayed electrical cord or corroded contacts, lock the equipment out and make arrangements for repair before reuse.

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

- **Many electrical devices are also potential ignition sources.** Never store flammable liquids such as solvents or fuels near electrical equipment, even temporarily.
- **Avoid cluttered work areas and benches because they invite accidents and injuries.** Good housekeeping and a well-planned layout of temporary wiring will reduce the dangers of fire, shock, and tripping hazards. Electrical equipment must not be installed near eye wash/safety shower stations.
- **Access to electric panels must be unobstructed;** a minimum of 3' of clearance is required in front of every electrical panel. Each panel must have all the circuit breakers labeled as to what they control. Contact Facilities if breaker panels, outlets, etc. are missing the required labeling.

3. Safe Use of Electrophoresis Equipment

Electrophoresis units present several possible hazards including electrical, chemical, and radiological hazards. All of these hazards need to be addressed before using the units. EH&S has prepared these guidelines to assist researchers in safely operating electrophoresis units.

- **Proper Equipment Set-Up**
 - Place electrophoresis units and their power supplies so that the on/off switch is easy to reach and the power-indicator lights are easily seen. Locate the equipment where it will not be easy to knock or trip over.
 - Because electrophoresis work involves handling conductive liquids around electricity, power supplies should be protected by Ground Fault Circuit Interrupters (GFCIs). GFCIs act as very sensitive circuit breakers and, in the event of a short circuit, will stop the power before it can hurt a person. You can identify GFCIs by their "test" and "reset" buttons.
- **Addressing Electrical Hazards**
 - Electrophoresis units use very high voltage (up to 2000 volts) and potentially hazardous current (80 milliamps or more). This high power output has the potential to cause a fatal electrical shock if not properly handled.
 - Routinely inspect electrophoresis units and their power supplies to ensure they are working properly. Power supplies should be inspected to ensure that all switches and lights are in proper working condition, that power cords and leads are undamaged and properly insulated, and that "Danger--High Voltage" warning signs are in place on the power supply and buffer tanks. Inspect the buffer tanks for cracks or leaks, exposed connectors, or missing covers. If your units have such hazards, replace them or perform necessary retrofitting before use.

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

- **Training and Work Procedures**
 - Principal Investigators are responsible for providing instruction on the safe use of electrophoresis units to those in the laboratory who work with them. The instruction should cover the operating procedures written by the manufacturer or laboratory, as well as the associated hazards, the correct personal protective equipment, and applicable emergency procedures. As with all safety training, this instruction should be documented. Employees must wear all appropriate personal protective equipment when working with electrophoresis units, including lab coats, gloves, and eye protection.
 - Do not leave electrophoresis units unattended for long periods of time since unauthorized persons may accidentally come in contact with the unit, or the buffer tank liquid may evaporate, resulting in a risk of fire.
 - Laboratories that perform electrophoresis work during off hours should consider using a "buddy system" to ensure that emergency services can be notified if someone is injured or exposed. It is also recommended that laboratory personnel be trained in CPR and First Aid. (Classes are periodically scheduled at DRI or can be taken at various locations in the community.)

E. Extraction, Distillation, and Evaporation

Some routine laboratory operations have physical hazards that can be avoided by good technique. Here are some guidelines to prevent common mishaps:

1. Extractions using a separatory funnel:

- Do not attempt to extract a solution until it is cooler than the boiling point of the extractant due to the risk of overpressurization, which could cause the vessel to burst.
- When a volatile solvent is used, the solution should be swirled and vented repeatedly to reduce pressure before separation.
- When opening the stopcock, your hand should keep the plug firmly in place.
- The stopcock, if glass, should be lubricated.
- Vent funnels away from ignition sources and people, preferably into a hood.
- Keep volumes small to reduce the risk of overpressure; if large volumes are needed, break them up into smaller batches.

2. Distillations:

- Avoid bumping (sudden boiling) since the force can break apart the apparatus and result in splashes. Bumping can be avoided by even heating, such as using a heat mantle. Also, stirring can prevent bumping. Boiling stones can be used only if the process is at atmospheric pressure.

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

- Do not add solid items such as boiling stones to liquid that is near boiling since it may result in the liquid boiling over spontaneously.
 - Organic compounds should never be allowed to boil to dryness unless they are known to be free of peroxides, which can result in an explosion hazard when concentrated.
3. Reduced pressure distillation and rotary evaporation:
- Do not overheat the liquid. Superheating can result in decomposition and uncontrolled reactions.
 - Superheating and bumping often occur at reduced pressures so it is especially important to abide by the previous point on bumping and to ensure even, controlled heating. Inserting a nitrogen bleed tube may help alleviate this issue.
 - Evacuate the assembly gradually to minimize bumping.
 - Maintain appropriate water bath level; do not allow to boil dry.
 - Keep hands, clothing and jewelry (particularly necklaces) away from rotating assemblies.
 - Allow the system to cool and then slowly bleed in air. Air can cause an explosion of some reactive materials in a hot system (in most cases, pure nitrogen is preferable to air for releasing the vacuum).
 - See Section J, [Vacuum Hazards](#) in this document for other vacuum precautions.

F. General Equipment Set Up¹

1. Assembling Apparatus

Following these recommendations will help make apparatus assembly easier and equipment safer:

- Keep your work space free of clutter.
- Set up clean, dry apparatus, firmly clamped and well back from the edge of the lab bench making adequate space between your apparatus and others work. Choose sizes that can properly accommodate the operation to be performed. As a rule, leave about 20% free space around your work.
- Use only equipment that is free from flaws such as cracks, chips, frayed wiring, and any other apparent defects. Glassware can be examined in polarized light for strains. Even the smallest crack or chip can render glassware unsound. Cracked or chipped glassware should be repaired or discarded.

¹ The following recommended laboratory techniques for general equipment set up was taken from the American Chemical Society's booklet – Safety in Academic Chemistry Laboratories

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

- A properly placed pan under a reaction vessel or container will act as secondary containment to confine spilled liquids in the event of glass breakage.
- When working with flammable gases or liquids, do not allow burners or other ignition sources in the vicinity. Use appropriate traps, condensers, or scrubbers to minimize release of material to the environment. If a hot plate is used, ensure the temperatures of all exposed surfaces are less than the autoignition temperature of the chemicals likely to be released and that the temperature control device and the stirring / ventilation motor (if present) do not spark.
- Whenever possible, use controlled electrical heaters or steam in place of gas burners.
- Addition and separatory funnels should be properly supported and oriented so that the stopcock will not be loosened by gravity. A retainer ring should be used on the stopcock plug. Glass stopcocks should be freshly lubricated. Teflon stopcocks should not be lubricated.
- Condensers should be properly supported with securely positioned clamps and the attached water hoses secured with wire or clamps.
- Stirrer motors and vessels should be secured to maintain proper alignment. Magnetic stirring is preferable. Only non-sparking motors should be used in chemical laboratories.
- Apparatus attached to a ring stand should be positioned so that the center of gravity of the system is over the base and not to one side. There should be adequate provision for removing burners or baths quickly. Stands bearing heavy loads should be firmly attached to the bench top. Equipment racks should be securely anchored at the top and bottom.
- Apparatus, equipment, or chemical bottles should not be placed on the floor. If necessary, keep these items under tables and out of aisle ways to prevent creating a tripping hazard.
- Never heat a tightly closed container. Provide a vent as part of the apparatus for chemicals that are to be heated. Prior to heating a liquid, place boiling stones in unstirred vessels (except test tubes). If a burner is used, distribute the heat with a ceramic-centered wire gauze. Use the thermometer with its bulb in the boiling liquid if there is the possibility of a dangerous exothermic decomposition as in some distillations. This will provide a warning and may allow time to remove the heat and apply external cooling. The setup should allow for fast removal of heat. A lab jack under the heating mantle is a good way to accomplish this.

2. Apparatus in Hoods

- Whenever hazardous gases, vapors, dusts, or fumes are likely to be evolved, an appropriate sized local exhaust system or laboratory hood must be used. Most vapors have a density greater than air and will settle on a bench top or floor where they may flow to a distant burner or ignition source. These vapors

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

will roll out over astonishingly long distances and, if flammable, an ignition can cause a flash back to the source of vapors. Once diluted with significant amounts of air, vapors move in air by diffusion in all directions.

- Consider using a hood when working with a system under reduced or positive pressure (which may implode or explode - see Sections J, [Vacuum Hazards](#), and T, [Pressurized Systems](#)). Close the sash to provide a shield. If a hood is not available, use a standing shield. Shields that can be knocked over must be stabilized with weights or fasteners. Standing shields are preferably secured near the top. Proper eye and face protection must be worn even when using safety shields or laboratory hoods. Note that while hoods will provide some protection, they are not designed or expected to contain significant explosions.
- When assembling apparatus in hoods, be mindful of limitations on hood performance, airflow clearance around the apparatus (especially ovens), and location of contaminant sources with respect to sash, air slots, and baffles. More information on laboratory hoods can be found at: [Safe Work Practices for Using the Laboratory Hood](#).

G. Glassware Handling, Cleaning and Disposal

1. General Information about Glass and Plastic Ware

- Borosilicate glassware (i.e. Pyrex, Kimax) is recommended for all lab glassware, except for special experiments using UV or other light sources. Soft glass should only be used for un-heated things such as reagent bottles, measuring equipment, stirring rods and tubing.
- Glass containers of hazardous chemicals should be transported in rubber bottle carriers or buckets to protect them from breakage and contain any spills or leaks. It is recommended to transport plastic containers this way as well since they also can break or leak.
- Plastic containers can deteriorate with time, typically becoming yellow and brittle. The process is accelerated by exposure to solvents, sunlight, and heat. Be particularly aware of hazardous chemicals stored for a long time in plastic bottles. Also, exercise caution with older plastic pails in which handles may break off, or bottoms crack.
- Some plastic containers generate static that can ignite flammable vapors. Avoid storing flammables in unapproved plastic containers.

2. Handling

- When handling glassware, check for cracks and chips before using it. Damaged glassware must be repaired (if an option) before use or disposed.
- Handle glassware with care – avoid impacts, scratches, and intense heating of glassware.
- Use care when inserting glass tubing into stoppers: use glass tubing that has been fire-polished, lubricate the glass, and protect your hands with heavy

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

gloves. (Because so many glassware related injuries occur during this operation, it is discussed in detail below.)

3. Preparation of Glass Tubing and Stoppers²

- To cut glass tubing:
 - Hold the tube against a firm support and make one firm quick stroke with a sharp triangular file or glass cutter to score the glass long enough to extend approximately one third around the circumference.
 - Cover the tubing with cloth and hold the tubing in both hands away from the body. Place thumbs on the tubing opposite the nick 2 to 3 cm apart and extended toward each other.
 - Push out on the tubing with the thumbs as you pull the sections apart, but do not deliberately bend the glass with the hands. If the tubing does not break, re-score the tube in the same place and try again. Be careful to not contact anyone nearby with your motion or with long pieces of tubing.
 - All cut lab glass, including stir rods, should be fire polished before use. Unpolished tubing can cut skin, and inhibit insertion into stoppers by tearing the rubber. After polishing or bending glass, give ample time for it to cool before grasping it. *Hot glass looks just like cold glass!*

- When drilling a stopper:
 - Use only a sharp borer one size smaller than that which will just slip over the tube to be inserted. For rubber stoppers, lubricate with water or glycerol. Holes should be bored by slicing through the stopper, twisting with moderate forward pressure, grasping the stopper only with the fingers, and keeping the hand away from the back of the stopper.
 - Keep the index finger of the drilling hand against the barrel of the borer and close to the stopper to stop the borer when it breaks through. Preferably, drill only part way through and then finish by drilling from the opposite side.
 - Discard a stopper if a hole is irregular or does not fit the inserted tube snugly, if it is cracked, or if it leaks.
 - Corks should have been previously softened by rolling and kneading. Rubber or cork stoppers should fit into a joint so that one-third to one-half of the stopper is inserted.
 - When available, glassware with ground joints is preferable. Glass stoppers and joints should be clean, dry and lightly lubricated.

- Insertion of Glass Tubes or Rods into Stoppers
 - Make sure the diameter of the tube or rod is compatible with the diameter of the hose or stopper.
 - If not already fire polished, fire polish the end of the glass to be inserted; let it cool.

² taken from the American Chemical Society's booklet – Safety in Academic Chemistry Laboratories

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

- Lubricate the glass. Water may be sufficient, but glycerol is a better lubricant.
- Wear heavy gloves or wrap layers of cloth around the glass and protect the other hand by holding the hose or stopper with a layered cloth pad.
- Hold the glass not more than 5 cm from the end to be inserted.
- Insert the glass with a slight twisting motion, avoiding too much pressure.
- When helpful, use a cork borer as a sleeve for insertion of glass tubes.
- If appropriate, substitute a piece of metal tubing for glass tubing.
- Remove stuck tubes by slitting the hose or stopper with a sharp knife.

4. Cleaning

In most cases laboratory glassware can be cleaned effectively by using detergents and water. In some cases it may be necessary to use strong chemicals for cleaning glassware. Strong acids should not be used unless necessary. In particular, chromic acid should not be used due to its toxicity, carcinogenicity, and disposal concerns. One product that may be substituted for chromic acid is “Nochromix Reagent”. Generally, it is cheaper to dispose of grossly contaminated glassware as non-RCRA lab trash than to generate hazardous waste rinsate trying to decontaminate the glassware for disposal as regular trash. Contact EH&S for chemical-specific advice.

5. Disposal

Broken glassware must be managed to prevent injury. See Section 5.6 of the [DRI Hazardous Waste Generation Satellite Accumulation SOP](#) for disposal information. Put other sharps such as pipette tips and razor blades into puncture resistant containers before disposal. Normal sharps can then be placed in the regular trash. If you are generating hypodermic needles, contact EH&S for disposal information specific to your work location. Glassware and sharps that are grossly contaminated with hazardous materials will be shipped with similarly contaminated lab trash. If glassware/sharps are contaminated with human blood/body fluids or radioactive materials contact EH&S for specific disposal instructions.

H. Heat and Heating Devices

1. General Guidelines

Heat hazards within laboratories can occur from a number of sources; however, there are some simple guidelines that can be followed to prevent heat related accidents. These guidelines include:

- Heating devices (devices that become hot or produce flame) should be set up on a sturdy fixture and away from any ignitable materials (such as flammable

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

solvents, paper products and other combustibles). Do not leave open flames (Bunsen burners or alcohol lamps) unattended.

- Heating devices, and other electrical equipment, should not be installed near safety showers, eye washes, or other water spraying apparatus due to electrical shock concerns and potential splattering of hot water or breakage of hot glass.
- Heating devices should have a backup power cutoff or temperature limiting controller to prevent overheating. If a backup controller is used, an alarm should notify the user that the main controller has failed.
- Make sure set temperatures do not cause violent reactions and that a means to cool potentially exothermic (heat generating) reactions is readily available. Note that larger volumes are exponentially more difficult to control should an exothermic process run away.
- Post “Caution: High Temperature” signs to warn people of the heat hazard near hot assemblies and to prevent burns.
- Never use space heaters in labs.

2. When using **ovens**, the follow additional guidelines should be followed:

- Heat generated should be adequately removed from the area. Leave ample clearances around all sides of the oven.
- If toxic, flammable, or otherwise hazardous chemicals are evolved from the oven, then only use ovens with a single pass through design where air is ventilated out of the lab and the exhausted air is not allowed to come into contact with electrical components or heating elements.
- Heating flammables should only be done with a heating mantle, steam bath, or special explosion proof oven equipment.
- Ovens placed in hoods can interfere with/disrupt airflow. See [DRI Safe Work Practices for Using the Laboratory Hood](#) for proper setup advice.

3. When using **heating baths**, these additional guidelines should be followed:

- Heating baths should be of sound construction and set up with firm support to prevent tipping.
- Route cords out of the way to further reduce the risk of tipping.
- Since combustible liquids are often used in heating baths, the thermostat should be set so the temperature never rises above the flash point of the liquid. Check the MSDS for the chemical to determine the flashpoint. Compare that flashpoint with the expected temperature of the reaction to gauge risk of starting a fire.
- Never use mercury thermometers in heating baths.
- When filling a water bath, do not turn on the water and leave the area unless your bath has an automatic water shut off device.

I. Mechanical Hazards

Many laboratory instruments have moving parts. Some of these devices are automatic samplers, belt-driven pumps, centrifuges, fans, shakers, mixers, and rotary evaporators. Generally these machines have safeguards or interlocks to prevent machinery-related injuries, however, caution must always be exercised around moving parts. If working with such equipment, follow these safety guidelines:

- Avoid wearing loose fitting clothing or necklaces that could be drawn into a rotating assembly.
- Do not defeat interlocks on doors, access panels, etc.
- Do not brake moving parts by hand; wait for motion to stop on its own.
- Be aware of assemblies that vibrate and could “walk” into other objects or fall off a counter.
- Safety glasses must always be worn around any power tool operation.
- Use caution with automatic or computer-controlled machines that could start unexpectedly. This is covered in greater detail in Section D, [Electrical Safety](#) in this document and under the [DRI Energy Control \(lock-out/tagout\) Program](#).

J. Vacuum Hazards

Many laboratories employ vacuum apparatus for analytical equipment like mass spectrometers, reactive chemical handling and transfer in Schlenk lines, filtration, and desiccation.

1. Some general guidelines for glass apparatus under vacuum include:
 - **Inspect glassware** that will be used for reduced pressure to make sure there are no defects such as chips or cracks that may compromise its integrity.
 - **Use only approved glassware** for low pressure work. Never use a flat bottom flask (unless it is a heavy-walled filter flask) or other thin-walled flask that is not appropriate to handle atmospheric pressure.
 - **Use a shield between the user and any glass under vacuum** or wrap the glass with tape to contain any glass in the event of an implosion.
 - **Glass Dewar flasks, some distillation columns, CRTs, and other apparatus are permanently under vacuum.** The same precautions apply to these items. Note that “Thermos” flasks are especially thin and prone to breakage. Wrap them with tape to contain glass shards in the event of an implosion.
2. Vacuum systems:
 - **Cold traps should be used to prevent pump oil from being contaminated** which can create a hazardous waste or contaminate the pump.
 - **Pump exhaust should be vented** into a hood when possible.

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

- **Belts, pulleys, and other moving parts must be properly guarded.** See Section I, Mechanical Hazards, in this document for more details.
- **Follow appropriate lock-out procedures** if you cannot directly unplug the device for maintenance. Pumps may start automatically.
- **Connect pump inlet and outlet properly.** Pump connections can look the same. Reversing the flow direction can pressurize your apparatus leading to an explosion. At minimum you will contaminate it with oil.
- **Allow diffusion pumps to cool completely before venting or servicing.** These pumps contain oil at very high temperature. Keep combustibles away.
- **Do not cryopump reactive materials.** Condensing or adsorbing oxygen, ozone, and flammable and/or reactive gases is dangerous. Upon warming, in the case of pump regeneration or power outage, those adsorbed gases may react violently causing an explosion.
- **Used pump fluids must be managed.** Oil removed from vacuum pumps for disposal should be labeled “used oil” unless a known contaminant is present. Contact EH&S for additional guidance on vacuum pump oil disposal.
- **Use extra caution with vacuum evaporator applications.** Some evaporated films are air reactive, and others may generate particles that can be inhaled. Determine any possible health hazards with process products and protect yourself accordingly. It’s a wise practice to minimize exposure to all respirable nanomaterials as risks are yet unknown.
- **Many vacuum gauges are also ignition sources.** Hot filaments in BA type ionization gauges and thermocouple gauges and high voltage in cold cathode gauges may all ignite organic vapors of flammable gases. Consider equipment limitations carefully.

Part II: Laboratory Environment Hazards

K. Ergonomics

Many lab tasks such as looking through microscopes, working in laboratory hoods, and pipetting, require repetitive movements and sustained posturing, usually reaching. These tasks can lead to discomfort or even injury if discomfort develops and is ignored. Specific laboratory tasks that can lead to musculoskeletal problems and possible solutions are detailed below.

- **Prolonged standing at laboratory benches or hoods:** This can be addressed by comfortable footwear, antifatigue mats, or use of a stool that can be adjusted to a proper height. Also shifting weight from side to side and/or a foot rest rail might be helpful.
- **Pipetting:** Long term use of a pipette with a thumb-operated plunger can lead to soreness and eventual repetitive use injury. Consider trigger operated and/or electric pipette pumps. If reaching (due to the length of the pipette) is a problem, a shorter tube may be used, or a taller stool.

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

- **Microscopy:** Prolonged viewing through a microscope can cause problems with the neck and shoulders as well as eyestrain. An adjustable chair and/or different kind of eye piece might help. Also, equipping the microscope with a video camera and monitor can allow for much greater flexibility in workstation configuration.
- **Lifting heavy objects:** Back injuries can be prevented by proper lifting techniques, and knowing when to get help. For guidance on safe lifting, please see [back safety tips](#).

Remember, if a specific task is causing discomfort, try first to change it, or if suitable changes are not readily achievable, report it early on so that an assessment and mitigation can be made. Generally, work-related musculoskeletal problems tend to get worse if ignored, so don't delay in addressing them.

L. Hot or Cold Environments

Greenhouses, walk-in refrigerators/freezers, environmental chambers, and temperature controlled rooms may present the hazard of an unusually hot, cold, or humid environment. Most also have limited air exchanges (see Section O, [Recirculating Air and Confined Spaces](#)).

1. Heat Stress

A general form of heat hazard is heat stress. Under certain conditions, your body might have trouble regulating its temperature. If your body cannot reduce its temperature, it may overheat and suffer some degree of heat stress. This can occur very suddenly and, if unrecognized and left untreated, can lead to a medical emergency.

Some laboratory activities that may lead to heat stress are:

- **Working near radiant heat sources** like furnaces, lamps, or steam pipes.
- **High temperatures coupled with increased humidity and/or decreased air movement** may exist in environmental chambers or greenhouse environments.
- **Wearing insulated clothing** such as clean room garments and especially airtight chemical-resistant clothing.

For more information, symptoms, treatment, and prevention measures, see the [DRI Heat Stress Fact Sheet](#).

2. Hypothermia

The opposite of heat stress, hypothermia is a dangerous drop in body temperature caused by losing too much body heat. This is a distinct problem from localized

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

cold injury, such as frostbite or cryogenic burn, and the effects are systemic. In addition to typical symptoms of illness, hypothermia may cause loss of cognitive ability and judgment, making it potentially insidious. Hypothermia, if left untreated, can also rapidly escalate into a medical emergency.

Some laboratory activities that may lead to hypothermia are:

- **Working in walk-in freezers**, refrigerators, or environmental chambers.
- **Prolonged use of an unheated safety shower** (likely the hypothermia will be less severe than consequences of remaining contaminated with chemicals, but be aware of the potential).

For additional information on cold stress/hypothermia, including symptoms, treatment, and prevention measures, see [Common Winter Injuries](#).

M. Lighting

Having a properly lighted laboratory is essential to working safely. Key points to remember about lighting:

- Lighting in laboratories must adequately illuminate all work areas (100-200 lumens). Contact Facilities via a work request if you have concerns about lighting levels or burned-out bulbs that need replacing.
- Some lab work requires a dark environment. Always allow time for your pupils to adjust to low light situations. This also applies when entering any lab from the outside.
- Do not wear safety sunglasses in a lab. If you have photosensitive lenses in your prescription glasses, be sure they have adjusted to interior lighting before conducting lab work.
- For fine work you may need to add task lighting.
- Be cognizant of glare created by overhead lighting on computer screens. Adjust the angle of the screen or add a glare reducing device to reduce the possibility of eye strain.
- Keep a flashlight handy. Avoid fumbling blindly in the dark recesses of cupboards, especially where chemicals or breakable apparatus are stored.
- Certain lamps/light bulbs must not be disposed as normal trash. Examples are mercury vapor lamps and UV tubes that are used in some scientific equipment. Contact EH&S for disposal options.
- Certain metal halide, sodium vapor, xenon, and halogen bulbs operate at high pressures and temperatures and can present a bursting/fire hazard. The types above, as well as hollow cathode and deuterium lamps also produce ultraviolet radiation (UV). All lamp types having these hazards must only be operated in enclosed fixtures designed to contain hot fragments and/or shield the user's eyes and skin from UV.

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

- As an energy conservation measure, please remember to turn off your lights when you leave your lab.

N. Noise

Noise is the most common cause of hearing loss, and one of the most common occupational illnesses in the United States. An explosion of a small quantity of an unstable chemical (such as an azide or organic peroxide) experienced at close range, may permanently damage your hearing. Repeated exposures to loud machinery may, over an extended period of time, also damage your hearing. DRI currently has no lab activities where hearing protection is required; however, certain lab activities do produce noise.

Examples of noise generating operations include machinery such as generators, compressors, blowers, pumps, mixers, and shakers; operation of cell sorters, sonicators, blenders, and grinders; and venting of high pressure gases.

If a situation arises where a worker is frequently exposed to a noise sufficiently loud to require raising one's voice to be understood, it may be at a level that requires a more detailed analysis. Contact EH&S to arrange for a noise survey.

Some strategies to protect yourself from noise induced hearing loss include:

- **Reduce noise at the source** by placing the machine inside an enclosure, adding mufflers, or by lubrication and general maintenance.
- **Wear hearing protective devices (HPDs)** such as earplugs or earmuffs, when involved in loud activities both at work and in recreation. Be aware that HPDs may make some laboratory activities more hazardous because you may not hear coworkers, alarms, etc.
- **Seek a hearing test** if you experience hearing loss, ringing ears, or difficulty understanding speech. Although noise exposures are hazardous, other medical causes for hearing loss should be ruled out by a qualified healthcare provider.

O. Recirculating Air and Confined Spaces

Walk-in freezers, refrigerators, or environmental chambers typically have very little air exchange. While a typical laboratory may provide adequate ventilation for the limited use of gases and solvents outside of the hood, both **use and storage of volatiles are strictly prohibited in limited ventilation environments** where they pose a risk of over-exposure, fire, or explosion.

A closely-related topic is working in *confined spaces*. A confined space is a space that 1) is large enough for an employee to enter and perform assigned work, 2) has a limited or restricted means of entry or exit, and 3) is not designed for continuous employee occupancy. Examples include tanks, underground vaults, vacuum chambers, and critical atmosphere (glove) boxes.

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

Some confined spaces **require permits to enter** because they may contain a hazardous atmosphere or other serious safety or health hazard. These are specially posted. **No employee may enter any Permit Required Confined Space.** Upon request, EH&S can inspect a space to determine its status.

P. Radiation

Some examples of radiation use at DRI include:

1. Ionizing radiation sources:

- Radioactive Materials
 - Sealed sources generating alpha, beta, or gamma radiation, primarily for calibration or completely contained in instruments (like soil moisture meters).
 - Radioactive solids, liquids, and gases used as tracers, markers, and electron microscopy stains.
- Radiation Generating Equipment
 - X-ray diffraction apparatus
 - X-ray generators for other analytical devices
 - Electron microscopes

2. Non-Ionizing radiation sources:

- Radio Frequency Devices
 - Microwave generators
 - Radio frequency generators
- Lasers
 - Visible
 - Invisible (Infrared or UV)
 - Pulsed or Continuous.
- Ultraviolet Light Sources (considered non-ionizing for our purposes)
 - Plasma flames in spectrometers
 - Germicidal lamps in biosafety cabinets
 - Transilluminating lamps

The use of radioactive materials or radiation producing equipment is managed by the UNR Radiation Safety Officer under the University of Nevada, Reno's Nevada State radiation license. Larger lasers (class IIIb and above) and open use of significant power microwaves or RF will also require pre-approval by the UNR RSO. For further information contact DRI EH&S or the UNR RSO at 775-784-4540.

Part III: Cryogenics, Compressed Gases, and Pressure Hazards

Q. Cryogenic Liquid and Dry Ice Safety

1. A cryogenic gas (cryogen) is a material that is normally a gas at standard temperature and pressure, but which has been cooled such that it is a liquid at standard (atmospheric) pressure. Commonly used cryogenic materials include the liquids nitrogen, argon, oxygen, and helium. Detailed information on cryogenic liquid safety can be found in [CHP Appendix E](#).
2. Dry ice (solid carbon dioxide) presents some similar hazards:
 - **Pressure build-up:** Dry ice sublimates continuously, and if it is confined in a gas tight container, it can build pressure until the container bursts. Dry ice must never be sealed in gas-tight containers.
 - **Frost bite:** Skin contact with dry ice will result in frostbite/cryogenic burns. Protective insulated gloves or tongs must always be used when handling dry ice.
 - **Oxygen deficiency:** If kept in an enclosed, poorly ventilated space (like a car with closed windows) the carbon dioxide evolved from dry ice can displace oxygen resulting in a suffocation hazard. Dry ice must only be kept in well ventilated areas.
 - **Embrittlement:** Dry ice can render flexible materials brittle. To avoid cracks or other damage, keep bare dry ice off counter tops and away from electrical cords, tubing, fabrics, and other items that may be damaged by the extreme cold.

Shipping of materials kept cold with dry ice (considered a hazardous material) is regulated by the DOT and IATA. Click [here](#) for a DRI guideline on this topic.

R. Cold Traps³

Cold traps have the hazards of cryogenics (see [CHP appendix E](#) for details), and some additional ones:

- **Many chemicals commonly captured in cold traps are hazardous.** Care should be taken and appropriate protective equipment should be worn when handling these chemicals. Hazards include flammability, toxicity, and cryogenic temperatures, which can burn the skin.
- **Since oxygen in air has a higher boiling point than nitrogen, liquid oxygen can be produced and cause an explosion hazard.** If liquid nitrogen is used, the chamber should be evacuated before charging the system with coolant.

³ If working under vacuum see Section J, "Vacuum Hazards."

- **A blue tint to liquid nitrogen indicates contamination with oxygen and represents an explosion hazard.** Contaminated liquid nitrogen should be disposed of by evaporation away from organic materials.
- **Boiling and splashing** generally occur when charging (cooling) a warm container, so stand clear and wear appropriate protective equipment. Items should be added slowly and in small amounts to minimize splash.
- **Incompatible materials may be condensed together in a cold trap and subsequently explode upon warming.** Use caution with sorbtion and cryopumping applications, especially those where process gases change from oxidizing to reducing.
- **Cold traps should never be totally “valved-off”** as this may result in uncontrolled pressure build up upon warming.
- **Cold traps using dry ice with acetone or alcohol pose a flammability hazard.** These must be used with adequate ventilation away from ignition sources, with care taken to assure that the solvent is recovered after the trap warms up.

S. Compressed Gases

Compressed gases commonly used in laboratories for many different operations present a number of hazards for the laboratory worker such as asphyxiation, chemical burns, flammability, and high pressure. The topic is sufficiently detailed to be covered by itself in [CHP appendix E](#).

T. Pressurized Systems⁴

Pressurized vessels, chambers, and lines have specific hazards associated with their operation. These pressurized components exist in a diverse array of laboratory equipment including hydraulic systems, analytical fluid paths, autoclaves, reactors and test chambers, atomization/spraying devices, refrigeration equipment, and anything connected to a high pressure pump or gas cylinder. These systems are typically complex and require training prior to use. Developing thorough knowledge of each specific system via instruction and close supervision is highly recommended.

1. Some of the generic hazards of pressurized systems are:

- **Rupture** - A component may burst or break, releasing high pressure fluids or gases and flying debris. A catastrophic failure may also be accompanied by a shock wave which can cause damage some distance away. Causes of rupture include over-pressurization, corrosion, metal fatigue, over-heating, and faulty design or assembly.
- **Injection** - High pressure fluids can cut/penetrate the skin causing damage to tissues and toxic effects from the substance itself.

⁴ For pressure hazards associated with vacuum pumps, see Section J.

DRI Chemical Hygiene Plan
Appendix F: Physical Hazards in the Laboratory

- **Atomization** - Materials with little flammability hazard, such as hydraulic oil, may become a profound fire hazard if released as a mist from a high pressure leak.
 - **Auto-ignition** - Rapid compression can generate temperatures sufficiently high to ignite common materials like plastics, oils, and greases. Systems using oxygen, fluorine, or other oxidizing gases are particularly susceptible to auto-ignition and must be specially cleaned and certified to avoid this problem.
2. The following guidelines apply to pressurized systems at DRI⁵:
- The vessel and all components must be properly selected for the process parameters including operating pressure, temperature, and chemical compatibility. Also, when designing or purchasing a pressure vessel, consider safety margin, inspection and certifications, design life, and decommissioning.
 - Always operate vessel within design specifications. Never use a vessel if specifications are unknown or if there is any indication a vessel has been damaged or degraded. Many commercial vessels are ASME Code stamped (or rated) for a particular use.
 - All pressurized vessels must have a pressure relief valve or other safety device to prevent catastrophic failure of the vessel. The relief valve should be tested regularly. When hazardous vapors are involved, make sure the safety relief mechanisms are properly vented.
 - The chamber or vessel must be inspected regularly. If feasible, dimensional inspections should be performed periodically during service to check for plastic deformation or wall thickness loss. Pay particular attention to high-pressure fittings and seals.
 - Accurate records of use must be maintained. Most vessels have a specified “service life” or number of cycles permitted between inspections or replacement of components.
 - Prepare for power outages whether you are present or not. Some automatic valves close upon loss of power or actuation air, some open. Understand and mitigate any hazardous effects that a series of valve openings and closings will have upon the system's safety.
 - Follow manufacturer's instructions when operating so as to avoid injury and/or damage to equipment and facilities.

⁵ Portions of the following adapted from DOE Pressure Safety Guidelines, M-089.