UNIVERSITY OF ONTARIO
INSTITUTE OF TECHNOLOGY

LABORATORY SAFETY MANUAL

FOR

GENERAL LABORATORY OPERATIONS

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1. INTRODUCTION

This manual outlines the requirements for the management and use of hazardous materials in research and teaching laboratories at the University of Ontario Institute of Technology.

The operation of laboratories exposes workers to a wide range of hazards and risks. The complex and highly variable nature of research places particular responsibility on the research director to identify and assess risks and put in place procedures and controls to eliminate or minimize these risks.

The purpose of this manual is to delineate the responsibilities for health and safety in the laboratory, to set out the minimum standards and requirements of the University and to provide guidance to Laboratory Supervisors (or their delegates) in establishing a safe working environment in the laboratory.

Laboratory operations are subject to the requirements of a variety of legislation among which are:

- Canadian Environmental Protection Act and Regulations
- Controlled Drugs and Substances Act
- Transportation Dangerous Goods Act and Regulations
- Environmental Protection Act and Regulations
- Hazardous Products Act and Regulations
- Nuclear Safety and Control Act and Regulations
- Ontario Occupational Health and Safety Act
    - Regulation for Industrial Establishments (O.Reg. 851)
    - Control of Exposure to Biological or Chemical Agents (O. Reg. 833)
    - Workplace Hazardous Materials Information System (O. Reg. 860)
    - Designated Substance Regulations
    - X-Ray Safety (O. Reg. 861)
- Ontario Fire Code

In addition to these Acts and Regulations there are numerous standards and guidelines which may be applicable and constitute accepted standards of practice.

The University Health and Safety policy (Pg. 4) outlines the University's commitment to comply with statutory requirements and to make every reasonable effort to provide and maintain a safe and healthful work and learning environment.

UOIT POLICY ON HEALTH AND SAFETY

The University of Ontario Institute of Technology has a vital interest in the health and safety of its employees, students, visitors and contractors. The prevention of occupational illness or injury is a major continuing objective and the University will make every reasonable effort to provide and maintain a safe and healthy work and learning environment. As a minimum standard, the University shall comply with all statutory requirements, including the Ontario Occupational Health and Safety Act, the Environmental Protection Act and other applicable federal, provincial, and local statutes and by-laws.

The University is responsible for establishing, maintaining and communicating a safety program to implement this policy. Specific safety policies, regulations and procedures shall be developed, documented and implemented in order to ensure that employees and students are aware of their rights and responsibilities and to facilitate the maintenance of safe working conditions.

Every employee and student has a responsibility to work safely in accordance with both the statutory requirements and the University safety policies and procedures and to report any unsafe or unhealthy conditions.

Employees in a supervisory position have an additional responsibility to ensure that persons under their supervision are made aware of any hazards in the workplace and that these individuals comply with all applicable safety policies and procedures. Supervisors are responsible for ensuring that any hazards or safety violations in workplaces under their control are investigated and corrected promptly.

Contractors and sub-contractors performing work for the University must, as part of their contract, comply with all relevant workplace and environmental health and safety statutes and to meet or exceed the University's safety program requirements.

It is the intent of the University that a commitment to health and safety form an integral part of the culture of the institution and all its activities.

The Health and Safety Policy, approved by the Board of Governors on November 12, 2003.

2. RESPONSIBILITIES

Laboratory Supervisor

The Laboratory Supervisor is the designated individual (usually a member of the University faculty) with overall responsibility for the research or teaching laboratory.

The Laboratory Supervisor is responsible for ensuring that the procedures specified in this manual are carried out.

The Laboratory Supervisor has the duties of a supervisor as outlined in the Ontario Occupational Health and Safety Act.

Workers

Workers are comprised of staff and students who work in the laboratory under the direction of the Laboratory Supervisor.

Workers are responsible for following the procedures specified in this manual and any additional procedures specified by the Laboratory Supervisor.

3. LABORATORY DESIGN

3.1 Exits

Any laboratory in which flammable or combustible liquids or dangerously reactive materials are to be used should be considered as a “hazardous room” as defined in the Ontario regulation for Industrial Establishments. Such laboratories must meet the requirements of Section 122 of the regulation.

Where the floor area is greater than fifteen square metres or there is a distance greater than 4.5 metres from any point in the room to an exit doorway the room must have at least two exit doorways.

3.2 Fume Hoods

The fume hood is the primary protective device in most laboratories for protecting workers from exposure to hazardous chemicals. It is designed to contain, dilute and disperse gases, vapours and aerosols to the external environment. It is also an integral part of the building air handling system. It is imperative that the fume hood be functioning properly at all times.

Fume hoods must meet the requirements of CSA Standard Z316.5-15 “Fume Hoods and Associated Exhaust systems” and the requirements of the Ontario Fire Code, Part 4. All new installations must comply with CSA standard Z316.5-15.
In particular, fume hoods must have a functioning alarming monitor which indicates any malfunction in the air flow through the hood.

Guidelines for Fume Hood Users

(1) Before using the fume hood check the flow meter to ensure that the hood is operating within the acceptable operating parameters. In general the face velocity should be between 0.4 and 0.65 $m.s^{-1}$ (80 – 130 feet/minute). **DO NOT CONDUCT WORK IN A MALFUNCTIONING HOOD.**
(2) All equipment and materials should be placed at least 6 inches (15 cm) back from the face of the hood. Flow of air into the hood should be unobstructed.
(3) Do not place your head into the hood when contaminants are being generated.
(4) The sash should be used to minimize the size of the working aperture and to act as a safety screen.
(5) The hood should not be used as a storage area or overloaded with unnecessary equipment and materials. The presence of these materials can seriously affect the air flow in the hood.
(6) The hood should not be used for long-term storage of hazardous chemical wastes. Dispose of chemical wastes promptly according to the procedures in the Hazardous Waste Manual.
(7) Materials requiring ventilated storage (e.g., volatile and highly toxic, or odorous substances) may be stored in a hood if they are properly segregated and the hood is posted to prohibit its use for experimental work.
(8) Electrical receptacles or other spark sources should not be placed inside the hood when flammable liquids or gases are present. Electrical connections should be made outside the hood and no permanent electrical receptacles should be permitted inside the hood.
(9) Foot traffic past the face of the hood should be minimized. Air flow caused by such traffic can seriously disrupt the operation of the hood and cause gases and vapours to be drawn out of the hood into the room. Cross drafts from windows and doors close to improperly located fume hoods will also affect the stability of the air flow within the hood.
(10) Keep the interior of the hood clean and tidy.
(11) Provide catch basins for containers that could break or spill to minimize the spread of spilled liquids.
(12) Do not use a hood for any function for which it is not intended. Certain chemicals or reactions require specially constructed hoods. For example, perchloric acid must only be used in a specially-designed perchloric acid fumehood. Perchloric acid vapors can settle on ductwork, resulting in the deposition of perchlorate crystals. Perchlorates can accumulate on surfaces and have been known to detonate on contact, causing serious injury to researchers and maintenance personnel. Specialized perchloric acid hoods, made of stainless steel and equipped with a washdown system must be used for such work.
(13) Where reactive materials are used in a hood and there is the chance of explosion, use an additional protective barrier inside the hood. The hood is not capable of containing explosions, even when the sash is fully closed. If an explosion hazard exists, the user should provide anchored barriers, shields or enclosures of sufficient strength to deflect or contain it. Note that such barriers can significantly affect the airflow in the hood.

3.3 Eyewash Units

All laboratories where chemical or biological agents are used must be provided with an eyewash fountain. The eyewash should be connected to the building drinking water supply. Plastic squeeze bottles are generally not acceptable. The installation should follow the ANSI standard Z358.1-1998 “Emergency Eyewash and Shower Equipment”. All new installations should comply with CSA standard Z358.1-2004

3.4 Deluge Showers

Where there is the potential for damage to the skin through contact with a hazardous material such as a corrosive chemical, a quick acting deluge shower must be provided. The installation should follow the ANSI Standard Z358.1-2014 “Emergency Eyewash and Shower Equipment”. All new installations should comply with CSA standard Z358.1-2014.

Showers should be placed such that there is a maximum of 10 seconds unimpeded run from the work location to the shower. This corresponds roughly to a distance between 15 and 30 metres.

4. GENERAL REQUIREMENTS FOR LABORATORY SUPERVISORS

4.1 Every laboratory shall have a “Laboratory Supervisor” (or delegate) who is responsible for ensuring that the procedures outlined in this manual are implemented and enforced.

4.2 The Laboratory Supervisor shall prepare and adopt procedures specific to the laboratory operations. These procedures shall identify known hazards and specify the procedures to be taken to eliminate or minimize these risks. A standard operating procedure shall be prepared for all laboratory instrumentation.

4.3 Access to laboratories must be strictly controlled and limited. Laboratories must be kept locked when unoccupied. Only individuals authorized by the Laboratory Supervisor should have access to the laboratory.

4.4 The Laboratory Supervisor shall ensure that all persons working in the laboratory receive appropriate training and instruction before beginning any work. Minimum training requirements are specified in Section 6 of this manual.

4.5 The Laboratory Supervisor shall maintain an up-to-date inventory of hazardous materials in the laboratory in the specified format.

4.6 Material Safety Data Sheets (MSDSs) or Safety Data Sheets (SDS) shall be readily available to laboratory personnel. The sheets may be provided in electronic format, however personnel must be able to produce a paper copy if they so wish.

4.7 All hazardous materials in the laboratory shall be labeled according to the Workplace Hazardous Materials Information System (WHMIS) or the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) requirements.

4.8 An appropriate spill kit shall be provided in each laboratory.

4.9 Appropriate portable fire extinguishers shall be provided in each laboratory and these shall be checked monthly.

4.10 No person under the age of 14 years shall be permitted in a laboratory unless that person is accompanied at all times by a responsible adult who has received appropriate training.

4.11 Incompatible chemicals shall not be stored together. Chemicals should be stored according to their WHMIS or GHS classification.

4.12 All experimental work with hazardous chemicals must have a written risk assessment which specifies the hazards, the safety precautions to be taken and personal protective equipment to be worn.

4.13 Experiments and processes using hazardous materials shall not be left unattended unless appropriate safety precautions have been made and approved by the Laboratory Supervisor.

4.14 Working alone in a laboratory is prohibited unless prior arrangements have been made with the Laboratory Supervisor to establish appropriate safety precautions and procedures.

4.15 Work with hazardous biological agents or ionizing radiation must follow the procedures outlined in the Biosafety and Radiation Safety Manuals.

5. GENERAL SAFETY RULES FOR LABORATORY WORKERS

The following general safety practices and rules are common to all laboratories handing hazardous biological and chemical agents.

5.1 The laboratory must be kept neat, orderly and clean, and storage of materials not pertinent to the work should be minimized. Aisles must be kept clear of all obstructions such as boots, coats, equipment, etc.

5.2 Eating and drinking are prohibited in all laboratories. Food or drinks must not be stored or brought into the laboratory work areas.

5.3 Oral pipetting of any substance is prohibited.

5.4 Long hair must be tied back or restrained. A simple rule is: if hair can be tied back, it must be tied back.

5.5 Protective laboratory coats must be worn and fastened when working in the laboratory. Laboratory coats must be left in the laboratory and not worn in non-laboratory areas. Loose or bulky clothing or neckties present a hazard and should not be worn in the laboratory.

5.6 Suitable footwear with closed toes and heels must be worn in the laboratory. Open shoes and sandals are prohibited as they do not adequately protect the feet from exposure to spilled chemicals.

5.7 Appropriate eye protection must be worn at all times when working in the laboratory. For recommendations on appropriate eye protection see Section 22 - Personal Protective Equipment.

5.8 Follow the appropriate procedures for disposal of hazardous wastes which are provided in the Hazardous Waste Manual. No hazardous materials may be disposed of down the drains or in normal garbage containers.

5.9 Before working with any hazardous chemical, obtain and read the MSDS/SDS and follow the instructions for handling and use of the chemical.

5.10 Label all hazardous materials according to the requirements of WHMIS/GHS for laboratory labels.

5.11 Clean up spills promptly according to the laboratory spill procedures or the procedures specified on the MSDS/SDS.

5.12 Report all accidents, incidents and spills to the Laboratory Supervisor as soon as circumstances permit.

6. TRAINING

All persons working in laboratories must receive appropriate safety training before commencing work. The training must be specific to the hazards involved and must, as a minimum, consist of the following:

1. All persons using hazardous materials shall receive general training in WHMIS or GHS before commencing work in a laboratory.

2. All persons working with flammable and combustible materials shall receive appropriate chemical safety training and training in fire safety before commencing work in a laboratory.

3. All persons using hazardous materials shall receive specific training in the safe storage, use and disposal of the specific hazardous materials used in the laboratory and in emergency response to spills.

4. All persons using laboratory instrumentation shall be trained in the procedures for the safe use of the instrumentation.

5. All persons working with ionizing radiation or radioactive materials must receive training as specified in the Radiation Safety Manual.

6. All persons working with biohazardous infectious materials must receive training as specified in the Biosafety Manual.

7. All persons working with compressed gas cylinders will receive Safe Handling and Storage of Compressed Gases training.

7. FLAMMABLE AND COMBUSTIBLE MATERIALS

Flammable and combustible materials fall under WHMIS Class B.

Storage and use of flammable and combustible materials are governed by the Ontario Fire Code and the Industrial Regulations under the Occupational Health and Safety Act.

Flammable and combustible liquids are classified by the Ontario Fire Code by their flash point and boiling point according to the criteria in Table 7.1

Flash point is the lowest temperature at which a liquid gives off sufficient vapour to form an ignitable mixture with air near the liquid surface.

A liquid that has a flash point in the range of normal ambient temperatures or below will, without any external heating, evolve vapours at concentrations which can easily be ignited. A liquid with a higher flash point will require some heating before sufficient vapours are given off to permit ignition. Therefore lower flash point liquids present the greater hazard.

TABLE 7.1
FLAMMABLE AND COMBUSTIBLE LIQUIDS

Class	Definition	Examples
Flammable – Class IA	Flash point below 22.8 °C Boiling point below 37.8 °C	Diethyl ether, gasoline,
Flammable – Class IB	Flash point below 22.8 °C Boiling point at or above 37.8 °C	Acetone, benzene, ethanol, methanol, toluene, carbon disulfide
Flammable – Class IC	Flash point at or above 22.8 °C and below 37.8 °C	Turpentine, xylene
Combustible – Class II	Flash point at or above 37.8 °C and below 60 °C	Kerosene,
Combustible – Class IIIA	Flash point at or above 60 °C and below 93.3 C °C	Aniline, cyclohexanol

In general, combustible liquids present a lower risk of fire or explosion than flammable liquids. However, heating of a liquid will increase its volatility or its ability to generate vapours. Therefore any combustible liquid heated to or stored at or above its flash point may present the same degree of fire and explosion risk as a flammable liquid.

QUANTITY AND STORAGE REQUIREMENTS

1. Class I liquids may not be stored, handled or used in basements.
2. A maximum of 50 L of a class I flammable liquid is permitted in the open area of a laboratory.
3. A maximum of 250 L of a Class II combustible liquid is permitted in the open area of a laboratory.
4. Individual storage containers should not exceed 5 L in volume. If containers in excess of 5 L are required, they must be approved safety containers whose volume does not exceed 25 L.
5. Quantities of flammable and combustible liquids in excess of those permitted in the open area must be stored in flammable storage cabinets.
6. The maximum amount permitted in one storage cabinet is 500 L of which not more than 250 L may be Class I liquids.
7. There may be only one flammable storage cabinet per laboratory.
8. Flammable and combustible materials must be stored away from heat or any other ignition sources and away from exits.
9. The quantity and storage requirements include waste materials.

OPERATIONAL REQUIREMENTS

1. Each laboratory must maintain a current inventory of all Class I and II liquids and ensure that the amounts do not exceed the maximum allowable for each class.
2. Laboratory personnel must receive training in the safe handling of flammable and combustible liquids.
3. Laboratory personnel must receive training in the WHMIS.
4. The laboratory must have written spill procedures which must be prominently posted.
5. Laboratories must implement security measures to ensure that unauthorized persons do not have access to the laboratory.
6. Fire drills must be held at least every six months.
7. Where any Class I or Class II liquid is used or handled at a temperature at or above its flash point, such operations shall be conducted in a fume hood.
8. Fume hoods must be provided with a monitoring device which indicates that the hood is in operation and which sounds an alarm if the system malfunctions.
9. Fume hoods and local exhaust systems must be inspected every six months.

8. DANGEROUSLY REACTIVE MATERIALS

Dangerously reactive materials fall under WHMIS Class F.

These are materials which can undergo vigorous polymerization, decomposition of condensation, may react violently under conditions of shock or increase in pressure or temperature, or may react vigorously with water to release a toxic gas.

8.1 General

(1) The Laboratory Supervisor must approve all purchases of dangerously reactive materials.
(2) Quantities of dangerously reactive materials must be kept to the absolute minimum necessary for immediate needs.
(3) All purchases of dangerously reactive materials must be reported to the University Health and Safety Officer.
(4) There must be written procedures for all work with dangerously reactive materials. These procedures shall include storage, handling, disposal and emergency procedures. The procedures shall be approved by the laboratory supervisor.

8.2 Peroxide Forming Compounds

Certain chemicals can form dangerous peroxides on exposure to air and light. Since they are sometimes packaged in an atmosphere of air, peroxides can form even though the containers have not been opened. Peroxides may detonate with extreme violence when concentrated by evaporation or distillation, when combined with other compounds, or when disturbed by unusual heat, shock or friction. Formation of peroxides in ethers is accelerated in opened and partially emptied containers. Refrigeration will not prevent peroxide formation and stabilizers will only retard formation

Peroxide formation can sometimes be detected by visual inspection for crystalline solids or viscous liquids. If you suspect that peroxides have formed, do not open the container since peroxides deposited on the threads of the cap could detonate.

Recommended Work Practices

(1) Know the properties and hazards of all chemicals you are using by thoroughly reviewing their MSDSs/SDSs.
(2) Identify chemicals that form peroxides or otherwise deteriorate or become more hazardous with age or exposure to air.
(3) Label containers with the date received, the date first opened and the date for disposal as recommended by the supplier.
(4) Inventory all chemical storage at least twice a year to detect forgotten items, leaking containers, and those that need to be discarded.
(5) Minimize peroxide formation in ethers by storing in tightly sealed containers placed in a cool place in the absence of light. Do not store ethers at or below the temperature at which the peroxide freezes or the solution precipitates.
(6) Choose the size container that will ensure use of the entire contents within a short period of time.
(7) Visually or chemically check for peroxides of any opened containers before use.
(8) Clean up spills immediately. The safest method is to absorb the material onto vermiculite or a similar loose absorbent.
(9) When working with peroxidizable compounds, wear impact-resistant safety eyewear and face shields
(10) Do not use solutions of peroxides in volatile solvents under conditions in which the solvent might be vaporized. This could increase the concentration of peroxide in the solution.
(11) Do not use metal spatulas or magnetic stirring bars (which may leach out iron) with peroxide forming compounds, since contamination with metals can lead to explosive decomposition. Ceramic, Teflon or wooden spatulas and stirring blades are usually safe to use.
(12) Do not use glass containers with screw-top lids or glass stoppers. Polyethylene bottles with screw-top lids may be used.

Some chemicals that form peroxides are listed below.

Chemicals that Form Peroxides on Storage

Divinyl Acetylene
Divinyl Ether
Isopropyl Ether
Vinylidene Chloride
Potassium Metal
Potassium Amide
Sodium Amide

DISCARD THESE AFTER THREE MONTHS

Chemicals that Form Peroxides upon Concentration (Distilation/Evaporation)

Acetal
Cumene
Cyclohexene
Cyclooctene
Cyclopentane
Cyclopentene
Diacetylene
Dicyclopentadiene
Diethyl ether
Diethylene glycol dimethyl ether
Dioxane (p-dioxane)
Ethlyene glycol dimethyl ether
Furan
Methyl acetylene
Methyl cyclopentane
Methyl-i-butyl ketone
Tetrahydrofuran
Tetrahydronaphthalene
Vinyl ethers

DISCARD THESE AFTER ONE YEAR

Chemicals that Polymerize Violently Due to Peroxide Formation

Acrylic Acid
Acrylonitrile *
Butadiene
Chloroprene
Chlorobutadiene
Chlorotrifluoroethylene
Methyl methacrylate
Styrene
Tetrafluoroethylene
Vinyl acetate
Vinyl acetylene
Vinyl chloride *
Vinyl pyridine
Vinylidene chloride

DISCARD THESE AFTER ONE YEAR

***** Designated and Controlled Substance (see Section 11)

9. CORROSIVE MATERIALS

Corrosive materials fall under WHMIS Class E.

These materials can cause permanent damage to human tissues. They present a hazard to the eyes and skin by direct contact, to the respiratory tract by inhalation and to the gastrointestinal tract by ingestion.

Corrosive materials may also cause metal containers or structural materials to become weak and eventually to leak or collapse.

9.1 Corrosive Liquids

Corrosive liquids (e.g. mineral acids, alkali solutions and some oxidizers) represent a very significant hazard because skin or eye contact can readily occur from splashes and their effect on human tissue generally takes place very rapidly. Bromine, sodium hydroxide, sulfuric acid and hydrogen peroxide are examples of highly corrosive liquids.

Hydrofluoric acid is particularly dangerous because the fluoride ion can readily penetrate the skin causing destruction of deep tissue layers including bone. Pain associated with solutions of HF can be delayed for up to 24 hours. If HF is not rapidly neutralized and the fluoride ion bound, tissue destruction may continue for days and result in limb loss or death. Special precautions are required for HF above and beyond those for most corrosive liquids.

The following procedures should be followed when working with corrosive liquids.

(1) Work with corrosive liquids should only be carried out where there is ready access to a deluge shower and eyewash station.
(2) The eyes are particularly vulnerable. It is therefore essential that approved eye and face protection be worn in all laboratories where corrosive chemicals are handled.
(3) Gloves and other chemically resistant protective clothing should be worn to protect against skin contact.
(4) To avoid a flash steam explosion due to the large amount of heat evolved, always add acids or bases to water (and not the reverse).
(5) Acids and bases should be segregated for storage.
(6) Liquid corrosives should be stored below eye level.
(7) Adequate quantities of spill control materials should be readily available.

9.2 Corrosive Gases and Vapours

Corrosive gases and vapors are hazardous to all parts of the body; certain organs (e.g. the eyes and the respiratory tract) are particularly sensitive. The magnitude of the effect is related to the solubility of the material in the body fluids. Highly soluble gases (e.g. ammonia, hydrogen chloride) cause severe nose and throat irritation, while substances of lower solubility (e.g. nitrogen dioxide, phosgene, sulfur dioxide) can penetrate deep into the lungs.

Warning properties such as odor or eye, nose or respiratory tract irritation may be inadequate with some substances. Therefore, they should not be relied upon as a warning of overexposure.

The following procedures should be followed when working with corrosive gases and vapours.

(1) Perform manipulations of materials that pose an inhalation hazard in a chemical fume hood to control exposure or wear appropriate respiratory protection.
(2) Protect all exposed skin surfaces from contact with corrosive or irritating gases and vapors.
(3) Regulators and valves should be closed when the cylinder is not in use and flushed with dry air or nitrogen after use.
(4) When corrosive gases are to be discharged into a liquid; a trap, check valve, or vacuum break device should be employed to prevent dangerous reverse flow.

9.3 Corrosive Solids

Corrosive solids, such as sodium hydroxide and phenol, can cause burns to the skin and eyes. Dust from corrosive solids can be inhaled and cause irritation or burns to the respiratory tract. Many corrosive solids, such as potassium hydroxide and sodium hydroxide, can produce considerable heat when dissolved in water.

The following procedures should be followed when working with corrosive solids.

(1) Wear gloves and eye protection when handling corrosive solids.
(2) When mixing with water, always slowly add the corrosive solid to water, stirring continuously. Cooling may be necessary.
(3) If there is a possibility of generating a significant amount of dust, conduct work in a fume hood.

10. COMPRESSED GASES

Compressed gases fall under WHMIS Class A.

Compressed gases can expose workers to both chemical hazards arising from the chemical properties of the gas, and mechanical hazards due to the high pressure in the cylinders. A compressed gas cylinder, when ruptured, can become a projectile with the potential to cause significant damage

10.1 Hazards

The following is an overview of the potential hazards when handling and storing compressed gases:

<u>Asphyxiation:</u> Simple asphyxiation is the primary hazard associated with *inert gases*. Because inert gases are colorless and odorless, they can escape into the atmosphere undetected and quickly reduce the concentration of oxygen below the level necessary to support life. The normal oxygen content of air is 21% and any concentration below 19% is considered an oxygen-deficient atmosphere. The use of oxygen monitoring equipment is strongly recommended for enclosed areas where inert gases are being used.

<u>Fire and Explosion:</u> Fire and explosion are the primary hazards associated with *flammable gases, oxygen and other oxidizing gases*. Flammable gases can be ignited by static electricity or by a heat source, such as a flame or a hot object. Oxygen and other oxidizing gases do not burn, but will support combustion of organic materials. Increasing the concentration of an oxidizer accelerates the rate of combustion. Materials that are nonflammable under normal conditions may burn in an oxygen-enriched atmosphere. Any enrichment of the oxygen content of air above 24% can also be hazardous.

<u>Chemical Burns:</u> *Corrosive gases* can chemically attack various materials, including fire-resistant clothing. Some gases are not corrosive in their pure form, but can become extremely destructive if a small amount of moisture is added. Corrosive gases can cause rapid destruction of skin and eye tissue.

<u>Chemical Poisoning:</u> Chemical poisoning is the primary hazard of *toxic gases*. Even in very small concentrations, brief exposure to these gases can result in serious poisoning injuries. Symptoms of exposure may be delayed.

High Pressure: All compressed gases are potentially hazardous because of the high pressure stored inside the cylinder. A sudden release of pressure can cause injuries by propelling a cylinder or whipping a line.

Cylinder Weight: A full size cylinder may weigh more than 130 pounds. Moving a cylinder manually may lead to back or muscle injury. Dropping or dragging a cylinder could cause serious injury.

10.2 Storage of Cylinders

(1) All cylinders must be secured to a wall, bench or fixed support using a chain or strap placed 2/3 of the way up. Cylinder stands are an alternative to straps.
(2) Cylinders should be strapped individually.
(3) Do not store full and empty cylinders together.
(4) Oxidizers and flammable gases should be stored in areas separated by at least 20 feet or by a noncombustible wall.
(5) Cylinders should not be stored near radiators or other heat sources. If storage is outdoors, protect cylinders from weather extremes and damp ground to prevent corrosion.
(6) No part of a cylinder should be subjected to a temperature higher than 52 ^{o}C (125^{o}F). A flame should never be permitted to come in contact with any part of a compressed gas cylinder.
(7) Do not place cylinders where they may become part of an electric circuit.
(8) Keep the number of cylinders in a laboratory to a minimum to reduce the fire and toxicity hazards.
(9) Lecture bottles should always be returned to the distributor or manufacturer promptly when no longer needed or discarded if at atmospheric pressure.
(10) Ensure that the cylinder is properly and prominently labeled as to its contents.
(11) NEVER place acetylene cylinders on their side.

10.3 Cylinder Handling Precautions

(1) Avoid dropping, dragging or sliding cylinders. Use a suitable hand truck or cart equipped with a chain or belt for securing the cylinder to the cart, even for short distances.
(2) Do not permit cylinders to strike each other violently. Cylinders should not be used as rollers for moving material or other equipment.
(3) Cylinder caps should be left on each cylinder until it has been secured against a wall or bench or placed in a cylinder stand, and is ready for installation of the regulator. Cylinder caps protect the valve on top of the cylinder from damage if knocked.
(4) Never tamper with pressure relief devices in valves or cylinders.

(5) Use only wrenches or tools provided by the cylinder supplier to remove a cylinder cap or to open a valve. Never use a screwdriver or pliers.
(6) Keep the cylinder valve closed except when in use.
(7) Position cylinders so that the cylinder valve is accessible at all times.
(8) Use compressed gases only in a well-ventilated area. Toxic, flammable and corrosive gases should be carefully handled in a hood or gas cabinet. Proper containment systems should be used and minimum quantities of these products should be kept on-site.
(9) When discharging gas into a liquid, a trap or suitable check valve should be used to prevent liquid from getting back into the cylinder or regulator.
(10) Where more than one type of gas is in use, label gas lines. This is particularly important when the gas supply is not in the same room or area as the operation using the gases.
(11) Do not use the cylinder valve itself to control flow by adjusting the pressure.
(12) Bond and ground all cylinders, lines and equipment used with flammable compressed gases.

10.4 Setup and Use of Gas Cylinders

(1) Before using cylinders, read all label information and MSDSs associated with the gas being used. The cylinder valve outlet connections are designed to prevent mixing of incompatible gases. The outlet threads vary in diameter; some are internal and some are external; some are right-handed and some are left-handed. Generally, right-handed threads are used for fuel gases.
(2) Attach the closed regulator to the cylinder. **Never open the cylinder valve ` unless the regulator is completely closed.** Regulators are specific to the gas involved. A regulator should be attached to a cylinder without forcing the threads. If the inlet of a regulator does not fit the cylinder outlet, no effort should be made to try to force the fitting. A poor fit may indicate that the regulator is not intended for use on the gas chosen.
(3) Turn the delivery pressure adjusting screw counter-clockwise until it turns freely. This prevents unintended gas flow into the regulator.
(4) Open the cylinder **slowly** until the inlet gauge on the regulator registers the cylinder pressure. If the cylinder pressure reading is lower than expected, the cylinder valve may be leaking.
(5) With the flow control valve at the regulator outlet closed, turn the delivery pressure adjusting screw clockwise until the required delivery pressure is reached.
(6) Check for leaks using soap solution. At or below freezing temperatures, use a glycerin and water solution, such as *Snoop*, rather than soap. Never use an open flame to detect leaks.
(7) When finished with the gas, close the cylinder valve and release the regulator pressure.

10.5 Setup of Equipment and Piping

(1) Do not force threads that do not fit exactly.
(2) Use Teflon tape or thread lubricant for assembly. Teflon tape should only be used for tapered pipe thread, not straight lines or metal-to-metal contacts.
(3) Avoid sharp bends of copper tubing. Copper tubing hardens and cracks with repeated bending.
(4) Inspect tubing frequently and replace when necessary.
(5) Tygon and plastic tubing are not appropriate for most pressure work. These materials can fail under pressure or thermal stress.
(6) Do not mix different brands and types of tube fittings. Construction parts are usually not interchangeable.
(7) Do not use oil or lubricants on equipment used with oxygen.
(8) Do not use copper piping for Acetylene.
(9) Do not use cast iron piping for Chlorine.

10.6 Leaking Cylinders

Most leaks occur at the valve in the top of the cylinder and may involve the valve threads valve stem, valve outlet, or pressure relief devices. Lab personnel should not attempt to repair leaking cylinders.

Where action can be taken without serious exposure to lab personnel:

(1) Move the cylinder to an isolated, well-ventilated area (away from combustible materials if the cylinder contains a flammable or oxidizing gas).
(2) Contact Security at 905-721-2000 Ext. 2400.

If a large or uncontrollable leak occurs, evacuate the area and immediately call Security at Ext. 2400.

10.7 Empty Cylinders

(1) Remove the regulator and replace the cylinder cap.
(2) Mark the cylinder as empty or MT and store in a designated area for return to the supplier.
(3) Do not store full and empty cylinders together.
(4) Do not have full and empty cylinders connected to the same manifold. Reverse flow can occur when an empty cylinder is attached to a pressurized system.
(5) Do not refill empty cylinders. Only the cylinder supplier should refill gases.
(6) Do not empty cylinders to a pressure below 25 psi (172 Kpa). The residual contents may become contaminated with air.

(7) Lecture bottles should always be returned to the distributor or manufacturer promptly when no longer needed. Do not purchase lecture bottles that cannot be returned.

10.8 Highly Toxic Gases

Highly toxic gases, such as arsine, diborane, fluorine, hydrogen cyanide, phosgene and silane can pose a significant health risk in the event of a leak. Use of these materials requires written approval by the Principal Investigator or supervisor, using the *Particularly Hazardous Substances Use Approval* form.

The following additional precautions must be taken:

(1) Use and store in a specially ventilated gas cabinet or fume hood.
(2) Use coaxial (double walled) tubing with nitrogen between the walls for feed lines operating above atmospheric pressure.
(3) Regulators should be equipped with an automatic shut-off to turn off gas supply in the event of sudden loss of pressure in the supply line.
(4) An alarm system should be installed to check for leaks in routinely used gases with poor warning properties. The alarm level must be set at or lower than the permissible exposure limit of the substance.
(5) Self-contained breathing apparatus (SCBA) may be appropriate for changing cylinders of highly toxic gases. Use of an SCBA requires training in the use of the SCBA and annual re-training and fit-testing.

11. DESIGNATED AND CONTROLLED SUBSTANCES

In Ontario, certain substances because of the nature of the hazards and their widespread use, have been “designated” by the Ministry of Labour for special regulation. Each of these substances has its own regulation. These are listed in Table 11.1.

Where one of these designated substances is present in the workplace, a written assessment must be made of the likelihood of worker exposure to the substance. This assessment must be conducted in consultation with the health and safety committee.

If one of these designated substances is used or proposed to be used, the health and safety committee must be notified so that the assessment can be made before workers are exposed to the substance and so that the appropriate controls can be put in place.

TABLE 11.1

DESIGNATED SUBSTANCES

Acrylonitrile
Arsenic
Asbestos
Asbestos on Construction Projects and in Buildings and Repair Operations
Benzene
Coke Oven Emissions
Ethylene Oxide
Isocyanates
Lead
Mercury
Silica
Vinyl Chloride

In addition to these regulated designated substances, the University has placed requirements on certain particularly hazardous chemicals. These requirements are similar to those for designated substances in that the health and safety committee must be notified of their proposed usage. Specific additional controls and emergency procedures may be required for these chemicals.

UOIT Particularly Hazardous Chemicals

Diborane
Cyanides
Fluorine
Hydrofluoric Acid
Hydrogen Cyanide
Phosgene
Silane

Dangerously Reactive Materials in Section 8

12. BIOHAZARDOUS INFECTIOUS MATERIALS

Biohazardous infectious materials fall under WHMIS Class D, Division 3.

Biohazardous infectious materials include any organisms and the toxins produced by these organisms that have been shown to cause disease or are believed to cause disease in either humans or animals.

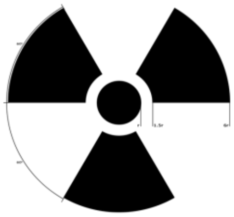
Blood and body fluids fall into this category since they can potentially contain hepatitis A, B or C viruses or HIV.

“Universal Precautions” are generally accepted standards for dealing with potentially infected materials. They cover personal protection, handling techniques and waste disposal.

All use of biohazardous infectious materials falls under the jurisdiction of the University Biosafety Committee and users must obtain a biosafety certification from the Committee. Detailed procedures are provided in the Biosafety Manual.

13. IONIZING RADIATION

Ionizing radiation and radioactive materials do not fall under the WHMIS classification and labeling system. They are regulated by the Canadian Nuclear Safety Commission and internally by the University Radiation Safety Committee.



All users of radiation and radioisotopes must obtain a permit from the Radiation Safety Committee and receive specific training in radiation protection.

Detailed procedures are given in the Radiation Safety Manual.

14. NON-IONIZING RADIATION

The non-ionizing part of the electromagnetic spectrum is divided into the following regions:

- Electric static and magnetic fields – 0 Hz
- Extremely low frequency (ELF) fields – >0 Hz to 300 Hz
- Radiofrequency (RF) and microwave radiation – 300 Hz to 300 GHz
- Optical radiations
    - Infrared (IR) – 760 to 10^6 nanometres (nm)
    - Visible – 400 to 760 nm,
    - Ultraviolet (UV) – 100 to 400 nm

The nature, extent and physiological importance of biological effects from exposures to non-ionizing radiation (NIR) depends on a number of factors such as the energy of the radiation, the power density of the field or beam, the emission characteristics of the source, the duration of the exposure, environmental conditions and the spacial orientation and biological characteristics of the irradiated tissues. In the lower frequency range (300 Hz to 1 MHz) induction currents may interfere with the functioning of the central nervous system. In the intermediate frequency range (100 kHz to 10GHz) the absorption of electromagnetic energy generates heat. At the upper frequency range (10 GHz to 300 GHz) heating of superficial tissues is possible. Except for optical radiation, there is little data on the quantitative relationships between exposures to different types of NIR and pathological responses in humans.

There are a number of published standards and guidelines relating to exposures to non-ionizing radiation:

- *"Limits of Human Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range from 3 kHz to 300 GHz".* Safety Code 6, Radiation Protection Bureau, Health Canada, 2015
- *"Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices"*. American Conference of Governmental Industrial Hygienists, (published annually).
- Publications of the International Commission on Non-Ionizing Radiation Protection

Each exposure to non-ionizing radiation will be evaluated on a case-by-case basis. Contact the University Radiation Safety Officer for more information.

15. LASERS

There are two types of laser hazards: laser beam hazards and the non-beam hazards. Laser beam hazards include eye and skin burns which are due to the beam hitting a person's body. Non-beam hazards are associated with the laser equipment (e.g. electrical high voltage) or the hazardous substances used in the laser (e.g., toxic gases and chemicals) and fumes emitted from materials exposed to laser beams.

All Class 3B and Class 4 lasers must be registered with the University Radiation Safety Officer and the Radiation Safety Committee and must meet the requirements set out in the laser safety program. The Laser Safety Program is developed to meet the requirements of the ANSI Standards Z136.5-2009 “Safe Use of Lasers in Educational Institutions” and Z136.1-2014 “Safe Use of Lasers”.

16. CRYOGENIC MATERIALS

16.1 Cryogenic Liquids

Cryogenic liquids have boiling points less than -73 ºC (-100ºF). Liquid nitrogen, liquid oxygen and carbon dioxide are the most common cryogenic materials used in the laboratory. Hazards may include fire, explosion, embrittlement, pressure buildup, frostbite and asphyxiation.

Oxygen Deficiency

The release of cryogenic liquids in the work area can result in the rapid displacement of air and the potential for asphyxiation (suffocation) by reducing the concentration of oxygen in air below levels necessary to support life.

Cryogenic liquids have very high volume expansion rates. For example, one litre of liquid nitrogen vapourizes to approroximately 700 litres of nitrogen gas at 20 ºC. This can rapidly displace the oxygen in the air.

Exposure to oxygen-deficient atmospheres may produce dizziness, nausea, vomiting, loss of consciousness and death. Such symptoms may occur in seconds without warning. Death may result from errors in judgement, confusion or loss of consciousness which prevents self-rescue.

Pressure Build-up

Overpressurization will develop in inadequately vented pressurized systems due to the expansion of cryogenic liquid vaporizing into large volumes of gas. Sudden release of this pressure can cause personal injury by issuing cold gas or liquid, or by expelling parts, as a result of leaks or bursts. The low temperatures of liquid cryogens also result in their potential to freeze water or other materials rapidly, and subsequent blockage and pressure build-up.

Cryogenic Burns and Frostbite

Exposure to liquid cryogens or the cold "boil off" gases can result in extensive tissue damage or severe skin burns. Contact with uninsulated pipes or metal containers which are used to contain or transfer cryogenic materials can cause the flesh to stick and be torn when attempts to withdraw it are made. Prolonged exposure to cold can also result in hypothermia or frostbite.

Cold Stress to Materials

Common materials such as carbon steel, plastics and rubber can become brittle and break, or fracture under stress at cryogenic temperatures. These can cause spills or leakages as a result of system rupture or failure.

Condensation of Atmospheric Oxygen

Oxygen in surrounding air can condense when exposed to the temperatures of cryogens such as liquid nitrogen. Such oxygen enrichment may result in increased flammability and explosion hazards.

16.2 Procedures

Most cryogenic liquids are odorless, colorless, and tasteless when vaporized. When cryogenic liquids are exposed to the atmosphere, the cold boil-off gases condense the moisture in the air, creating a highly visible fog.

(1) Always handle these liquids carefully to avoid skin burns and frostbite. Exposure that may be too brief to affect the skin of the face or hands may damage delicate tissues, such as the eyes.
(2) Boiling and splashing always occur when charging or filling a warm container with cryogenic liquid or when inserting objects into these liquids. Perform these tasks slowly to minimize boiling and splashing. Use tongs to withdraw objects immersed in a cryogenic liquid.
(3) Never touch uninsulated pipes or vessels containing cryogenic liquids. Flesh will stick to extremely cold materials. Even nonmetallic materials are dangerous to touch at low temperatures.
(4) Cylinders and dewars should not be filled to more than 80% of capacity, since expansion of gases during warming may cause excessive pressure buildup.
(5) Check cold baths frequently to ensure they are not plugged with frozen material.
(6) Face shields worn with safety glasses or chemical splash goggles are recommended during transfer and handling of cryogenic liquids.
(7) Wear loose fitting, dry insulated or leather gloves when handling objects that come into contact with cryogenic liquids and vapor. Trousers should be worn on the outside of boots or work shoes.

(8) Traps that open to the atmosphere condense liquid air rapidly. If you close the system, pressure builds up with enough force to shatter glass equipment. Therefore, only sealed or evacuated equipment should use liquid nitrogen cooled traps.

16.3 Dry Ice

(1) Neither liquid nitrogen nor liquid air should be used to cool a flammable mixture in the presence of air, because oxygen can condense from the air, leading to an explosion hazard.
(2) Wear insulated, dry gloves and a face shield when handling dry ice.
(3) Add dry ice slowly to the liquid portion of the cooling bath to avoid foaming over. Do not lower your head into a dry ice chest, since suffocation can result from carbon dioxide buildup.

17. VACUUM AND HIGH PRESSURES

17.1 Vacuum Work

The major hazard when working with vacuum lines and other glassware used at low pressures arises from the danger of injury from flying glass in the event of glass breakage. Other dangers can arise from the toxicity, flammability or reactivity of chemicals contained in the vacuum system.

Since vacuum lines frequently require cold traps (usually liquid nitrogen) between the pumps and vacuum line precautions regarding the use of cryogens must also be observed.

(1) Personal protective equipment such as safety glasses or chemical goggles, face shields, and/or an explosion shield should be used to protect against the hazards of vacuum procedures, and the procedure should be performed inside a fumehood.
(2) Do not allow water, solvents and corrosive gases to be drawn into vacuum systems. Protect pumps with cold traps and vent their exhaust into an exhaust hood.
(3) Assemble vacuum apparatus in a manner that avoids strain, particularly to the neck of the flask.
(4) Avoid putting pressure on a vacuum line to prevent stopcocks from popping out or glass apparatus from exploding.
(5) Place vacuum apparatus in such a way that the possibility of being accidentally hit is minimized. If necessary, place transparent plastic around it to prevent injury from flying glass in case of an explosion.
(6) When possible, avoid using mechanical vacuum pumps for distillation or concentration operations using large quantities of volatile materials. A water aspirator or steam aspirator is preferred. This is particularly important when large quantities of volatile materials are involved.

(7) When using a vacuum source, it is important to place a trap between the experimental apparatus and the vacuum source. The vacuum trap protects the pump and the piping from the potentially damaging effects of the material, protects people who must work on the vacuum lines or system, and prevents vapors and related odors from being emitted back into the laboratory or system exhaust.

Proper Trapping Techniques

For particulates, use filtration capable of efficiently trapping the particles in the size range being generated.

For most aqueous and non-volatile liquids, a filter flask at room temperature is adequate to prevent liquids from getting to the vacuum source.

For solvents and other volatile liquids, use a cold trap of sufficient size and cold enough to condense vapours generated, followed by a filter flask capable of collecting fluid that could be aspirated out of the cold trap.

For highly reactive, corrosive or toxic gases, use a sorbent canister or scrubbing device capable of trapping the gas.

Cold Traps

For most volatile liquids a cold trap, using a slush of dry ice and either isopropanol or ethanol, is sufficient (to -78 ºC). Avoid using acetone. Ethanol and isopropanol are cheaper and less likely to foam.

Liquid nitrogen may only be used with sealed or evacuated equipment, and then only with extreme caution. If the system is opened while the cooling bath is still in contact with the trap, oxygen may condense from the atmosphere and react vigorously with any organic material present.

Glass Vessels

(1) Conduct pressure and vacuum operations in glass vessels behind adequate shielding.
(2) Ensure the glass vessel is designed for the intended operation.
(3) Carefully check glass vessels for star cracks, scratches or etching marks before each use. Cracks can increase the likelihood of breakage or may allow chemicals to leak into the vessel.
(4) Seal glass centrifuge tubes with rubber stoppers clamped in place. Wrap the vessel with friction tape and shield with a metal screen. Alternatively, wrap with friction tape and surround the vessel with multiple layers of loose cloth, then clamp behind a safety shield.
(5) Glass tubes with high-pressure sealers should be no more than 3/4 full.
(6) Sealed bottles and tubes of flammable materials should be wrapped in cloth, placed behind a safety shield, then cooled slowly, first with an ice bath, then with dry ice.
(7) Never rely on corks, rubber stoppers or plastic tubing as pressure-relief devices.
(8) Glass vacuum dessicators should be made of Pyrex or similar glass and wrapped partially with friction tape to guard against flying glass. Plastic desiccators are a good alternative to glass, but still require shielding.
(9) Never carry or move an evacuated desiccator.

Dewar Flasks

Dewar flasks are under pressure and can collapse from thermal shock or slight mechanical shock.

(1) Shield flasks with friction tape or enclose in a wooden or metal container to reduce the risk of flying glass.
(2) Use metal flasks if there is a significant possibility of breakage.
(3) Styrofoam buckets offer a short-term alternative to dewar flasks.

17.2 High Pressure Work

(1) High-pressure operations should be performed only in pressure vessels appropriately selected for the operation, properly labeled and installed, and protected by pressure-relief and necessary control devices.
(2) Vessels must be strong enough to withstand the stresses encountered at the intended operating temperatures and pressures and must not corrode or otherwise react when in contact with the materials it contains.
(3) Systems designed for use at elevated temperatures should be equipped with a positive temperature controller. Manual temperature control using a simple variable autotransformer, such as a Variac, should be avoided. The use of a back-up temperature controller capable of shutting the system down is strongly recommended.

(4) All pressure equipment should be inspected and tested at intervals determined by the severity of the equipment's usage. Visual inspections should be accomplished before each use.

(5) Hydrostatic testing should be accomplished before equipment is placed in initial service. Hydrostatic testing should be re-accomplished every ten years thereafter, after significant repair or modification, or if the vessel experiences overpressure or over-temperature.

18. NOISE

Employers are to take all measures reasonably necessary in the circumstances to protect workers from exposure to hazardous sound levels that result in the $L_{ex,8}$ exposure limit of 85 dBA being exceeded (8-hour time-weighted average exposure) Exposures in excess of this level are associated with noise-induced hearing loss.

When the exposure limit prescribed by the regulations is exceeded, the employer is required to put in place measures to reduce or eliminate workers' exposure through the use of engineering and/or administrative controls. If this is not feasible, the use of approved hearing protection is mandatory for individuals exposed to levels in excess of those in Tables 18.3. Hearing protection devices must comply with CSA Standard Z94.2-14 – "Hearing protection devices – Performance, selection, care and use".

Employers must post clearly visible warning signs at the approaches to areas where the sound level regularly exceeds 85 dBA

A worker is considered noise-exposed if he/she experiences regular exposure to sound levels greater than an 8-hour time-weighted average of 85 dBA or an equivalent noise exposure (see Table 18.3).

The level of 85 dBA is not a line between safe and unsafe noise exposures. Some susceptible individuals may be at risk of developing noise-induced hearing loss when regularly exposed to noise levels between 80 and 85 dBA.

Noise assessments and appropriate hearing protection can be arranged by contacting the University Health and Safety Officer.

Legislative Reference:

> Ontario Ministry of Labour Health and Safety Guidelines for "Amendments to Noise Requirements in the Regulations for Industrial Establishments and Oil and Gas Offshore" July 2007

TABLE 18.3
EQUIVALENT NOISE EXPOSURES

Duration per Day	Steady Sound Level Without Hearing Protection* (dbA)
16 hours	82
8 hours	85
4 hours	88
2 hours	91
1 hour	94
30 min.	97
15 min.	100
7.5 min.	103
3.75 min.	106
1.88 min.	109

* Based on a 3 dB exchange rate

19. ELECTRICAL HAZARDS

Electrically powered equipment, such as hot plates, stirrers, vacuum pumps, electrophoresis apparatus, lasers, heating mantles, power supplies, and microwave ovens are essential elements of many laboratories. These devices can pose a significant hazard to laboratory workers, particularly when mishandled or not maintained. Many laboratory electrical devices have high voltage or high power requirements, carrying even more risk. Large capacitors found in many laser flash lamps and other systems are capable of storing lethal amounts of electrical energy and pose a serious danger even if the power source has been disconnected.

In dealing with electrical hazards it is important to realize that no electrical contact is “safe” and 110-volt circuits have the potential to electrocute a person.

The human body is extremely variable as a conductor and the effects of an accidental electrical contact depend on the current, the pathway of the current, the duration of the contact and the presence of water or dampness. The point of contact is very important. If current flow enters the body through the fingers and passes out through a contact at the elbow, no vital organs receive direct exposure. However, if the flow is from the hands through the body to the feet, vital organs such as the heart, chest muscles and lung diaphragm are affected with possibly fatal results.

A normal 110-volt circuit is fused at 15 – 30 amperes. Currents above about 10 milliamperes can paralyze the muscles so one cannot let go of the conductor. Currents above 20 milliamperes can paralyze the respiratory system and currents around 100 milliamperes can cause heart fibrillation and cardiac arrest.

19.1 Basic Precautions to Prevent Electrical Contact Injuries

There are various ways of protecting people from the hazards caused by electricity, including insulation, guarding, grounding, and electrical protective devices. Laboratory workers can significantly reduce electrical hazards by following some basic precautions:

(1) Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
(2) Ensure all electrical equipment and instrumentation is CSA approved.
(3) Use only equipment with three-prong plugs in the laboratory. The third prong provides a path to ground for internal electrical short circuits, thereby protecting the user from a potential electrical shock.
(4) Check that the circuit is protected by a ground-fault interrupter (GFI). The GFI, is designed to shutoff electric power if a ground fault is detected, protecting the user from a potential electrical shock. The GFI is required within 1 meter of sinks and wet locations. Since GFIs can cause equipment to shutdown unexpectedly, they may not be appropriate for certain apparatus. Portable GFI adapters (available in most safety supply catalogs) may be used with a non-GFI outlet.
(5) Limit the use of extension cords. Use only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet. The wire gauge of the extension cord should match the equipment which it is intended for.
(6) Multi-plug adapters (power bars) must have circuit breakers or fuses.
(7) Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
(8) Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
(9) Minimize the potential for water or chemical spills on or near electrical equipment. If water or a chemical is spilled onto equipment, shut off power at the main switch or circuit breaker and unplug the equipment.
(10) Avoid contact with energized electrical circuits. Disconnect the power source before servicing or repairing electrical equipment.
(11) When it is necessary to handle equipment that is plugged in, be sure hands are dry and, when possible, wear nonconductive gloves and shoes with insulated soles.

If it is safe to do so, work with only one hand, keeping the other hand at your side or in your pocket, away from all conductive material. This precaution reduces the likelihood of accidents that result in current passing through the chest cavity.

(12) Minimize the use of electrical equipment in cold rooms or other areas where condensation is likely. If equipment must be used in such areas, mount the equipment on a wall or vertical panel.

(13) If an individual comes in contact with a live electrical conductor, do not touch the equipment, cord or person. Disconnect the power source from the circuit breaker or pull out the plug using a leather belt.

(14) Repairs of high voltage or high current equipment should be performed only by Electrical Safety Association qualified electricians.

(15) Do not perform any direct wiring or modifications to the supplied electrical circuits. Contact Facilities Management for any such work.

20. HAZARDOUS WASTE MANAGEMENT

All hazardous wastes must be disposed of in accordance with the procedures in the UOIT Laboratory Hazardous Waste Management Manual.

Under no circumstances may hazardous materials be disposed of in the regular garbage or down the laboratory drains.

21. EMERGENCY PROCEDURES

21.1 Minor Spills

Minor spills involve small quantities of known materials which present minimal hazards. A minor spill will generally meet the following criteria.

- The quantity of material spilled is small (no more than a few litres)
- The spill will not spread extensively beyond the local area of the spill
- There is no respiratory hazard
- The spill will not endanger people or property
- The spill will not endanger the environment

In general such spills can safely be dealt with by laboratory personnel without outside assistance using the precautions and instructions on the MSDS using cleanup materials and protective clothing readily at hand.

21.2 Major Spills

A major or complex spill may present fire and explosion risks, respiratory hazards, dangers from toxic materials, or may escape from the local area either through the air handling systems or sewer system. If there is any doubt about a spill it should be considered a major spill and the posted emergency procedures followed.

21.3 Explosion or Fire

1. Evacuate the immediate area, closing doors behind you.
2. Activate the fire alarm
3. If possible, control the fire with the appropriate extinguisher but do not place yourself or others in danger.
4. Do not attempt to rescue injured persons if doing so places you in danger.
5. Everyone must evacuate the building when a fire alarm sounds, closing doors as they leave. Follow “Fire Evacuation Procedures” posted in each Laboratory.
6. Call Campus Security at 905-721-2000 Ext. 2400.
7. Wait for emergency personnel outside the main entrance of the building. Provide information on hazardous materials involved.
8. Do not re-enter the building until the Fire Department gives permission to do so.

21.4 Chemical, Biohazard or Radioactive Material Spills

1. Evacuate the immediate area and shut down equipment.
2. Isolate the area and prevent re-entry.
3. Call Campus Security at 905-721-2000 Ext. 2400.
4. Provide the following information about the spilled material to the operator.

   - Location
     - Street Address
     - Building/Department
     - Room Number
   - Injuries
   - Chemical Name
   - Quantity
   - Hazards

5. Do not hang up until the operator releases you.
6. Contact the Hazardous Materials Spill Reporting (24 hours) at 1-800-268-6060. If the spill is a reportable as defined by the Ontario Ministry of the Environment.
7. Wait for emergency response personnel outside the main entrance of the building. Provide information such as the MSDS or SDS.
8. Inform Laboratory Supervisor or Department Head.

22. PERSONAL PROTECTIVE EQUIPMENT

22.1 Eye Protection

Appropriate eye protection must be worn in laboratories at all times. Eye protection must be appropriate to the specific hazard and must provide a comfortable and secure fit. Table 22.1(a) provides a description of the common types of eye protection and Table 22.1(b) their recommended uses.

Contact Lenses

In recent years the recommendations with respect to the wearing of contact lenses in laboratories has changed. The American Chemical Society has reversed its earlier advice recommending against the wearing of contact lenses in laboratories and now agrees that ***"contact lenses can be worn in most work environments provided the same approved eye protection is worn as required of other workers in the area".***

Current evidence indicates that the use of contact lenses does not place the wearer at additional risk of eye injury. Concerns associated with an increased risk of eye injury due to chemical splash or absorption and retention of gases and vapours by the contact lens materials have not been supported by scientific evidence or human experience. There are some obvious advantages to contact lenses including increased visual acuity and better fit of protective eyewear than with eyeglasses.

It must be stressed, however, that contact lenses are not protective devices and must be used in conjunction with appropriate protective eyewear in eye hazard areas.

TABLE 22.1(a)

TYPES OF PROTECTIVE EYEWEAR

Spectacle Type Safety Glasses

Safety glasses have lenses that are impact resistant and frames that are stronger than those of regular eyeglasses. Safety glasses come in a variety of lens materials, shades and tints. Lens materials include polycarbonate, plastic or glass each of which varies in strength, impact resistance, scratch resistance and weight. They can also be to prescription for those who need corrective lenses. Safety glasses must comply with CSA Standard Z94.3-15.

Safety glasses with permanently attached side shields must be worn by those who require protection against flying particles.

Safety Goggles

Safety goggles offer greater eye protection than safety glasses by providing a secure shield around the entire eye area to protect against hazards coming from any direction.

Safety goggles may have direct or indirect ventilation to prevent fogging. Goggles with direct ventilation allow heat and humidity to dissipate, but do not protect against splash hazards. Goggles with indirect ventilation are designed to protect against dust and splash hazards.

Safety goggles must be worn where there is a danger of liquids being splashed into the eye.

Face Shields

Face shields worn alone are not considered protective eyewear. They are designed to provide general protection to the face and the front of the neck; they do not fully enclose the eyes and must be used in conjunction with primary eye protection such as safety glasses or goggles. Full face shields are often used to protect against chemicals, heat or glare hazards.

Welding Helmets

Welding helmets are used when welding or working with molten materials. They are designed to provide protection to the face and the front of the neck from heat, glare, weld splatter and impact hazards.

Specialty Filter Lenses-

Protective eyewear (goggles, helmets) equipped with appropriate filter lenses must be used to protect against harmful radiations such as infrared, ultraviolet, and laser light.

TABLE 22.1(b)

USAGE OF PROTECTIVE EYEWEAR

NATURE OF HAZARD	EXAMPLES	RECOMMENDED EYE PROTECTION
Impact	Flying objects such as large chips, fragments, particles, sand and dirt	Spectacles Goggles Face Shields*
Dust	Harmful dust	Goggles
Heat	Anything emitting extreme heat	Spectacles Goggles Face Shields*
Chemicals	Splash, fumes, vapours and irritating mists	Goggles Face Shields*
Optical Radiation	Radiant energy, glare and intense light (lasers, welding)	Depends on the wavelength and intensity

***** Face shields are not primary protection; they must be worn in conjunction with the primary protection of spectacles or goggles.

22.2 Hand Protection

Appropriate protective gloves must be worn where the hands are potentially exposed to chemicals, infectious agents, cuts, lacerations, abrasions, punctures, burns and harmful temperature extremes.

Choosing the appropriate glove can be a challenge in a laboratory setting. Considering the fact that dermatitis or inflammation of the skin accounts for 40-45% of all work-related diseases, selecting the right glove for the job is important.

Of particular concern is the increasing incidence of latex allergies. Allergic reactions due to the natural latex proteins or to the chemical additives added to the latex during the manufacturing process can present a serious health risk to a significant number of workers who need to wear glove protection. Symptoms can range from local skin reactions to more serious health effects such as rhinitis, conjunctivitis, asthma, and even rarely life-threatening anaphylactic shock. It is recommended that exposure to latex be minimized by either substituting other materials for latex, or if that is not possible, by using reduced-protein, powder free latex gloves.

Not only can many chemicals cause skin irritation or burns, but also absorption through the skin can be a significant route of exposure to certain chemicals. Dimethyl sulfoxide (DMSO), nitrobenzene, and many solvents are examples of chemicals that can be readily absorbed through the skin into the bloodstream, where the chemical may cause harmful effects.

There are a number of sources available on the internet which provide guidance in the election of proper materials for protective gloves. In addition to the Material Safety Data Sheet for the chemical one can consult the following sources.

- **Best Manufacturing: http://www.chemrest.com/ .**
- **Canadian Centre for Occupational Health and Safety: http://www.ccohs.ca/oshanswers/prevention/ppe/gloves.html** .
- **US National Institute for Occupational Safety and Health (NIOSH): http://www.cdc.gov/niosh/ncpc/** .

22.3 Foot Protection

Appropriate footwear must be worn at all times in laboratories where chemicals are used and stored. Sandals, open-toed shoes and the like must not be worn as they expose the foot to chemical spills and broken glass. Appropriate shoes must cover and protect the entire foot.

Depending on the type of hazard in the laboratory, footwear which provides additional protection may be required. Chemically resistant boots may be needed when working with large quantities of corrosive materials or solvents which might penetrate normal footwear (e.g. during spill cleanup). Where there is a risk of foot injury from impact of heavy objects, steel-toed safety shoes may be needed. Where the potential exists for electrical shock, appropriate electrically-resistant footwear may be appropriate. In these cases, appropriate CSA-approved footwear must be worn.

22.4 Respiratory Protection

A respirator should only be used when engineering controls, such as general ventilation or a fume hood, are not feasible or do not reduce the exposure of a chemical to acceptable levels. Even in this case respiratory protection should only be considered to be a temporary measure and if the exposures are to be ongoing, appropriate engineered controls should be put in place or the process changed to eliminate the offending chemical.

In the event that respiratory protection is required, the employee must have appropriate training and be properly fitted with the appropriate respirator. Contact the University Health and Safety Officer for assistance in this regard.

22.5 Hearing Protection

Most laboratory equipment and operations do not produce noise levels that require the use of hearing protection. The limits for exposure to noise without the use of hearing protection are give in Section 18 of this manual.

There are many types of hearing protectors available, including disposable or reusable plugs, headband plugs, and muffs. Reusable hearing protectors should be cleaned often and replaced when the plugs or muff cushions become hardened or discolored. It is important that the plugs are seated properly in the ear, that the muffs form an adequate seal around the ear and that the headband is not bent. All of these precautions will improve the noise attenuation (reduction) achieved by the hearing protection.

Contact the University Health and Safety Officer to determine if ear protection is required and for assistance in selection and fitting of appropriate hearing protection.

22.6 Protective Clothing

Appropriate protective clothing must be worn in laboratories where chemical, biological or radioactive materials are used and stored. In most cases a laboratory coat will suffice. Coats must be made of material suitable for the work environment (e.g. cotton or cotton/polyester). They must fit properly, be fastened when working and provide appropriate flexibility to carry out tasks. Laboratory coats must be regularly cleaned and maintained, and replaced when worn. Laboratory coats must only be worn in the laboratory and must be left in the laboratory. They must not be worn in eating areas, in offices or in public areas

Because of the limited protection afforded by laboratory coats, other clothing which affords a greater degree of protection may be warranted in some circumstances. Plastic or rubber aprons should be used when handling larger quantities of corrosive materials such as acids and bases.

Depending on the hazards in the laboratory, clothing which protects against other hazards such as cold, heat, moisture or electrical shock may also be needed.

Guidance on particular types of protective clothing can be obtained from the MSDS or SDS and through consultation with the University Health and Safety Officer.

23. REFERENCES

1. Prudent Practices in the Laboratory: Handling and Disposal of Chemicals. National Academy Press, 1995

2. Howard Hughes Medical Institute: Office of Laboratory Safety www.**hhmi**.org/about/research/**lab**safe.html

3. US Department of Labor, Occupational Safety and Health Administration http://www.osha.gov/SLTC/laboratories/

REVISION HISTORY

<table>
<tr><th>Revision #</th><th>Summary of Changes</th><th>Edited By:</th><th>Date Issued</th></tr>
<tr><td>Original</td><td>n/a</td><td>D. Gorman</td><td>April 2004</td></tr>
<tr><td colspan="4">Approved by: Faculty of Science - Feb. 2004
Approved by UOIT Health & Safety Committee – Mar. 04</td></tr>
<tr><td>R1</td><td>Update References</td><td>D. Gorman</td><td>April 2005</td></tr>
<tr><td colspan="4">Approved by: Faculty of Science - Feb. 2005
Approved by: UOIT Health & Safety Committee – Mar. 05</td></tr>
<tr><td>R2</td><td>Update CSA standard references, Update Sect. 18 Noise Exposure limits, minor edits for clarification of position titles, assure format consistency and add new UOIT logo</td><td>D. Roger</td><td>Aug. 2009</td></tr>
<tr><td colspan="4">Approved by: Faculty of Science – Sept. 09
Approved by: UOIT Health & Safety Committee – Sept. 09</td></tr>
<tr><td>R3</td><td>Update ANSI and CSA standard references; update WHMIS/GHS information and hazard symbols; assure format consistency and add new UOIT logo</td><td>T. Neretljak</td><td>Aug. 2016</td></tr>
<tr><td colspan="4">Approved by: Biosafety Committee – Sept. 16
Approved by: UOIT Joint Health & Safety Committee – Sept. 16</td></tr>
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