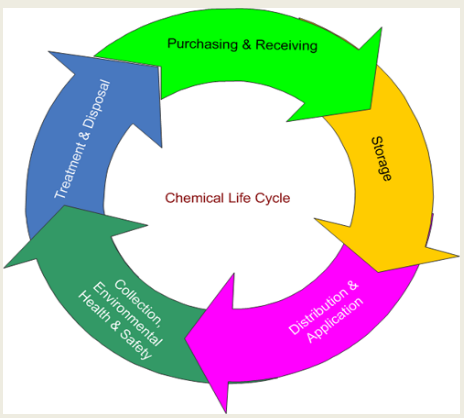
United Federation of Teachers
A Union of Professionals

Safety and Health
Professional Development
Science Teachers
Workshop



Chemistry

Earth Science

Biology

Physics

Prepared by the Safety and Health Department
United Federation of Teachers
A Union of Professionals

Conducted Under
NYSDOL HAB - OSH T& E Grant
Contract No.C16013GG

LABORATORY HEALTH AND SAFETY TRAINING
PROGRAM CURRICULUM

TABLE OF CONTENTS

CONTROLLING

LAB

HAZARDS

CONTROLLING HAZARDS IN THE LAB

The Lab Facility

The UFT/NYCOSH survey revealed that many labs had a number of deficiencies regarding the laboratory facility. As a result of Union pressure, the Board developed a systematic approach to correcting these deficiencies.

Secondary schools must have a number of minimal design elements as required by federal, state and local regulations. These design elements are intended to control exposure to chemicals during normal operations, to prevent accidents, and to prevent serious injury or loss of life during fires or chemical emergencies. The following elements must be installed in secondary school laboratories in the New York City public school system.

Eyewash fountains and Safety Showers

Emergency flushing equipment must be stationed in all lab areas that use or store chemicals that are corrosive or may irritate the eyes or skin. Safety showers and eyewash units are necessary whenever lab chemicals are used but they are most important around corrosive chemicals such as acids or bases. Emergency flushing equipment should be designed and installed to meet the American National Standards Institute (ANSI) requirements set forth in the ANSI standard for Emergency Eyewash and Shower Equipment Z358.1-1998. The safety shower and eyewash should provide hands-free operation and an adequate supply of water to permit 15 minutes of flushing. The eyewash should be plumbed and should provide 0.4 gallons per minute of water at a temperature between 78^{0}F and 92^{0}F. The safety shower should provide 20 gallons per minute of tepid water. Bottled eyewash units do not provide adequate water flow and are not a primary means of protection. A bottled eyewash may be used as a secondary protection when it is necessary to have a portable eyewash in close proximity, provided a proper eyewash is present nearby. Generally, a worker should be able to reach a safety shower or eyewash within 10 seconds of an accident. The pathway to the eyewash or shower should be clear and level. The location of the shower and eyewash should be indicated by signs and accessible at all times. Eyewash units and safety showers should be visually inspected weekly and should receive a maintenance check annually.

In response to the UFT/NYCOSH survey findings, combination eyewash/drench hose units have been installed by the teacher's demonstration bench in the lab. These are sink-mounted hoses with a special nozzle and fitting that permits hands-free operation. There is also an eyewash fountain and safety shower in the chemical preparation room. In both these areas the emergency flushing equipment is designed and installed to meet the ANSI standard.

Lab Furniture - The lab benches are designed with a chemically resistant finish usually made of epoxy. The older lab benches have a stone bench top. The lab bench finish is usually resistant to strong acids and most solvents as well as other reactive chemicals. It is usually possible to clean the lab benched with detergents and water and eliminate contamination. However, for some chemicals such as toxic metals, it may be extremely difficult to remove contamination and it is frequently necessary to cover the bench top with laboratory spill paper. The spill paper is designed to absorb any spills and protect the bench top surface. Spill paper is usually changed whenever it is visibly contaminated, or after a spill occurs, or on a periodic basis.

Portable fire extinguishers-Laboratories must have fire extinguishers with a class B rating mounted within 50 feet of each chemical use area. Because of the presence of electrical equipment in labs and the possibility of a paper or other combustible fire, laboratory fire extinguishers are frequently ABC rated. The fire extinguishers are mounted at a height of three to four feet and along the exit paths from the lab. Usually a fire extinguisher is mounted at the exit door. A worker should never be put in greater danger to get to a fire extinguisher. There should be a sign or some other way of indicating the presence of a fire extinguisher and the extinguishers must always be readily accessible. OSHA/PESH standards (1910.157) require that all fire extinguishers be visually inspected monthly and should receive an annual maintenance check. All fire extinguishers must have an inspection tag.

In school labs where water-reactive and/or flammable metals are used or stored (for example, sodium or lithium metals), a class D fire extinguisher is required. The extinguishing agent in the Class D extinguisher engulfs the burning metal and quenches the chemical reaction.

The type of Class D fire extinguisher depends on whether lithium or lithium alloys are involved, in which case a copper extinguishing agent is used. A Class D copper-based fire extinguisher will put out all combustible metal fires, including lithium and lithium alloys. Otherwise, a sodium chloride based dry powder type of Class D fire extinguisher is acceptable and suited for fires involving magnesium, sodium, potassium, powdered aluminum (and others).

General Ventilation

The OSHA/PESH lab standard (1910.1450) recommends general ventilation for all laboratories that provides air by mechanical means sufficient to provide four to twelve room air changes per hour. This can be accomplished either through supply or exhaust ventilation. It is important to verify that the ventilation system is operating when chemicals are used. The flow of air can quickly verified by using tissue paper attached to the ventilation grill. Many secondary school labs do not have mechanical ventilation and rely on openable windows. Although windows provide adequate fresh air to dilute chemical vapors, mechanical ventilation is preferred. If windows are the only source of ventilation, experiments should utilize chemicals of low volatility and low toxicity and, of course, when chemicals are used the windows should be opened.

Chemical Storerooms

Chemical storerooms must have a dedicated mechanical exhaust ventilation system that provides a minimum of 4 air changes per hour as per 1910.1450.

Laboratory Hoods

Laboratory hoods should be used when concentrated acids or bases are used to make stock dilutions. The hood should also be used when toxic volatile organic chemicals are handled or when highly reactive chemicals are used. As

a rule of thumb, use a fume hood or other local ventilation device when working with any appreciably volatile substance with a PEL or TLV of less than 50 ppm (parts per million) or when working with any volatile hazardous chemical (those with vapor pressures above 20 mm Hg). Procedures involving moderately or slightly toxic chemicals (those with PELs or TLVs greater than 100 ppm and 500 ppm respectively) may have to be conducted in a fume hood depending on the quantity involved and the rate of evaporation.

Ideally the lab hood should have the following design elements:

- The hood should have a vertically sliding sash.
- The sash should be adjusted so the average velocity across the face of the hood is 100 feet per minute (fpm).
- The face velocity should be checked frequently using a velometer or other flow meter capable of measuring down to 50 fpm. When testing the hood nine measurements should be made across the entire hood face.
- The hood should be exhausted to the outdoors and the exhaust fan should be located at the discharge end of the exhaust duct.
- The hood should be constructed with chemically-resistant materials and should have stainless steel ducts.

In many schools there are no standard fume hoods and installation of a hood requires major building renovations. The science labs in these schools have been provided ductless fume hoods. These hoods have their own fan that draws air out of the hood and through filters and ultimately recycles the air back into the room. The filters are usually particulate filters combined with activated charcoal. The collection efficiency of the charcoal filters decreases with time and varies with the types of contaminants. It is important to review the manufacturer's manual and verify that the filter will remove vapors or gases expected to be produced in the hood. The hoods should only be used for chemicals where the hazards are low. Since the filters have a limited life, the hood fan should only be operated while chemicals are used in the hood.

For both standard lab fume hoods and the ductless fume hoods, the following guidelines should be followed:

- Always check the hood prior to use. Exhaust and supply vents should not be blocked. Make sure air is actually flowing into the hood. If a piece of tissue paper is taped to the sash, the tissue paper should be "pulled" into the hood.

- Position the vertical sash as low as possible. This protects the user from splashes and increases the face velocity.

- Place chemicals at least six inches inside the hood.

- Do not store chemicals in the hood. Only materials actively in use should be in the hood. This will provide optimal containment and reduce the risk of extraneous chemicals being involved in fire or explosions which may occur in the hood.

- Do not use large equipment inside the hood since this blocks airflow.

- Do not place electrical equipment in the hood when flammable liquids or gases are being used.

- Regularly clean the grille along the bottom slot of the hood so it does not become clogged with papers and dirt.

- Minimize foot traffic in front of the hood. Keep lab doors closed.

- Report any suspected or known hood malfunctions immediately.

- Do not modify fume hoods in any way.

- Never intentionally evaporate waste chemicals out the hood exhaust.

- Never put your head inside an operating fume hood to check an experiment. The plane of the sash is the barrier between contaminated and uncontaminated air.

- Keep the ducted fume hood exhaust on at all times. Operate portable ductless fume hoods only while chemicals are being used in the hoods.

- Regularly test the fume hoods with your vaneometer.

Written Records

A number of written records are required by OSHA/PESH to be maintained in each school laboratory. Maintaining these records will also maintain safety in the lab. Each lab should perform an inventory of chemicals and update it annually. For each chemical product on the inventory, a material safety data sheet (MSDS) should also be kept on file. The MSDS provides information on storage and disposal of the chemical, the health effects, and emergency spill response and first aid information. The lab should also have a current permit from the New York City Fire Department (NYCFD). The NYCFD Bureau of Fire Prevention inspects lab facilities and renews permits annually.

Written Chemical Hygiene Plan

The hazards in labs and the controls to minimize the hazards are uniquely different compared to industry. As a result the Occupational Safety and Health Administration (OSHA) regulates laboratory safety and health under a specific lab standard cited as 29 CFR 1910.1450. The most essential element of the OSHA/PESH lab standard is the development of a written chemical hygiene plan (CHP). Each facility should have a site-specific chemical hygiene plan. New York City public schools can accomplish this by modifying the New York City Board of Education "boiler-plate" chemical hygiene plan so that it provides information specific to the school. Every CHP should identify the chemical hygiene officer for the school.

Working with Chemicals

Flammable and Highly Reactive Chemicals

Laboratory work frequently requires the use of flammable chemicals such as alcohols, ketones, aliphatic, aromatic hydrocarbons and other organic solvents. Although the volumes used frequently are small, it is still often possible to cause fires or explosions in laboratory work. Some general

precautions for safe handling of flammable materials in laboratories are given below:

Use only in areas free of ignition sources- Flammable materials should obviously not be utilized near an open flame. However, in addition to open flames, ignition sources include electrical equipment, static electricity, and even hot surfaces.

Heating flammables- Never heat flammables with an open flame. Steam baths, water baths, oil and wax baths, salt and sand baths, heating mantles and hot air or nitrogen baths may be used.

Storing flammables - Chemicals that are flammable or combustible, including most organic solvents and oils, must be stored separate from other chemicals and in one of the following methods:

1. Small quantities may be stored in an Underwriters Lab (UL) approved safety can. These cans usually have self-closing lids, a flame arrestor under the lid, and a pressure vent.

2. If flammable or combustible chemicals are stored in the original shipping containers or in any container that is not a UL approved safety can, they must be stored in an approved flammable storage cabinet or room. An approved flammable storage cabinet is made of durable material (generally steel), has a sill at the door, and a liquid tight construction to prevent spills from leaking out. The doors are self-closing and they are labeled flammable. They are designed to protect the chemicals in a fire and prevent the interior from overheating for at least ten minutes during a fire. The cabinets must never be modified, and the bung covers and flame arrestors on the top and bottom of each side must be in place. Venting of these cabinets is not recommended nor is it required. The volume of chemicals in these cabinets is limited to 60 gallons.

3. An approved flammable storage room is designed to store larger quantities of flammable and combustible chemicals. Most high school labs have acid storage rooms which do not meet all the requirements for flammable storage rooms. For this reason, flammables must be

stored in approved safety cans or flammable storage cabinets. The requirements for a flammable storeroom include the following:

- The room and door must have two-hour fire rated construction.
- The room must have mechanical ventilation that provides 6 room air changes per hour.
- The floor must be impervious to chemicals and there must be a sill at the door.
- The electrical wiring in the room must be rated as Division 1 Class 1 or 2.
- The room must have a fire suppression system such as sprinklers or a dry chemical system.

Other important rules for storage of chemicals are listed below:

1. The quantities of chemicals should be limited as much as possible, but should never exceed the limits set by the NYC Fire Department.
2. Compressed gas cylinders should be secured upright.
3. Chemicals should not be stored near sources of heat and should be out of the sunlight.
4. Corrosive chemicals should be stored below eye level.
5. All chemicals should be properly labeled.
6. Chemicals should not be stored in the hood.
7. Chemicals should be segregated into compatible groups.
    - Oxidizers must be stored away from all other chemicals
    - Acids should be segregated from bases.
    - Nitric acid, a strong oxidizer, should be separate from other chemicals including acids, bases, flammables, and combustibles.
    - Concentrated acetic acid should be stored with the combustibles.

Hazardous Waste

There must be a comprehensive program for the identification, segregation, and disposal of hazardous chemical wastes. Such a program should include the development of laboratory procedures that minimize the generation of hazardous wastes and the development of procedures for the appropriate disposal of other chemical wastes. For example, dilute acids and bases (pH 5

- 9) can be poured down the drain. Salts and sugars and many other solid chemicals can be safely disposed of as nonhazardous waste.

Emergency Response Equipment

An essential part of life safety and chemical safety in the lab involves responding to emergencies and evacuation. In addition to fire extinguishers, and emergency flushing equipment (the eyewash, safety shower, combination drench hose/eyewash unit), the following items should be a part of emergency response:

1. There should be two unobstructed exits from each laboratory.
2. Access to the emergency flushing equipment (eyewash, safety shower, and or combination drench hose/eyewash unit) and fire extinguishers should be clear and unobstructed.
3. A fire blanket should be hung in an accessible and clearly visible area.
4. The master cutoff controls should be accessible and clearly labeled for the utility gas, electrical power, and in newer labs for water.
5. The locations of fire alarm pull stations should be identified and should be along the exit routes.
6. Emergency exit signs should be illuminated and should identify the pathways to the exits and the exit doors.
7. The evacuation routes should be posted.
8. Emergency phone numbers should be posted at the phone.
9. Fire doors should be kept closed unless the doors are controlled by electromagnetic openers that are part of the fire alarm system.
10. Chemical spill supplies should be readily accessible and appropriate for the types of chemicals used.

Chemical spills response

Laboratories should have chemical spill kits tailored to deal with the potential risks associated with chemicals used in the lab. Chemical spill kits are used to confine and limit the spill. The school administration is responsible for providing these kits. The spill kits should be located in an identifiable location near the exit from the lab. Typical spill kits include the following:

1. Spill control pillows, pads, rolls, booms, etc.

2. Inert absorbents (such as diatomaceous earth)
3. Mercury spill kits
4. Neutralizing agents acid spills
5. Neutralizing agents for alkali spills
6. Large plastic scoops and brooms, pails and bags
7. Appropriate personal protective equipment

Personal Protective Equipment

Each laboratory worker should be properly protected when handling chemicals. The school administration is responsible for providing the appropriate personal protective equipment for protecting the eyes, face, hands, and feet. Types of protective equipment typically used in lab work are summarized below:

Personal Clothing - The laboratory worker should wear clothes that do not expose large areas of the skin. Laboratory coats should be worn, and they should be buttoned and the sleeves rolled down. Lab coats should also be fire-resistant. Cotton is a good material for lab coats, but it reacts rapidly with acids. Lab coats should be left in the lab.

Foot Protection - Street shoes provide adequate protection for most general lab work but they may not be appropriate where some chemical or mechanical hazards exist. Sandals, clogs or shoes with openings should not be used.

Eye Protection - Safety glasses with side shields meeting the ANSI standard Z87.1 should be required in the lab. Chemical splash goggles should be worn when handling concentrated chemicals where there is a risk of splashing. Protective safety glasses may also be needed around lasers, UV light, cryogenics, or intense visible light.

Face Shield - When there is a chance of chemical splashes to the face or eyes both splash goggles and a face shield should be worn. A face shield is necessary when highly hazardous chemicals are used or when potentially explosive chemicals are used.

Hand Protection - The degradation and permeation characteristics of glove material from hazardous chemicals should be evaluated before choosing a glove. Glove selection guides are available from most manufacturers. For example, methylene chloride permeates latex in 30 seconds. The thin latex and vinyl gloves used in most laboratories are usually not appropriate for highly toxic chemicals. Heavy-duty gloves can and should be washed with soap and water after use. If they cannot be cleaned the gloves should be discarded.

Other Lab Equipment

Refrigerators

Refrigerators are commonly found in biological and chemical science laboratories. Refrigerators used in laboratories should be explosion-proof. Explosion-proof refrigerators are designed so that all ignition sources both inside and outside are sealed in explosion-proof housing and cannot ignite a vapor. There have been a number of laboratory explosions when flammable or combustible materials stored in standard, household, or commercial refrigerators. The light switches, the lights themselves and the thermostat have served as ignition sources to ignite the vapors.

Compressed
Gas
Cylinders

HANDLING COMPRESSED GASES IN THE LABORATORY

Compressed gases in laboratory settings present both physical and chemical hazards. Gases may be flammable, combustible, explosive, corrosive, poisonous, asphyxiants or a combination of hazards. Some gases are highly reactive or toxic. Even harmless gases such as nitrogen can cause asphyxiation if concentrations are high enough.

Compressed gases are contained in heavy, pressurized metal cylinders. The high pressure of the compressed gas makes the cylinder a potential rocket or bomb. Should the cylinder be damaged it can explode or become a projectile. The following procedures are necessary for safely handling the various compressed gases, the cylinders containing the compressed gases, regulators or valves used to control gas flow, and the piping.

1. Identification - The contents of any compressed gas cylinder should be clearly identified. The label should also indicate the hazard of the contents; such as flammable, toxic, reactive, corrosive, or oxidizer. Color coding is not a reliable means of identification since cylinder colors vary with the supplier. Labels on caps have little value as caps are interchangeable.

2. Signs should be conspicuously posted in areas where flammable compressed gases are stored, identifying the substances and appropriate precautions (e.g., HYDROGEN - FLAMMABLE GAS - NO SMOKING - NO OPEN FLAMES).

3. Store cylinders in an upright position.

4. <u>Secure the cylinder from falling</u> - Since gas cylinders are tall and narrow, they should be secured at all times to prevent tipping. Cylinders may be attached to a bench top, individually to the wall, placed in a holding cage, or have a non-tip base attached. Use a chain or cylinder strap to secure the cylinder. Attach the strap or chain at least 2/3's up the cylinder from the bottom.

5. Store cylinders away from heat (never in areas above 125 C), including steam or hot water pipes, and away from areas where they might be subjected to mechanical damage.

6. Compressed gas cylinders should not be subjected to rough handling or abuse. Such misuse can seriously weaken the cylinder making it unsafe.

7. Only wrenches or tools provided by the cylinder supplier should be used to open or close a valve. At no time should pliers be used to open a cylinder valve.

8. Cylinders containing flammable gases such as hydrogen or acetylene should not be stored in close proximity to open flames, areas where electrical sparks are generated, or where other sources of ignition may be present.

9. Oxygen cylinders as well as other oxidizers should not be stored in the same vicinity as flammable gases. Cylinders that are in use may be temporarily stationed together; such as oxygen and acetylene on a welding cart. Oxygen cylinders should be stored a minimum of 20 from flammable gas cylinders unless they are separated by a fire rated wall.

10. Piping material should be compatible with the gas being supplied. If in doubt check with the gas supplier when choosing gas line material. Be sure all connections are tight; use soapy water to locate leaks.

11. Always use safety glasses when handling and using compressed gases, especially when connecting and disconnecting compressed gas regulators and lines.

12. All compressed gas cylinders, including lecture-size cylinders, should be returned to the supplier when empty or no longer in use.

13. To transport a cylinder, use a hand truck equipped with a chain or belt for securing the cylinder. Make sure the protective cap covers the cylinder valve. Never move a cylinder while a regulator is attached. Do not move cylinders by carrying, rolling, sliding, or dragging them across the floor. Do not transport oxygen and combustible gases at the same time.

14. Keep the protective cap that comes with a cylinder of gas on the cylinder when it is not in use. The cap prevents the main cylinder valve from being damaged or broken.

15. Never empty a compressed gas cylinder completely. An explosive mixture can be created in the cylinder. When a cylinder is nearly empty close the

valve to prevent air and moisture from entering the tank, remove the regulator, replace the cylinder cap, and label the tank "EMPTY."

Things you never do to a compressed gas cylinder:

- Never roll a cylinder to move it.
- Never carry a cylinder by the valve.
- Never leave an open cylinder unattended.
- Never leave a cylinder unsecured.
- Never force improper attachments on to the wrong cylinder.
- Never grease or oil the regulator, valve, or fittings of an oxygen cylinder.
- Never refill a cylinder.
- Never use a flame to locate gas leaks.
- Never attempt to mix gases in a cylinder.
- Never discard pressurized cylinders in the normal trash.

ELECTRICAL

SAFETY

ELECTRICAL SAFETY IN HIGH SCHOOL LABORATORIES

Electrical Shocks

Electricity is a common hazard in the laboratory. Electricity travels in closed circuits and its normal route is through a conductor. Shock occurs when the body becomes part of the electric circuit. The current must enter the body at one point and leave at another. Shock normally occurs in one of three ways. The person must come in contact with: both wires of the electric circuit; one wire of an energized circuit and the ground; or a metallic part that has become "hot" by being in contact with an energized wire, while the person is in contact with the wire.

Accidental contact with electricity can cause serious injury or death. If people come in contact with a "live" (ungrounded) conductor while they are in contact with the ground, they become part of the circuit and current passes through their bodies. The most damaging route of electricity is through the chest cavity or brain. The table at the end of this document provides a summary of the effects of electrical current on the human body. As the table illustrates, a difference of less than 100 milliamperes exists between a current that is barely perceptible and one that can kill. Severe injuries, such as deep internal burns, can occur even if the current does not pass through the vital organs or nerve center.

Electrical Burns

The most common shock-related injury is a burn. Burns suffered in electrical accidents are of three basic types: electrical burns, arc burns, and thermal contact burns. Electrical burns are the result of the electric current flowing through tissue or bone. Tissue damage is caused by the heat generated by the current flow through the body. Electrical burns are one of the most serious injuries you can receive and should be given immediate attention.

Arc burns are the result of high temperatures near the body and are produced by an electric arc or explosion. Temperatures generated by electric arcs can melt nearby material, vaporize metal in close vicinity, and

burn flesh and ignite clothing at distances up to 3 m (10 ft). Thermal contact burns are those normally experienced from skin contact with the hot surfaces of overheated electric conductors, conduits or other energized equipment.

Delayed Effects

Damage to the internal tissues may not be apparent immediately after contact with the current. Delayed internal tissue swelling and irritation are possible. Prompt medical attention can help minimize these effects and avoid death or long-term injury.

Other Hazards

Electrical shocks that are not in themselves lethal or injuries can still cause secondary injuries. A minor shock could cause a worker to rebound into a lethal circuit. Such an involuntary reaction may also result in bruises, bone fractures, chemical spills and falls.

Electrical current can also start fires as a result of overheated equipment or by conductors that carry too much current.

Electrical Hazards in Labs

There are a number of potential electrical hazards in laboratories that increase the risk of electrical short circuits. These include:

1. Frequently lab equipment is used that does not have reliable equipment grounds run with the circuit supply conductors or the equipment ground was removed. If an electrical device is grounded, its cord will have a 3-prong plug and the required 3-way receptacle to accommodate it.

2. Another common hazard observed in NYC labs was the use of extension cords in place of permanent wiring. Extension cords are probably involved in more electrical code and safety violations than any other device at the laboratory. They are stepped on, stretched, cut, overloaded, and, in general, used improperly. If you must use an extension cord the following precautions should be followed:

• Use only approved and properly maintained extension cords that have no exposed live parts, exposed ungrounded metal parts, damage, or splices.
• Use only heavy-duty or extra-heavy-duty rated cable with three conductors (grounded). Never use two-conductor extension cords at the laboratory.
• Ensure that the extension cord is of sufficient current-carrying capacity to power the device. Use of an undersized cord results in an overheated cord and insufficient voltage delivered to the device.

3. Power strips are considered equivalent to an extension cord. Power strips are commonly used in offices to provide multiple receptacles to office equipment. In general, all rules pertaining to extension cords also apply to power strips. Do not permanently mount power strips to any facility surface. Power strips are classified as temporary devices.

4. Corrosive chemicals and organic solvents can erode electrical equipment and insulation on wires. This may expose live current carrying parts, which will cause shocks when contacted.

5. Operation of some equipment such as lasers and electrophoresis involves the use of high voltage. Higher voltages increase the risk of electrical shock to persons using the equipment.

6. Most laboratory benches have cup sinks and other water sources in close proximity to electrical outlets. When wet, human skin becomes a good conductor. This increases the likelihood of electrical shock even when handling equipment operated at 120 volts. Newer labs are constructed with ground fault circuit interrupters (GFCI) at each electrical outlet near sinks. The GFCI is designed to disconnect a circuit in less than one second when a current loss is detected of 5 milliamps or less. The GFCI prevents electrical shocks and electrocutions when electrical equipment is handled around wet areas.

7. Electrical equipment used in hazardous atmospheres that may be flammable or combustible must be approved. For solvents that are flammable it may be necessary to use equipment classified as Class I Division 2. This is often called intrinsically safe equipment. This

equipment is designed and manufactured so that it is not a source of ignition. Refrigerators used to store flammable liquids should be intrinsically safe.

8. Inspect electrical equipment before use. Look for broken or bent plugs, frayed cords, bare wire, smoke, sparks from switch controls, liquids spilled on or in equipment or erratic operation. If you notice or suspect any of these defects, DO NOT USE the equipment. Take it out of service and have it repaired by authorized personnel. Only trained, qualified persons should maintain electrical equipment.

Grounding

Most electrical tools and laboratory equipment are required to be grounded. Grounding makes equipment safe by:

- Providing a low-impedance path for any unintended voltage that is present on a metal parts of the equipment.
- Facilitating operation of an overcurrent device (fuse or circuit breaker), when internal wiring contacts the equipment case.

As noted above, if an electrical device is grounded, its cord will have a 3-prong plug and the required 3-way receptacle to accommodate it.

Electrical Equipment

Electricity is a common hazard in the laboratory. Under normal conditions, protection from shock is provided by the safety features of the electrical equipment, which must be listed or labeled by a Nationally Recognized Testing Laboratory. Nationally Recognized Testing Labs are recognized by OSHA as being capable of independently assessing equipment for compliance to safety requirements and applicable standards. OSHA has accredited the following organizations:

- Canadian Standards Association (CSA).
- Communication Certification Laboratories (CCL).
- ETL Testing Laboratories, Inc. (ETL).
- Factory Mutual Research Corporation (FMRC).
- MET Laboratories, Inc. (MET).

- Southwest Research Institute (SWRI).
- Underwriters Laboratories, Inc. (UL).
- United States Testing Company, Inc. California Division (UST/CA).
- Wyle Laboratories.

Electrical wiring and permanent equipment must be installed in a building according to the New York City Electrical Code and the National Electric Code (NEC). When installed properly electrical wiring and equipment have inherent safety features, which normally protect the building occupants.

What to do in an Emergency

Don't touch the person that is in contact with a live electrical source.

- Shut off the power (fuse or circuit-breaker or pull the plug)
- Remove the person from the contact point using a non-conductive object such as a dry piece of wood, or a leather belt.
- Follow the notification, evacuation, and emergency medical treatment procedures for your school. Get immediate medical attention when the person is obviously injured (loss of consciousness, significant trauma, etc.) or appears confused or has slowed speech.

It is important to realize that symptoms of electrical shock may be delayed. It is a good idea to seek medical attention for any person that has received an electrical shock.

Effects of Electric Current in the Human Body

Current	Reaction
1 Milliampere	Perception level. Just a faint tingle.
5 Milliamperes	Slight shock felt; not painful but disturbing. Average individual can let go. However, strong involuntary reactions to shocks in this range *can* lead to injuries.
6-25 Milliamperes (women) 9-30 Milliamperes (men)	Painful shock, muscular control is lost. This is called the freezing current or "let-go" range.
50-150 Milliamperes	Extreme pain, respiratory arrest, severe muscular contractions. * Individual cannot let go. Death is possible.
1,000-4,300 Milliamperes	Ventricular fibrillation. (The rhythmic pumping action of the heart ceases.) Muscular contraction and nerve damage occur. Death is most likely.
10,000- Milliamperes	Cardiac arrest, severe burns and provable death.

* If the extensor muscles are excited by the shock, the person may be thrown away from the circuit.

Source: W. B. Kouwenhoven, "Human Safety and Electric Shock," **Electrical Safety Practices**, Monograph, 112, Instrument Society of America, p. 93. (Papers delivered at the third presentation of the Electrical Safety course given in Wilmington, DE, in November 1968.)

HAZARDOUS

CHEMICAL SPILLS

AND RELEASES

& OTHER

EMERGENCIES

HAZARDOUS CHEMICAL SPILLS AND RELEASES & OTHER EMERGENCIES

Experiments should always be designed so as to minimize the possibility of an accidental release of hazardous substances. Be familiar with the properties (physical, chemical and toxicological) of hazardous substances before working with them. Make sure that the necessary safety equipment, protective apparel and spill control materials are readily available.

Laboratory emergencies require prompt action to prevent or reduce undesirable effects. Laboratory employees must be able to immediately take control of the situation and quickly assess the existing and potential hazards and carry out the appropriate response actions. Immediate hazards of fire, explosion, and release of toxic vapors, gases and particulates are of prime concern.

The type of response depends on the level of training of the responder and on whether the spill is an incidental release (non-emergency) or an uncontrolled release (emergency). Incidental or non-emergency releases are defined under the OSHA Hazardous Waste Operations and Emergency Response standard (29 CFR 1910.120) as those releases that have no potential safety or health hazards. Non-emergency spills or leaks can be absorbed, neutralized or otherwise controlled at the time of the release by employees in the immediate area or by maintenance personnel who are not considered emergency responders. Spill control procedures for incidental releases should be covered in Right-to-know (Hazard Communication, 1910.1200) training and in laboratory safety training (1910.1450).

Emergency releases are uncontrolled releases that require a response effort by employees from outside the immediate release area or by other designated responders such as the New York City Fire Department or a Board of Education Hazardous Materials contractor. The level of response depends on the level of training.

Some of the problem-solving scenarios in this course focus on emergency chemical releases whereas others involve incidental chemical releases. **As a lab specialist, you should only respond to incidental chemical releases, which are hereafter referred to as small spills in this manual.** The

following written emergency response procedures address spill response procedures for small spills. Large spills require an emergency response effort by employees or designated responders who have more specialized training.

The material herein is only a guideline. You must explore and know the specific procedures for your own school and those outlined in your school's School Safety Plan and Chemical Hygiene Plan.

Spill Control Equipment

The laboratory must have appropriate spill control materials. These materials may include commercial spill control products as absorbent pillows and/or spill kits that contain solid neutralizers for acids and alkalis and solid absorbents for organic solvents. Every laboratory using acids must have containers of sodium bicarbonate as per New York City Fire Department regulations. The spill kits should be labeled properly. For example, sodium bicarbonate for acid spills should be labeled "For acid spills" and not as sodium bicarbonate.

SPILLS THAT CAN BE CLEANED UP IN-HOUSE:

Spill control for acids, alkalis and solvents:

> As a general guideline, spills of less than 1 liter of these materials are considered small (that is, incidental). However, spills of particularly hazardous substances regardless of the amount spilled, may be hazardous. Particularly hazardous substances include carcinogens, reproductive toxins, and substances with a high degree of acute toxicity. Ordinarily such substances should not be used or stored in the school laboratory. Whenever a spill occurs, treat the spill as a potentially dangerous situation until the spill is cleaned up.

The Chemical Hygiene Plan should specify the types of incidental spills that can be cleaned up by lab specialists. As an example, the CHP for one school laboratory may state:

The following spills may be cleaned up if spills are less than 1 liter of the materials below:

- Dilute (less than 5 Normal) acids including nitric, hydrochloric, glacial acetic and sulfuric
- Dilute alkalis such as ammonium hydroxide
- Organic solvents such as isopropyl alcohol, petroleum ether, acetone, hexane, and toluene

The following materials may be cleaned up if spills are less than 0.25 liters:

Concentrated acids including nitric, hydrocholoric and sulfuric

Standard Operating Procedures (SOPs) for chemical spills and releases:

1. Quickly assesses whether there are any injured persons and attend to any person who may have been inured and/or contaminated. Treating victims will generally take priority over the spill control measures outlined below.

2. Follow the notification, evacuation and emergency medical treatment procedures for your school and if necessary, the procedures for notification to the DOE Office of Occupational Safety and Health (DOE OOSH) at 718 935 2319 and the DOE Division of School Facilities Environmental Health and Safety (DOE EHS) office (718 361-3808). Be sure to give as much information as possible (chemical name and chemical category such as corrosive, flammable, toxic, reactive; amount; location, etc.). Arrangements should be made to request an ambulance if there appears to be serious injuries.

3. Evacuate the immediate area until the hazardous release has been characterized and controlled. Take steps to confine and limit the spill if this can be done without injury or contamination. A spill of a hazardous chemical can produce a very dangerous situation or can be fairly minor depending on many factors, such as chemical

toxicity, physical state, vapor pressure, reactivity, temperature, location of the spill (small storeroom versus large classroom), whether there is adequate ventilation, etc. In the event of a flammable spill, extinguish ignition sources on your exit route. For large spills, hit the emergency stop button or remotely shut off electrical power to the laboratory (circuit panel or fuse box) to prevent sparks setting off a fire or explosion (turning light switches on or off can create sparks). Shut the laboratory doors after everyone has safely exited in order to control the potential spread of the release.

4. Conduct clean-up of small spills only if you have the proper spill control materials and personal protective equipment.
   a. Wear personal protective equipment such as laboratory coats, eye goggles, face shield, and gloves that will provide chemical resistance protection. Latex surgical gloves do not provide adequate protection against most materials. Respirators may be necessary even in a small spill clean-up, depending on the substance. Respirators are not approved for normal use in the laboratory. **You should not conduct spill cleanup if respirators are required.**

   b. Use the proper spill clean-up material such as liquid or solid neutralizers for acid or base spills, and solid absorbents or commercial pillows, pads and booms for solvent spills.

   c. Confine the spill to a small area. Do not let it spread. Dispose of all spill clean-up material in an appropriately marked hazardous waste container and label the contents. Neutralized (such as acid or base) spills that contain no other hazardous contaminants can be disposed of as solid waste. Fill out an incident report form and contact the Assistant Principal of Science or the Chemical Hygiene Officer for follow-up. Make arrangements with DOE DSF EHS for correct disposal of hazardous materials.

Standard small spill cleanup procedures:

Small or incidental spills can be cleaned up in-house by laboratory specialists. Conduct clean-up of small spills only if you have the proper spill control materials and personal protective equipment. If you are unsure whether to initiate clean-up procedures, DON'T. Follow the notification, evacuation, and emergency medical treatment procedures for your school, including notification to the Board of Education Division of School Facilities Environmental Health and Safety (DOE DSF EHS) and/or Office of Occupational Safety and Health (OOSH). DOE DSF EHS and/or DOE OOSH will have an outside hazardous materials consultant or designated hazardous materials response team handle the release.

Spills of solid materials

a. Most solid chemicals used or stored in the lab can be cleaned up when spills are in quantities of 1 pound or less. Solids include dry silica gel powder and diatomaceous earth. (Some forms of diatomaceous earth such as calcined or cooked diatomaceous earth contain higher percentages of crystalline silica, a suspected human carcinogen. Chronic exposure to crystalline silica may also cause silicosis, a permanent scarring of the lung tissue. Uncalcined (natural) diatomaceous earth, which is referred to as amorphous diatomaceous earth, has much less crystalline silica (less than 1%) and is considered a nuisance dust). Spills of these materials can be cleaned up using protective equipment outlined below. Do not dry sweep dry silica powder or diatomaceous earth. If possible, lightly mist with water prior to removal. Scoop up powder with a clean shovel or scoop and place in a dry container approved by the Department of Transportation. Flush the spill area with water and then wash the area with a detergent. Fill out an incident report form and contact the Assistant Principal of Science or Chemical Hygiene Officer for any needed follow-up. Dispose of this material as regular waste but contain it so as to minimize the generation of any airborne dust or particulates.

b. Solid materials that are highly hazardous should not be cleaned up by lab personnel even when spilled in small quantities.

2. Spills of acids or alkalis

a. Neutralize the spilled chemical with the appropriate material such as sodium bisulfate, citric acid, or boric acid for alkalis and sodium carbonate or sodium bicarbonate for acids. Cautiously start at the outer edge of the spill and work in towards the center. There may be some splashing due to the exothermic reaction when neutralizing acid spills. Monitor the effectiveness of the neutralization with pH paper. Be sure to protect any floor drains in the area.

b. Clean up the neutralized material. Dispose of all properly neutralized material as regular waste. Flush the spill area with water and then wash with a detergent.

c. Fill out an incident report form and contact the Assistant Principal of Science or Chemical Hygiene Officer for any needed follow-up.

d. Although commercial absorbents such as spill pads, pillows and booms can be used to soak up acid or alkali spills, such materials are not recommended. Because the acid or alkali is not neutralized, all spilled material must be disposed of as hazardous waste. Therefore chemical neutralizers are the preferred method of acid or alkali spill clean-up.

3. Spills of flammable solvents

a. Fast action is crucial. Immediately alert everyone in the laboratory to evacuate, extinguish all ignition sources on the way out, and remotely shut off power to the laboratory, if possible. Remotely shut off power to avoid creating sparks or static electricity. For example, turning light switches on or off can create sparks.

b. Maintain any laboratory fume hood ventilation as this will help exhaust vapors from the area. Window can also be opened.

c. Soak up the spilled solvent with spill control pillows, pads, booms, etc. Activated charcoal can be sprinkled over the spill to absorb flammable

vapors. (It is the vapors that ignite, not the liquid). Start at the outer edge and work in towards the center. Protect any floor drains in the area. Clean up the contaminated material using spark-proof tools such as plastic, bronze, etc. Place the contaminated material in an appropriate hazardous waste bag or container, date and label the contents, and arrange for pickup. Flush the spill area with water and then wash with a detergent.

d. Fill out an incident report form and contact the Assistant Principal of Science or Chemical Hygiene Officer for any needed follow-up.

Large spills - Spills Handled by Designated Hazardous Materials Responders

Large spills of materials are those that exceed the quantities outlined above. Only hazardous materials consultants or designated hazardous materials responders can clean up such releases. The following procedures should be followed for large spills:

1. Quickly assess whether there are any injured persons and attend to any person who may have been contaminated.

2. Follow the notification, evacuation and emergency medical treatment procedures for your school, including notification to the DOE Office of Occupational Safety and Health (DOE OOSH) at 718 935 2319 and the DOE Division of School Facilities Environmental Health and Safety (DOE EHS) office (718 361-3808. The Board will make arrangements to bring in outside emergency response teams. Be sure to give as much information as possible (chemical name and chemical category such as corrosive, flammable, toxic, reactive; amount; location, etc.). Arrangements should be made to request an ambulance if there appears to be serious if there appears to be serious injuries.

3. Evacuate the immediate area until the hazardous release has been characterized and controlled. A spill of a hazardous chemical can produce a very dangerous situation or can be fairly minor, depending on many factors, such as chemical toxicity, physical state, vapor pressure, reactivity, temperature, location of the spill (small storeroom versus large classroom, whether there is adequate ventilation, etc). In the event of a flammable

spill, extinguish ignition sources on your exit path and remotely shut off electrical power to the laboratory (circuit panel or fuse box) to prevent sparks setting off a fire or explosion. For example, turning light switches on or off can create sparks. Shut the laboratory doors after everyone has safely exited in order to control the potential spread of the release.

Other Types of Releases

Compressed gas cylinders

For laboratories that use compressed gas cylinders, the following procedures apply regarding leaking compressed gas cylinders:

1. Occasionally, a cylinder or one of its component parts develops a leak. Such leaks often occur around the manifold in areas such as valve thread, safety device, valve stem and valve outlet. If a leak is suspected, use a flammable gas leak detector or soapy water or other suitable solution. The presence of bubbles in soapy water indicates a leak.

2. If the leak cannot be remedied by tightening a valve gland or packing nut, follow the notification, evacuation and emergency medical treatment procedures for your school and also notify the supplier. Laboratory employees should never attempt to repair a leak at the valve threads or safety devices.

3. The following are standard operating procedures for compressed gases in the lab. Leaking cylinders should be kept in an isolated, well-ventilated laboratory area near the laboratory fume hood. If possible, post warning signs describing the hazard and precautions to be taken until the supplier can come. Leaking flammable gas cylinders should be moved outdoors to a secure, isolated area.

4. Fill out an incident report form and contact the Assistant Principal of Science or Chemical Hygiene Officer for any needed follow-up.

NYC Department of Education

Office of Occupational Safety and Health
718-935-2319 | www.schools.nyc.gov/offices/DHR/OSH

MERCURY REMOVAL IN SCHOOLS

Mercury is a silver-colored, liquid metal that occurs naturally in the earth's surface. Mercury was used for many years in measurement intruments used by schools, primarily in science labs but also in the nurse's office, gymnasiums, and boiler rooms. Schools should ensure that staff members understand the dangers associated with mercury and follow the specified protocols below if mercury is located or spilled.

WHERE IS MERCURY FOUND IN SCHOOLS? Liquid mercury is used in measurement instruments including thermometers, barometers, sphygmomanometers, sling psychrometer, hygrometers, laboratory manometers, anemometers, etc. Mercury can also be found in lights (particularly gymnasium and fluorescent lights), thermostats, heating/ventilation and air conditioning (HVAC) systems, plumbing, cafeteria equipment and medical devices.

WHY IS MERCURY DANGEROUS? Mercury's properties are toxic and allow it to break into small droplets and vaporize. Mercury can be absorbed through the skin, lungs or intestinal tract in either liquid or gaseous form and can affect the central nervous system, resulting in memory loss, headache, sleeplessness, irritability, and tremors. Short-term exposure to high levels can also cause coughing, shortness of breath, chest pain, nausea, vomiting, diarrhea, fever, high blood pressure and skin rashes. In 2004, New York State banned the purchase of elemental mercury in schools.

WHAT SHOULD A SCHOOL DO TO PREVENT MERCURY EXPOSURE? Schools should inform staff that instruments containing mercury may be present in the school. Staff members should thoroughly inspect rooms for instruments or containers that house mercury.

WHAT SHOULD A SCHOOL DO IF MERCURY IS LOCATED? Do not handle, move, or remove items containing mercury. Mercury requires professional disposal and can cause hazardous conditions and expensive damage if it is discarded or poured down the drain.

1. Use the *Inventory form* to document the location of any equipment containing mercury.
2. Provide the form to your custodian who should prepare a Passport work request for mercury removal, using Trade Code 75.
3. The DOE Deputy Director of Facilities (DDF) will approve the work request and have a work order prepared for removal by a professional waste removal company.
4. The professional waste removal company will use the inventory to locate and remove mercury sources, and may conduct an assessment of the area where the mercury was found to determine whether it has spilled.

WHAT SHOULD A SCHOOL DO IF MERCURY SPILLS?

1. Do not touch it or attempt to clean it up.
2. Evacuate the area immediately.
3. Close and lock the door to the affected area.
4. Immediately notify the principal and custodian, who will arrange for professional clean-up.

WHAT SHOULD SCHOOLS DO TO REPLACE EQUIPMENT WITH NON-MERCURY ALTERNATIVES? Schools should ensure that devices containing mercury are handled professionally, in accordance with the protocols decsribed above. Schools can replace devices with alternatives that do not contain mercury.

DEVICES CONTAINING MERCURY	REPLACEMENT ALTERNATIVES
Lab thermometer	Alcohol glass bulbs, mineral spirits glass bulbs, or digital.
Barometer	Aneroid or digital; new liquid one is being developed.
Spectrum tube	Ask your scientific supplies distributor for a list of alternative gases
Gas law apparatus	A simple Charles' Law Apparatus may suffice.
Anemometer	Digital versions are available.
Other metallic mercury containing instruments	Check with the original manufacturer for contents of older devices and components; they may have a swap-out program available. Non-mercury alternatives are available for most instruments. Additional information is available at: http://www.epa.gov/glnpo/seahome.

Mercury is Banned from Schools

A 2004 New York State regulation prohibits all storage, use and purchase of mercury and mercury-containing devices in primary and secondary schools.

Most school science labs have widely eliminated use of elemental (metallic) mercury for experiments as well as mercury-containing thermometers, and manometers. However, inspections of labs still reveal its use despite this 2004 New York State regulation which took effect on September 4, 2004.

Mercury Exposure is a Health Concern

Exposure to metallic mercury can occur by breathing mercury vapors or via skin contact with liquid mercury. Metallic mercury is a silvery liquid metal that releases mercury vapor into the air at room temperature. Mercury vapor is colorless and odorless.

Metallic mercury can cause serious health effects depending on the level of exposure. The nervous system is very sensitive to all forms of mercury. Metallic mercury vapors are more harmful than other forms, because more mercury in this form reaches the brain. Chronic exposure to high levels of metallic, inorganic, or organic mercury can permanently damage the brain, kidneys, and developing fetus.

Mercury Inventory and Removal

- Schools (science faculty) must conduct an inventory to identify mercury and mercury-containing items in the science facilities and complete the proper hazardous chemical removal request forms.
- Carefully canvass your classrooms, preparation rooms, storerooms, under sink areas, and cabinets for bottles, jars or vials that contain mercury.
- Follow the recommendations outlined at http://www.uft.org/chapter/lab/resources/mercury-removal/
- School personnel must not attempt to move or relocate these containers and devices or clean up any visible mercury.
- Notify the principal and custodian as to the location and amount and number of any containers or devices (mercury thermometers included). Complete the Chemical Removal Request Form (www.uft.org/chapter/lab/forms/ChemicalRemovalForm.pdf) and please include the room number and specific location within the room that the suspected mercury has been found. The administration and custodian will arrange for proper removal of these items.
- The AP must sign off that the inventory has been done and indicate either that there is no mercury/mercury-containing devices on-site or that all

mercury/mercury containing devices will be removed following the hazardous chemical removal procedures outlined by the DOE Division of School Facilities (DSF).

- As soon as the DOE Division of School Facilities (DSF) receives the hazardous chemical removal request form, DSF will make arrangements for removal.
- A professional hazardous chemical removal company will remove the mercury and mercury-containing items.

What to do if you see beads of mercury or there is mercury spill

Accidental spills have happened when well-intentioned staff has moved mercury or mercury containing items. If you see evidence of mercury (such as beads of mercury) or if there is an accidental release or spill of mercury:

- Evacuate and Isolate (for example, close and lock the door) the Room/Affected Area and Notify.
- IMMEDIATELY follow the notification procedures for your school and also notify:
    - UFT Health & Safety Department at 212-598 9207
    - DOE Office of Occupational Safety & Health at 718-935-2319
    - DOE Division of School Facilities Environmental Health & Safety Department at 718-361-3808
- DO NOT ATTEMPT ANY CLEANUP.

Removal of mercury and mercury-containing items

A professional hazardous chemical removal company will remove these items. After any clean up and removal of mercury and mercury-containing items, a professional monitoring company will monitor for mercury vapor to verify that the area is safe for occupancy by students and staff.

NYCDOE Office of Occupational Safety and Health

The NYCDOE Office of Occupational Safety and Health prepared a brochure "Mercury Removal in NYC Department of Education Facilities". Please refer to this brochure at www.xxxx.xxxx for specific instructions and guidance regarding the mercury inventory and removal of mercury and mercury-containing equipment.

We need your help

We need your help and cooperation to ensure our schools are safe and free of mercury and mercury-containing devices.

UFT

MERCURY MONITORING

Most school science labs have widely eliminated use of elemental mercury for experiments as well as mercury-containing thermometers, and manometers. However, inspections of labs still reveal its use despite the 2004 New York State regulation that prohibits all storage, use and purchase of mercury and mercury-containing devices in primary and secondary schools.

The use or storage of mercury has an associated risk of spills. In the past, mercury may have been spilled from containers or when thermometers were broken. In one college lab, a plumber removed a clogged sink trap and over one pound of mercury spilled into the cabinet and floor. Most people didn't realize that when mercury was poured down the drain it settles in the trap and stayed there. Droplets of mercury become trapped in the crevices between and beneath floor tiles, under cabinets, and will soak into wood. Cleaning up mercury spills is extremely difficult and past spills, no matter how carefully cleaned, will leave an invisible residue. Unfortunately after a spill the droplets of mercury trapped in building materials can release mercury vapor into the air. Inhalation of the mercury vapors will result in absorption of the mercury into the blood stream. The mercury can also be absorbed through the skin when in contact with contaminated surfaces or materials.

Over time mercury droplets often form an oxidized skin that reduces the release of vapors, however vibrations or building maintenance activities can disturb mercury and permit evaporation. Measuring airborne mercury vapor is frequently the most effective method for detecting the presence of mercury contamination in materials, and it also provides information on the level of mercury exposure.

The best way to assess airborne mercury is by measuring vapors with a real-time monitor that detects levels as low as 0.001 milligrams of mercury per cubic meter of air (mg/m^3). The monitor uses a gold foil as part of a Wheatstone bridge in a circuit. The mercury plates out on the gold, changing the resistance of the circuit, causing a response on the equipment. The gold foil can be regenerated after each use. This method is specific to mercury, and there are no interferences from other contaminants. The important feature of the mercury vapor monitor is that it can be used to "sniff out" the presence of mercury contamination in building materials. Normally the background level of mercury in air is 0.000 mg/m^3. Any measured mercury is indicative of contamination and every effort should be made to eliminate or encapsulate contamination.

Exposure Limits

The Occupational Safety and Health Administration (OSHA) has set a ceiling limit (which must not be exceeded) of 100 micrograms of inorganic mercury per cubic meter of air (or 100 ug/m^3) and 50 ug/m^3 averaged over an 8-hour shift and 40-hour work week. OSHA regulations for public sector workplaces in New York State are enforced by the New York State Department of Labor Public Employees Safety and Health Bureau. This regulatory levels are intended to prevent long-term health effects for adults exposed to airborne mercury. These limits will not adequately protect children. The presence of mercury vapor levels at the PEL requires immediate action; however, even levels below the PEL may indicate a problem.

New York City Department of Health and Mental Health Reoccupancy Criteria

The New York City Department of Health and Mental Health criteria for reoccupancy is that all breathing zone measurements must be less than 1 ug/m^3. This limit is designed to protect children.

Mercury Spills

It is important to differentiate the health implications between a small mercury spill and larger ones. A spill of a few droplets of mercury from a thermometer onto the floor or a tabletop can usually be cleaned sufficiently with a mercury spill kit. Any residue of mercury in the spill area can be absorbed and amalgamated using the materials in the spill kit. Our experience using the mercury vapor monitor has shown that using a mercury spill kit to clean small spills is effective and results in negligible exposure to airborne vapors.

Monitoring mercury levels for all spills regardless of size

Monitoring mercury levels after any type of release or spill must always be done. Be sure to immediately report all releases and spills of mercury regardless of size.

Call the UFT Health and Safety Department at 212-701-9404, the DOE Office of Occupational Safety and Health at 718-935-2319, and the DOE Division of School Facilities Environmental Health and Safety Department at 718-361-3808.

UFT

How to have unwanted chemicals and chemical waste removed

- During the course of your annual chemical inventory take note of any chemicals that should be considered for removal. **Any and all mercury and mercury containing devices** should be included in removal as per the 2004 New York State law which prohibits the storage, use and purchase of mercury and mercury-containing devices in primary and secondary schools.
- Inform your Assistant Principal of any chemicals that are old, in excess of what is needed, & have deteriorating containers.
- Biological specimens that are not properly sealed and are off gassing should be included with other unwanted chemicals.
- Confer with the Assistant Principal and grade leaders/teachers to ascertain which chemicals and specimens need to be removed and disposed of properly. Any and all mercury must be removed.
- Use the "Chemical Removal Form" to complete the list.
- When completing the form be as specific as possible as to the number, and sizes of containers that are to be removed. Any unidentified chemicals should be included on the list as " unknown" or waste.
- **Do not pack or move the chemicals or mercury containing devices yourself. Identify the container for removal with a mark or tag.** Once tagged/marked the assistant principal and custodian should be shown where these items are located.
- When the list is completed the Assistant Principal will ask the custodian to prepare a PO 18 request for chemical removal, attaching the prepared list(s) of chemicals.
- PO 18 request should use Trade Code 75 Crew # IN27 Job type EB.
- The custodian then contacts the DOE Deputy Director of Facilities (DDF) to prepare a work order for removal.
- Keep a copy of the request and list(s) in your files.
- The DOE Deputy Director of Facilities (DDF) manager will also **fax** the request to the attention of M. Pedram at 718-361-3844.

In the event of a chemical release or spill (for example mercury) immediately call the UFT Health and Safety Department at 212-701-9407, the DOE Office of Occupational Safety and Health at 718-935-2319, and the DOE Division of School Facilities Environmental Safety and Health Department at 718-361-3808. Follow notification procedures for your school.

June 2010

- Make as many copies of this form as needed.
- Attach the form(s) to a PO I8 request
- Keep a copy for your records

Fax to: (718) 361-3844
Att: M. Pedram

Via Passport System
Notify M. Pedram

Use: **Trade Code 75 – Crew# IN27 – job type EB** on the PO I8 request.

Chemical Removal Request Form

School:____

Address:____

Borough:__________________________**Zip Code:**______-_____

Date:__________________

Name of chemical	Number x Size = Total	Room No.
	x =	
	x =	
	x =	
	x =	
	x =	
	x =	
	x =	
	x =	
	x =	
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	x =	
	x =	

Principal's Signature:__________________

Contact Person:__________________ **Telephone:**(___)____________
Custodian:______________________ **Telephone:**(___)____________

Biohazard spills

The following are guidelines for cleaning up blood.

1. Follow the notification, evacuation and emergency medical treatment procedures for your school and if necessary, notification to the DOE Office of Occupational Safety and Health (DOE OOSH) at 718 935 2319.

2. Wear the appropriate personal protective equipment (lab coat, goggles and 2 pairs of gloves).

3. Cover the spill with absorbent material.

4. Apply a 1:10 sodium hypochlorite (household bleach) solution directly to the spill area.

5. Allow the solution to remain for at least 30 minutes.

6. Dispose of all material using a mechanical device such as forceps and place in a red BIOHAZARD disposal bag. Contact the custodian (who is in charge of the medical waste storage and pickup).

7. The spill area should be flushed with water and washed with a detergent.

8. Fill out an incident report form and contact the Assistant Principal of Science or Chemical Hygiene officer for any needed follow-up.

After any chemical release or blood spill, you should contact the Lab Specialists Chapter Leader Laurie Campetella at 212 598-7764 and Catherine Henihan at UFT Safety & Health office at 212 589-7757 so that the UFT can follow up on the status of the spill response.

FIRE SAFETY/FIRE EMERGENCIES

Weekly inspection of the laboratory should be conducted and include the following:

Laboratory inspection:

- Means of egress from the laboratory must not be blocked. An unobstructed path to the exit must be maintained at all times.

- Access to emergency equipment, safety showers, eyewashes, combination drench hose/eyewash units, fire extinguishers, first aid kits, etc. must not be obstructed. Test the eyewashes and combination drench hose/eyewash units weekly to make sure they are functioning properly. (The custodian should test the safety shower periodically to ensure proper functioning).

- Chemicals stored and used in the laboratory must be limited to daily needs only. Chemicals not required for the procedure(s) in progress are to be promptly stored in the appropriate cabinets or chemical (acid) storeroom.

- Fire extinguishers must be charged, tagged and dated.

Corridor inspection:

- Exit signs on the floor must be illuminated.

- Stairwell doors must be operational.

- Stairwells must be clear and unobstructed.

- Conduct a weekly visual check of fire extinguishers. Fire extinguishers must be tagged, charged and dated.

Evacuation:

Upon hearing the fire alarm:

- Follow the procedures for your school each and every time the alarm sounds. These procedures can be found in the *"School Safety Plan"*.

When evacuating the building:

- Exit the laboratory, turning off all equipment in your path of travel, and close the laboratory door as you exit.

- Exit the building via the staircase. Never use the elevator. Do not reenter the building for any reason until you have received permission from the New York City Fire Department or the School Fire Marshal.

Upon discovering a fire:

- Evacuate the area, closing all doors in your path of travel.

- Alert all occupants by sounding the building alarm system from the manual pull stations located at the exit stairways throughout the building.

- Follow the notification, evacuation and emergency medical treatment procedures for your school. The individual discovering a fire must report as much information as possible to the principal, security officers, and/or arriving firefighting forces including floor of incident, room number, type of room (laboratory, storeroom, office, etc.) substances or materials involved, if known, and any other pertinent information such as explosives, water-reactives, etc.

Fire extinguishment:

Fires in small vessels can usually be suffocated by loosely covering the vessel. Never pick up a flask or container of burning material.

A small fire (noticeably less than 1 foot), which has just started, can sometimes be extinguished with a laboratory fire extinguisher. Extinguish

such fires if you have been trained in the use of portable fire extinguishers, are confident that you can extinguish the fire successfully and quickly, and can do so from a position in which you are always between the fire and your back is to an exit from the laboratory. In general: remove the fire extinguisher form its bracket, maintain the means of egress to your back to provide a means of escape in the event the fire is not extinguished.

Remember "PASS"

Pull the pin
Aim the nozzle at the base of the fire
Squeeze the handle to discharge the product
Shoot the product at the base of the fire, moving the nozzle in a sweeping motion from side to side.

Do not stop the discharge of product from the fire extinguisher until you have backed away from the fire source.

Follow the notification procedures for your school. Upon extinguishment, the affected areas should be inspected by the appropriate school personnel and/or NYC Fire Department and arrangements should be made for the proper removal of burned and/or contaminated materials.

Small fires involving reactive materials and organometallic compounds, (such as magnesium, sodium, potassium, etc.) should be extinguished with Class D fire extinguishers.

Personal injuries involving fires:

Minor clothing fires can sometimes be extinguished by immediately dropping to the floor and rolling. (**Stop, Drop, & Roll**). If a person's clothing catches fire, the victim should be doused with water from the safety shower or drench hose. Fire blankets should only be used as a last-resort measure to extinguish fires since they tend to hold in heat and to increase the severity of burns. Quickly remove contaminated clothing, douse the person with water, and place clean, wet cold cloth on burned areas. Wrap the victim in a blanket to avoid shock and get medical attention immediately.

Medical Emergencies

In the event of a medical emergency, it is important to remain calm and to do only what is necessary to protect life.

Follow the notification procedures for your school to summon assistance. Emergency Medical Service personnel will respond and can transport the injured to the hospital.

Do not move an injured person unless he or she is in danger of further harm.

If a person has ingested a toxic substance, follow the procedures at your school to contact Poison Control at 212 764 7667 and to obtain medical assistance at once. Attempt to learn exactly what substances were ingested and inform the medical staff as soon as possible.

If a person is bleeding severely, elevate the wound above the level of the heart and apply firm pressure directly over the wound with a clean cloth, handkerchief or your hand. Obtain medical assistance. Wear personal protective equipment to prevent exposure to blood and other body fluids.

Do not touch a person in contact with a live electrical circuit - disconnect the power first!

Procedures for handling medical emergencies involving exposure to hazardous substances include the following:

If an individual is injured or contaminated with a hazardous substance, then treating the victim generally will take priority over spill control measures. It is important to obtain medical attention as soon as possible.

For spills covering small amounts of skin, immediately flush with flowing water for no less than 15 minutes. If there is no visible burn, wash with warm water and soap, removing any jewelry to facilitate removal of residual materials. Check the MSDS to see if any delayed effects should be expected. Seek medical attention for even minor chemical burns and give a copy of the MSDS to the medical personnel.

For spills on clothes don't attempt to wipe the clothes. Quickly remove all contaminated clothing, shoes and jewelry while using the safety shower or drench hose. Seconds count and no time should be wasted because of modesty! Be careful not to spread the chemical on the skin, or especially in the eyes. Use caution when removing pullover shirts or sweaters to prevent contamination of the eye; it may be better to cut the garments off. Immediately flood the affected body with warm (tepid) water for at least 15 minutes. Resume if pain returns. Do not use creams, lotions or salves. Get medical attention as soon as possible. Contaminated clothes should be discarded or laundered separately from other clothing.

For splashes in the eye, immediately flush the eye(s) with potable water from a gently flowing source for at least 15 minutes. Hold the eyelids away from the eyeball, move the eye up and down and sideways to wash thoroughly behind the eyelids. An eyewash should be used, but if one is not available, injured persons should be placed on their backs and tepid (warm) water gently poured into their eyes for at least 15 minutes. First aid must be followed by prompt treatment by a member of a medical staff or an ophthalmologist especially alerted and acquainted with chemical injuries.

Chemical burn accident at a university in New York City

This incident occurred at 7:00 PM the evening before Thanksgiving. Two students were cleaning up a laboratory. During the clean-up, a bottle of ethylamine was accidentally broken and ethylamine splashed onto the arms of one of the students. Because the student was not aware of the safety shower, the ethylamine was not immediately washed off, resulting in severe chemical burns on both arms.

CHEMICAL DISPOSAL

CHEMICAL DISPOSAL

Chemicals must be disposed of in ways that avoid harm to people and the environment. The methods of disposal must comply with local, state and federal laws including the Federal Resource Conservation and Recovery Act (RCRA). Local laws are administered and enforced by the New York City Department of Environmental Protection (NYCDEP). State and federal RCRA regulations are administered and enforced by the New York state Department of Environmental Conservation (NYSDEC).

Consideration of the means of disposal of chemical wastes should be part of the planning of all experiments before they are carried out. The cost of disposing of excess and waste chemicals has become extremely expensive and can even exceed the original cost of purchasing the chemical by **5 to 10** times. Whenever practical, order the minimum amount of material possible in order to avoid the accumulation of large stocks of "excess chemicals". Such collections of "excess chemicals" frequently constitute safety hazards, since many substances decompose upon long storage and occasionally their containers become damaged or degrade. In addition, the disposal of significant quantities of excess chemicals ultimately presents a very significant financial burden.

Under RCRA, hazardous wastes are those chemical wastes that are included on one of several regulatory lists (and referred to as listed wastes) or that meet the defined characteristics as ignitable, corrosive, reactive or possessing a toxicity characteristic. RCRA defines these characteristics as follows:

Ignitability

A solid waste exhibits the characteristic of ignitability if the waste exists in any of the following forms:

- Liquid, other than an aqueous solution containing less than 24% alcohol, by volume and with a flash point less than 60 degrees C (140 ^{0}F).

- Not a liquid, which under standard conditions is capable of causing fire through friction, absorption of moisture, or spontaneous chemical changes and when, ignited, burns in a manner that creates a hazard.
- Ignitable compressed gas, a compressed gas that under certain conditions forms a flammable or explosive mixture with air.
- Oxidizer, a "substance such as chlorate, permanganate, inorganic peroxide, or a nitrate that yields oxygen readily to stimulate the combustion or organic matter" (quoted from 49 CFR 173.151).

Corrosivity

A solid waste exhibits the characteristic of corrosivity if the waste is:

- Aqueous and has a pH less than or equal to 2, or greater than 12.5 , using EPA-specified or approved test methods, or
- Liquid and corrodes steel (SAE 1020) at a rate greater than 6.35 mm (0.250 inch) per year at a test temperature of 55 ^{0}C (130 ^{0}F).

Reactivity

A solid waste exhibits the characteristic of reactivity if the waste:

- Is normally unstable and readily undergoes violent change without detonation, or
- Reacts violently with water, or
- Forms potentially explosive mixtures with water, or
- Generates toxic gases, vapors, or fumes when mixed with water, or
- Is a cyanide or sulfide bearing waste that generates toxic gases, vapors, or fumes at a pH between 2 and 12.5, or
- Is capable of detonation or explosive reaction when subject to a strong initiating source or if heated in confinement.

Toxicity characteristic

A solid waste exhibits this characteristic when the EPA-defined test procedure (Toxicity Characteristic Leaching Procedure (TCLP) indicates that an extract derived from the waste contains at least one of a specified group of heavy metals, organic toxicants, and pesticides at a higher level than the regulatory level. The TCLP deals with the risk to human health by ground

water contamination and not environmental risks or risks to human health by other methods of exposure.

Specific Procedures for Chemical Disposal

This section presents specific procedures for the most common classes of chemicals. Follow the procedures outlined in the January 2001 Lab Specialist Health and Safety training manual (with the gray cover). Provide a list of unwanted chemicals and/or hazardous waste to the Assistant Principal who will have the custodian prepare a Work Order (PO 18) request with this list. Disposal of excess and waste chemicals is arranged by faxing the PO 18 and the list of chemicals to Board of Education Division of School Facilities Environmental Health and Safety Office (718-361-3808). Do not pack the chemicals yourself. A DOE DSF EHS hazardous materials/waste contractor will pick up and properly pack the waste chemicals for shipment. The contractor generally will pack the materials in break-resistant containers (metal, plastic or plastic-coated glass or in breakable containers enclosed within "approved secondary containers" (i.e. large rubber, metal or plastic bottle carriers with carrying handles). Each container should have a tag identifying the type of waste and the hazards associated with it. A packing list must be filled out providing information concerning the quantity and identity of the chemical and any hazards associated with it. (flammable, toxic, water-reactive, etc.)

Liquid Organic Chemicals

Local regulations governing the New York City sewer system expressly prohibit the discharge of organic solvents into the sewer system. No liquid organic chemicals should be disposed of "down the drain", and this rule applies to all solvents whether or not they are miscible with water. Compatible mixtures of liquid organic compounds can be stored in one container but the tag should indicate the relative proportion of each component.

Halogenated compounds and ethers (ethyl ether, isopropyl ether) should not be used in the secondary school setting. If such materials are identified in the laboratory, arrangements should be made with DOE DSF EHS to remove them via a PO 18 request (see the above section). Halogenated compounds

(e.g. methylene chloride) should be segregated in separate containers from other organic compounds. Note that chlorinated solvents form explosive mixtures with certain other organic compounds (e.g. with some amines, with acetone in the presence of base, etc.) Prolonged storage of ethers must be avoided since they can form explosive peroxides upon standing. (Treat old, unopened containers of ether with extreme caution).

Aqueous Solutions

Aqueous solutions of acids and bases in the pH range 5-9 can be disposed of by pouring them down the drain provided that they do not contain toxic contaminants such as certain heavy metal salts. Concentrated acids and alkalis should be neutralized and then disposed of down the drain.

For example, the following compounds can be disposed of via the drain:

- Potassium chloride
- Sodium chloride
- Sodium carbonate
- Sugars
- Amino Acids
- Noncontaminated gels and resins

Solid Inorganic and Organic Chemicals/Reagents

Toxic solid wastes should be stored in properly labeled, tightly sealed containers. Alkali metals such as sodium and potassium should be stored under mineral oil in tightly sealed containers. Store other pryrophoric metals and compounds such as magnesium in tightly sealed metal containers. Store waste mercury or broken thermometers that contain mercury in tightly sealed bottles or jars. These chemical substances are typically handled in hazardous waste packaging units called labpacks. Labpacks are packed by authorized off-site personnel and are packaged in drums according to hazardous class.

Unknown Waste Chemicals

The composition of the unknown waste must be identified usually through the services of an outside analytical laboratory. Such services are often

quite expensive. Once the composition of the waste material is known, it can then be disposed of according to the procedures outlined above.

Always label the contents of chemical containers immediately.

Recordkeeping

Maintain records of waste chemicals on hand. Records must also be kept of those chemicals that have been picked up for disposal. At a minimum, the name of the person responsible, the chemical identity or description of the waste, the amount, the date designated as a waste, and the date of pickup. All such records must be retained for at least three years.

Waste Minimization Procedures

1. Use purchasing methods to reduce the quantity and variety of products. (At the UFT's request, the Department of Education Bureau of Supplies (DOE BOS) changed its purchasing procedures so that lab specialists can now order smaller quantities of chemicals, if necessary. Please refer to the January 2001 Lab Specialist Health and Safety Manual for further information).

2. Reduce to a minimum the number of different products used.

3. Implement micro-level or small scale operations.

4. Order chemicals in smaller containers, and order only the amount of material needed for a project. There are companies that will ship chemicals in small quantities, such as milligram amounts, at competitive prices.

5. Reduce or eliminate the production of waste chemicals by modifying the laboratory procedure, by using a different method, or by substituting other reagents.

6. Work with minimal quantities of reagents and use the least quantities to demonstrate the principles of student experiments.

7. Keep chemically different wastes separate. Never mix hazardous and nonhazardous wastes as this renders the entire mixture hazardous. This increases the total volume of hazardous waste to be disposed and thus the total cost.

8. Examples of waste reduction procedures include:

- Reduce chemical use by conducting microscale chemistry experiments.
- Neutralize acids or bases as the final step in experiments.
- Precipitate hazardous metals as insoluble sulfides using sodium sulfide.
- Finely divided metals can be oxidized by water.
- Reduce oxidizers with sodium bisulfite.

Chemical disposal accident at a university in New York City

This accident occurred late in the evening and involved an explosion. Fortunately, no lab work was being done nor was anyone in the room at the time of the explosion. Although the exact nature of the explosion could not be determined, it is believed that someone mistakenly poured waste acid into a bottle containing methylene chloride waste. The only label on the bottle was one that said **Waste**. This mixture can result in a violent reaction and possible explosion. Glass fragments were spewn throughout the area, one with enough force to completely cut through a plastic hose attached to a water source.

OSHA

LAB STANDARD

29 CFR 1910.1450

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** Z
- **Subpart Title:** Toxic and Hazardous Substances
- **Standard Number:** 1910.1450
- **Title:** Occupational exposure to hazardous chemicals in laboratories.
- **Appendix:** A , B

1910.1450(a)
Scope and application.

1910.1450(a)(1)
This section shall apply to all employers engaged in the laboratory use of hazardous chemicals as defined below.

1910.1450(a)(2)
Where this section applies, it shall supersede, for laboratories, the requirements of all other OSHA health standards in 29 CFR part 1910, subpart Z, except as follows:

1910.1450(a)(2)(i)
For any OSHA health standard, only the requirement to limit employee exposure to the specific permissible exposure limit shall apply for laboratories, unless that particular standard states otherwise or unless the conditions of paragraph (a)(2)(iii) of this section apply.

1910.1450(a)(2)(ii)
Prohibition of eye and skin contact where specified by any OSHA health standard shall be observed.

1910.1450(a)(2)(iii)
Where the action level (or in the absence of an action level, the permissible exposure limit) is routinely exceeded for an OSHA regulated substance with exposure monitoring and medical surveillance requirements paragraphs (d) and (g)(1)(ii) of this section shall apply.

1910.1450(a)(3)
This section shall not apply to:

1910.1450(a)(3)(i)
Uses of hazardous chemicals which do not meet the definition of laboratory use, and in such cases, the employer shall comply with the relevant standard in 29 CFR part 1910, subpart Z, even if such use occurs in a laboratory.

1910.1450(a)(3)(ii)
Laboratory uses of hazardous chemicals which provide no potential for employee exposure. Examples of such conditions might include:

1910.1450(a)(3)(ii)(A)
Procedures using chemically-impregnated test media such as Dip-and-Read tests where a reagent strip is dipped into the specimen to be tested and the results are interpreted by comparing the color reaction to a color chart supplied by the manufacturer of the test strip; and

1910.1450(a)(3)(ii)(B)
Commercially prepared kits such as those used in performing pregnancy tests in which all of the reagents needed to conduct the test are contained in the kit.

1910.1450(b)
Definitions —
Action level means a concentration designated in 29 CFR part 1910 for a specific substance, calculated as an eight (8)-hour time-weighted average, which initiates certain required activities such as exposure monitoring and medical surveillance.

Assistant Secretary means the Assistant Secretary of Labor for Occupational Safety and Health, U.S. Department of Labor, or designee.

Carcinogen (see *select carcinogen*).

Chemical Hygiene Officer means an employee who is designated by the employer, and who is qualified by training or experience, to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan. This definition is not intended to place limitations on the position description or job classification that the designated individual shall hold within the employer's organizational structure.

Chemical Hygiene Plan means a written program developed and implemented by the employer which sets forth procedures, equipment, personal protective equipment and work practices that (i) are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace and (ii) meets the requirements of paragraph (e) of this section.

Emergency means any occurrence such as, but not limited to, equipment failure, rupture of containers or failure of control equipment which results in an uncontrolled release of a hazardous chemical into the workplace.

Employee means an individual employed in a laboratory workplace who may be exposed to hazardous chemicals in the course of his or her assignments.

Hazardous chemical means any chemical which is classified as health hazard or simple asphyxiant in accordance with the Hazard Communication Standard (§1910.1200).

Health hazard means a chemical that is classified as posing one of the following hazardous effects: Acute toxicity (any route of exposure); skin corrosion or irritation; serious eye damage or eye irritation; respiratory or skin sensitization; germ cell mutagenicity; carcinogenity; reproductive toxicity; specific target organ toxicity (single or repeated exposure); aspiration hazard. The criteria for determining whether a chemical is classified as a health hazard are detailed in appendix A of the Hazard Communication Standard (§1910.1200) and §1910.1200(c) (definition of "simple asphyxiant").

Laboratory means a facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.

Laboratory scale means work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person. "Laboratory scale" excludes those workplaces whose function is to produce commercial quantities of materials.

Laboratory-type hood means a device located in a laboratory, enclosure on five sides with a moveable sash or fixed partial enclosed on the remaining side; constructed and maintained to draw air from the laboratory and to prevent or minimize the escape of air contaminants into the laboratory; and allows chemical manipulations to be conducted in the enclosure without insertion of any portion of the employee's body other than hands and arms.

Walk-in hoods with adjustable sashes meet the above definition provided that the sashes are adjusted during use so that the airflow and the exhaust of air contaminants are not compromised and employees do not work inside the enclosure during the release of airborne hazardous chemicals.

Laboratory use of hazardous chemicals means handling or use of such chemicals in which all of the following conditions are met:

(i) Chemical manipulations are carried out on a "laboratory scale;"

(ii) Multiple chemical procedures or chemicals are used;

(iii) The procedures involved are not part of a production process, nor in any way simulate a production process; and

(iv) "Protective laboratory practices and equipment" are available and in common use to minimize the potential for employee exposure to hazardous chemicals.

Medical consultation means a consultation which takes place between an employee and a licensed physician for the purpose of determining what medical examinations or procedures, if any, are appropriate in cases where a significant exposure to a hazardous chemical may have taken place.

Mutagen means chemicals that cause permanent changes in the amount or structure of the genetic material in a cell. Chemicals classified as mutagens in accordance with the Hazard Communication Standard (§1910.1200) shall be considered mutagens for purposes of this section.

Physical hazard means a chemical that is classified as posing one of the following hazardous effects: Explosive; flammable (gases, aerosols, liquids, or solids); oxidizer (liquid, solid, or gas); self reactive; pyrophoric (gas, liquid or solid); self-heating; organic peroxide; corrosive to metal; gas under pressure; in contact with water emits flammable gas; or combustible dust. The criteria for determining whether a chemical is classified as a physical hazard are in appendix B of the Hazard Communication Standard (§1910.1200) and §1910.1200(c) (definitions of "combustible dust" and "pyrophoric gas").

Protective laboratory practices and equipment means those laboratory procedures, practices and equipment accepted by laboratory health and safety experts as effective, or that the employer can show to be effective, in minimizing the potential for employee exposure to hazardous chemicals.

Reproductive toxins mean chemicals that affect the reproductive capabilities including adverse effects on sexual function and fertility in adult males and females, as well as adverse effects on the development of the offspring. Chemicals classified as reproductive toxins in accordance with the Hazard Communication Standard (§1910.1200) shall be considered reproductive toxins for purposes of this section.

Select carcinogen means any substance which meets one of the following criteria:

(i) It is regulated by OSHA as a carcinogen; or

(ii) It is listed under the category, "known to be carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition); or

(iii) It is listed under Group 1 ("carcinogenic to humans") by the International Agency for Research on Cancer Monographs (IARC) (latest editions); or

(iv) It is listed in either Group 2A or 2B by IARC or under the category, "reasonably anticipated to be carcinogens" by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria:

(A) After inhalation exposure of 6–7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m^3;

(B) After repeated skin application of less than 300 (mg/kg of body weight) per week; or

(C) After oral dosages of less than 50 mg/kg of body weight per day.

1910.1450(c)
Permissible exposure limits. For laboratory uses of OSHA regulated substances, the employer shall assure that laboratory employees' exposures to such substances do not exceed the permissible exposure limits specified in 29 CFR part 1910, subpart Z.

1910.1450(d)
Employee exposure determination –

1910.1450(d)(1)
Initial monitoring. The employer shall measure the employee's exposure to any substance regulated by a standard which requires monitoring if there is reason to believe that exposure levels for that substance routinely exceed the action level (or in the absence of an action level, the PEL).

1910.1450(d)(2)
Periodic monitoring. If the initial monitoring prescribed by paragraph (d)(1) of this section discloses employee exposure over the action level (or in the absence of an action level, the PEL), the employer shall immediately comply with the exposure monitoring provisions of the relevant standard.

1910.1450(d)(3)
Termination of monitoring. Monitoring may be terminated in accordance with the relevant standard.

1910.1450(d)(4)
Employee notification of monitoring results. The employer shall, within 15 working days after the receipt of any monitoring results, notify the employee of these results in writing either individually or by posting results in an appropriate location that is accessible to employees.

1910.1450(e)
Chemical hygiene plan -- General. (Appendix A of this section is non-mandatory but provides guidance to assist employers in the development of the Chemical Hygiene Plan).

1910.1450(e)(1)
Where hazardous chemicals as defined by this standard are used in the workplace, the employer shall develop and carry out the provisions of a written Chemical Hygiene Plan which is:

1910.1450(e)(1)(i)
Capable of protecting employees from health hazards associated with hazardous chemicals in that laboratory and

1910.1450(e)(1)(ii)
Capable of keeping exposures below the limits specified in paragraph (c) of this section.

1910.1450(e)(2)
The Chemical Hygiene Plan shall be readily available to employees, employee representatives and, upon request, to the Assistant Secretary.

1910.1450(e)(3)
The Chemical Hygiene Plan shall include each of the following elements and shall indicate specific measures that the employer will take to ensure laboratory employee protection;

1910.1450(e)(3)(i)
Standard operating procedures relevant to safety and health considerations to be followed when laboratory work involves the use of hazardous chemicals;

1910.1450(e)(3)(ii)
Criteria that the employer will use to determine and implement control measures to reduce employee exposure to hazardous chemicals including engineering controls, the use of personal protective equipment and hygiene practices; particular attention shall be given to the selection of control measures for chemicals that are known to be extremely hazardous;

1910.1450(e)(3)(iii)
A requirement that fume hoods and other protective equipment are functioning properly and specific measures that shall be taken to ensure proper and adequate performance of such equipment;

1910.1450(e)(3)(iv)
Provisions for employee information and training as prescribed in paragraph (f) of this section;

1910.1450(e)(3)(v)
The circumstances under which a particular laboratory operation, procedure or activity shall require prior approval from the employer or the employer's designee before implementation;

1910.1450(e)(3)(vi)
Provisions for medical consultation and medical examinations in accordance with paragraph (g) of this section;

1910.1450(e)(3)(vii)
Designation of personnel responsible for implementation of the Chemical Hygiene Plan including the assignment of a Chemical Hygiene Officer, and, if appropriate, establishment of a Chemical Hygiene Committee; and

1910.1450(e)(3)(viii)
Provisions for additional employee protection for work with particularly hazardous substances. These include "select carcinogens," reproductive toxins and substances which have a high degree of acute toxicity. Specific consideration shall be given to the following provisions which shall be included where appropriate:

1910.1450(e)(3)(viii)(A)
Establishment of a designated area;

1910.1450(e)(3)(viii)(B)
Use of containment devices such as fume hoods or glove boxes;

1910.1450(e)(3)(viii)(C)
Procedures for safe removal of contaminated waste; and

1910.1450(e)(3)(viii)(D)
Decontamination procedures.

1910.1450(e)(4)
The employer shall review and evaluate the effectiveness of the Chemical Hygiene Plan at least annually and update it as necessary.

1910.1450(f)
Employee information and training.

1910.1450(f)(1)
The employer shall provide employees with information and training to ensure that they are apprised of the hazards of chemicals present in their work area.

1910.1450(f)(2)
Such information shall be provided at the time of an employee's initial assignment to a work area where hazardous chemicals are present and prior to assignments involving new exposure situations. The frequency of refresher information and training shall be determined by the employer.

1910.1450(f)(3)
Information. Employees shall be informed of:

1910.1450(f)(3)(i)
The contents of this standard and its appendices which shall be made available to employees;

1910.1450(f)(3)(ii)
the location and availability of the employer's Chemical Hygiene Plan;

1910.1450(f)(3)(iii)
The permissible exposure limits for OSHA regulated substances or recommended exposure limits for other hazardous chemicals where there is no applicable OSHA standard;

1910.1450(f)(3)(iv)
Signs and symptoms associated with exposures to hazardous chemicals used in the laboratory; and

1910.1450(f)(3)(v)
The location and availability of known reference material on the hazards, safe handling, storage and disposal of hazardous chemicals found in the laboratory including, but not limited to, safety data sheets received from the chemical supplier.

1910.1450(f)(4)
Training.

1910.1450(f)(4)(i)
Employee training shall include:

1910.1450(f)(4)(i)(A)
Methods and observations that may be used to detect the presence or release of a hazardous chemical (such as monitoring conducted by the employer, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released, etc.);

1910.1450(f)(4)(i)(B)
The physical and health hazards of chemicals in the work area; and

1910.1450(f)(4)(i)(C)
The measures employees can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect employees from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and personal protective equipment to be used.

1910.1450(f)(4)(ii)
The employee shall be trained on the applicable details of the employer's written Chemical Hygiene Plan.

1910.1450(g)
Medical consultation and medical examinations.

1910.1450(g)(1)
The employer shall provide all employees who work with hazardous chemicals an opportunity to receive medical attention, including any follow-up examinations which the examining physician determines to be necessary, under the following circumstances:

1910.1450(g)(1)(i)
Whenever an employee develops signs or symptoms associated with a hazardous chemical to which the employee may have been exposed in the laboratory, the employee shall be provided an opportunity to receive an appropriate medical examination.

1910.1450(g)(1)(ii)
Where exposure monitoring reveals an exposure level routinely above the action level (or in the absence of an action level, the PEL) for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements, medical surveillance shall be established for the affected employee as prescribed by the particular standard.

1910.1450(g)(1)(iii)
Whenever an event takes place in the work area such as a spill, leak, explosion or other occurrence resulting in the likelihood of a hazardous exposure, the affected employee shall be provided an opportunity for a medical consultation. Such consultation shall be for the purpose of determining the need for a medical examination.

1910.1450(g)(2)
All medical examinations and consultations shall be performed by or under the direct supervision of a licensed physician and shall be provided without cost to the employee, without loss of pay and at a reasonable time and place.

1910.1450(g)(3)
Information provided to the physician. The employer shall provide the following information to the physician:

1910.1450(g)(3)(i)
The identity of the hazardous chemical(s) to which the employee may have been exposed;

1910.1450(g)(3)(ii)
A description of the conditions under which the exposure occurred including quantitative exposure data, if available; and

1910.1450(g)(3)(iii)
A description of the signs and symptoms of exposure that the employee is experiencing, if any.

1910.1450(g)(4)
Physician's written opinion.

1910.1450(g)(4)(i)
For examination or consultation required under this standard, the employer shall obtain a written opinion from the examining physician which shall include the following:

1910.1450(g)(4)(i)(A)
Any recommendation for further medical follow-up;

1910.1450(g)(4)(i)(B)
The results of the medical examination and any associated tests;
1910.1450(g)(4)(i)(C)
Any medical condition which may be revealed in the course of the examination which may place the employee at increased risk as a result of exposure to a hazardous workplace; and

1910.1450(g)(4)(i)(D)
A statement that the employee has been informed by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment.

1910.1450(g)(4)(ii)
The written opinion shall not reveal specific findings of diagnoses unrelated to occupational exposure.

1910.1450(h)
Hazard identification.

1910.1450(h)(1)
With respect to labels and safety data sheets:

1910.1450(h)(1)(i)
Employers shall ensure that labels on incoming containers of hazardous chemicals are not removed or defaced.

1910.1450(h)(1)(ii)
Employers shall maintain any safety data sheets that are received with incoming shipments of hazardous chemicals, and ensure that they are readily accessible to laboratory employees.

1910.1450(h)(2)
The following provisions shall apply to chemical substances developed in the laboratory:

1910.1450(h)(2)(i)
If the composition of the chemical substance which is produced exclusively for the laboratory's use is known, the employer shall determine if it is a hazardous chemical as defined in paragraph (b) of this section. If the chemical is determined to be hazardous, the employer shall provide appropriate training as required under paragraph (f) of this section.

1910.1450(h)(2)(ii)
If the chemical produced is a byproduct whose composition is not known, the employer shall assume that the substance is hazardous and shall implement paragraph (e) of this section.

1910.1450(h)(2)(iii)
If the chemical substance is produced for another user outside of the laboratory, the employer shall comply with the Hazard Communication Standard (29 CFR 1910.1200) including the requirements for preparation of safety data sheets and labeling.

1910.1450(i)
Use of respirators. Where the use of respirators is necessary to maintain exposure below permissible exposure limits, the employer shall provide, at no cost to the employee, the proper respiratory equipment. Respirators shall be selected and used in accordance with the requirements of 29 CFR 1910.134.

1910.1450(j)
Recordkeeping.

1910.1450(j)(1)
The employer shall establish and maintain for each employee an accurate record of any measurements taken to monitor employee exposures and any medical consultation and examinations including tests or written opinions required by this standard.

1910.1450(j)(2)
The employer shall assure that such records are kept, transferred, and made available in accordance with 29 CFR 1910.1020.

1910.1450(k)
[Reserved]

1910.1450(l)
Appendices. The information contained in the appendices is not intended, by itself, to create any additional obligations not otherwise imposed or to detract from any existing obligation.

[55 FR 3327, Jan. 31, 1990; 55 FR 7967, March, 6, 1990; 55 FR 12777, March 30, 1990; 61 FR 5507, Feb. 13, 1996; 71 FR 16674, April 3, 2006; 77 FR 17887, March 26, 2012]

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- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** Z
- **Subpart Title:** Toxic and Hazardous Substances
- **Standard Number:** **1910.1450 App A**
- **Title:** National Research Council Recommendations Concerning Chemical Hygiene in Laboratories (Non-Mandatory)

To assist employers in developing an appropriate laboratory Chemical Hygiene Plan (CHP), the following non-mandatory recommendations were based on the National Research Council's (NRC) 2011 edition of "Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards." This reference, henceforth referred to as "Prudent Practices," is available from the National Academies Press, 500 Fifth Street NW., Washington DC 20001 (www.nap.edu). "Prudent Practices" is cited because of its wide distribution and acceptance and because of its preparation by recognized authorities in the laboratory community through the sponsorship of the NRC. However, these recommendations do not modify any requirements of the OSHA Laboratory standard. This appendix presents pertinent recommendations from "Prudent Practices," organized into a form convenient for quick reference during operation of a laboratory and during development and application of a CHP. For a detailed explanation and justification for each recommendation, consult "Prudent Practices."

"Prudent Practices" deals with both general laboratory safety and many types of chemical hazards, while the Laboratory standard is concerned primarily with chemical health hazards as a result of chemical exposures. The recommendations from "Prudent Practices" have been paraphrased, combined, or otherwise reorganized in order to adapt them for this purpose. However, their sense has not been changed.

Section F contains information from the U.S. Chemical Safety Board's (CSB) Fiscal Year 2011 Annual Performance and Accountability report and Section F contains recommendations extracted from the CSB's 2011 case study, "Texas Tech University Laboratory Explosion," available from: http://www.csb.gov/.

Culture of Safety

With the promulgation of the Occupational Safety and Health Administration (OSHA) Laboratory standard (29 CFR 1910.1450), a culture of safety consciousness, accountability, organization, and education has developed in industrial, governmental, and academic laboratories. Safety and training programs have been implemented to promote the safe handling of chemicals from ordering to disposal, and to train laboratory personnel in safe practices. Laboratory personnel must realize that the welfare and safety of each individual depends on clearly defined attitudes of teamwork and personal responsibility. Learning to participate in this culture of habitual risk assessment, experiment planning, and consideration of worst-case possibilities—for oneself and one's fellow workers—is as much part of a scientific education as learning the theoretical background of experiments or the step-by-step protocols for doing them in a professional manner.

A crucial component of chemical education for all personnel is to nurture basic attitudes and habits of prudent behavior so that safety is a valued and inseparable part of all laboratory activities throughout their career.

Over the years, special techniques have been developed for handling chemicals safely. Local, state, and federal regulations hold institutions that sponsor chemical laboratories accountable for providing safe working environments. Beyond regulation, employers and scientists also hold themselves personally responsible for their own safety, the safety of their colleagues and the safety of the general public. A sound safety organization that is respected by all requires the participation and support of laboratory administrators, workers, and students. A successful health and safety program requires a daily commitment from everyone in the organization. To be most effective, safety and health must be balanced with, and incorporated into, laboratory processes. A strong safety and health culture is the result of positive workplace attitudes—from the chief executive officer to the newest hire; involvement and buy-in of all members of the workforce; mutual, meaningful, and measurable safety and health improvement goals; and policies and procedures that serve as reference tools, rather than obscure rules.

In order to perform their work in a prudent manner, laboratory personnel must consider the health, physical, and environmental hazards of the chemicals they plan to use in an experiment. However, the ability to accurately identify and assess laboratory hazards must be taught and encouraged through training and ongoing organizational support. This training must be at the core of every good health and safety program. For management to lead, personnel to assess worksite hazards, and hazards to be eliminated or controlled, everyone involved must be trained.

A. General Principles

1. Minimize All Chemical Exposures and Risks

Because few laboratory chemicals are without hazards, general precautions for handling all laboratory chemicals should be adopted. In addition to these general guidelines, specific guidelines for chemicals that are used frequently or are particularly hazardous should be adopted.

Laboratory personnel should conduct their work under conditions that minimize the risks from both known and unknown hazardous substances. Before beginning any laboratory work, the hazards and risks associated with an experiment or activity should be determined and the necessary safety precautions implemented. Every laboratory should develop facility-specific policies and procedures for the highest-risk materials and procedures used in their laboratory. To identify these, consideration should be given to past accidents, process conditions, chemicals used in large volumes, and particularly hazardous chemicals.

Perform Risk Assessments for Hazardous Chemicals and Procedures Prior to Laboratory Work:

(a) Identify chemicals to be used, amounts required, and circumstances of use in the experiment. Consider any special employee or laboratory conditions that could create or increase a hazard. Consult sources of safety and health information and experienced scientists to ensure that those conducting the risk assessment have sufficient expertise.

(b) Evaluate the hazards posed by the chemicals and the experimental conditions. The evaluation should cover toxic, physical, reactive, flammable, explosive, radiation, and biological hazards, as well as any other potential hazards posed by the chemicals.

(c) For a variety of physical and chemical reasons, reaction scale-ups pose special risks, which merit additional prior review and precautions.

(d) Select appropriate controls to minimize risk, including use of engineering controls, administrative controls, and personal protective equipment (PPE) to protect workers from hazards. The controls must ensure that OSHA's Permissible Exposure Limits (PELs) are not exceeded. Prepare for contingencies and be aware of the institutional procedures in the event of emergencies and accidents.

One sample approach to risk assessment is to answer these five questions:

(a) What are the hazards?

(b) What is the worst thing that could happen?

(c) What can be done to prevent this from happening?

(d) What can be done to protect from these hazards?

(e) What should be done if something goes wrong?

2. Avoid Underestimation of Risk

Even for substances of no known significant hazard, exposure should be minimized; when working with substances that present special hazards, special precautions should be taken. Reference should be made to the safety data sheet (SDS) that is provided for each chemical. Unless otherwise known, one should assume that any mixture will be more toxic than its most toxic component and that all substances of unknown toxicity are toxic.

Determine the physical and health hazards associated with chemicals before working with them. This determination may involve consulting literature references, laboratory chemical safety summaries (LCSSs), SDSs, or other reference materials. Consider how the chemicals will be processed and determine whether the changing states or forms will change the nature of the hazard. Review your plan, operating limits, chemical evaluations and detailed risk assessment with other chemists, especially those with experience with similar materials and protocols.

Before working with chemicals, know your facility's policies and procedures for how to handle an accidental spill or fire. Emergency telephone numbers should be posted in a prominent area. Know the location of all safety equipment and the nearest fire alarm and telephone.

3. Adhere to the Hierarchy of Controls

The hierarchy of controls prioritizes intervention strategies based on the premise that the best way to control a hazard is to systematically remove it from the workplace, rather than relying on employees to reduce their exposure. The types of measures that may be used to protect employees (listed from most effective to least effective) are: engineering controls, administrative controls, work practices, and PPE. Engineering controls, such as chemical hoods, physically separate the employee from the hazard. Administrative controls, such as employee scheduling, are established by management to help minimize the employees' exposure time to hazardous chemicals. Work practice controls are tasks that are performed in a designated way to minimize or eliminate hazards. Personal protective equipment and apparel are additional protection provided under special circumstances and when exposure is unavoidable.

Face and eye protection is necessary to prevent ingestion and skin absorption of hazardous chemicals. At a minimum, safety glasses, with side shields, should be used for all laboratory work. Chemical splash goggles are more appropriate than regular safety glasses to protect against hazards such as projectiles, as well as when working with glassware under reduced or elevated pressures (e.g., sealed tube reactions), when handling potentially explosive compounds (particularly during distillations), and when using glassware in high-temperature operations. Do not allow laboratory chemicals to come in contact with skin. Select gloves carefully to ensure that they are impervious to the chemicals being used and are of correct thickness to allow reasonable dexterity while also ensuring adequate barrier protection.

Lab coats and gloves should be worn when working with hazardous materials in a laboratory. Wear closed-toe shoes and long pants or other clothing that covers the legs when in a laboratory where hazardous chemicals are used. Additional protective clothing should be used when there is significant potential for skin-contact exposure to chemicals. The protective characteristics of this clothing must be matched to the hazard. Never wear gloves or laboratory coats outside the laboratory or into areas where food is stored and consumed.

4. Provide Laboratory Ventilation

The best way to prevent exposure to airborne substances is to prevent their escape into the working atmosphere by the use of hoods and other ventilation devices. To determine the best choice for laboratory ventilation using engineering controls for personal protection, employers are referred to Table 9.3 of the 2011 edition of ''Prudent Practices.'' Laboratory chemical hoods are the most important components used to protect laboratory personnel from exposure to hazardous chemicals.

(a) Toxic or corrosive chemicals that require vented storage should be stored in vented cabinets instead of in a chemical hood.

(b) Chemical waste should not be disposed of by evaporation in a chemical hood.

(c) Keep chemical hood areas clean and free of debris at all times.

(d) Solid objects and materials, such as paper, should be prevented from entering the exhaust ducts as they can reduce the air flow.

(e) Chemical hoods should be maintained, monitored and routinely tested for proper performance.

A laboratory ventilation system should include the following characteristics and practices:

(a) Heating and cooling should be adequate for the comfort of workers and operation of equipment. Before modification of any building HVAC, the impact on laboratory or hood ventilation should be considered, as well as how laboratory ventilation changes may affect the building HVAC.

(b) A negative pressure differential should exist between the amount of air exhausted from the laboratory and the amount supplied to the laboratory to prevent uncontrolled chemical vapors from leaving the laboratory.

(c) Local exhaust ventilation devices should be appropriate to the materials and operations in the laboratory.

(d) The air in chemical laboratories should be continuously replaced so that concentrations of odoriferous or toxic substances do not increase during the workday.

(e) Laboratory air should not be recirculated but exhausted directly outdoors.

(f) Air pressure should be negative with respect to the rest of the building. Local capture equipment and systems should be designed only by an experienced engineer or industrial hygienist.

(g) Ventilation systems should be inspected and maintained on a regular basis. There should be no areas where air remains static or areas that have unusually high airflow velocities.

Before work begins, laboratory workers should be provided with proper training that includes how to use the ventilation equipment, how to ensure that it is functioning properly, the consequences of improper use, what to do in the event of a system failure or power outage, special considerations, and the importance of signage and postings.

5. Institute a Chemical Hygiene Program

A comprehensive chemical hygiene program is required. It should be designed to minimize exposures, injuries, illnesses and incidents. There should be a regular, continuing effort that includes program oversight, safe facilities, chemical hygiene planning, training, emergency preparedness and chemical security. The chemical hygiene program must be reviewed annually and updated as necessary whenever new processes, chemicals, or equipment is implemented. Its recommendations should be followed in all laboratories.

6. Observe the PELs and TLVs

OSHA's Permissible Exposure Limits (PELs) must not be exceeded. The American Conference of Governmental Industrial Hygienists' Threshold Limit Values (TLVs) should also not be exceeded.

B. Responsibilities

Persons responsible for chemical hygiene include, but are not limited to, the following:

1. Chemical Hygiene Officer

(a) Establishes, maintains, and revises the chemical hygiene plan (CHP).

(b) Creates and revises safety rules and regulations.

(c) Monitors procurement, use, storage, and disposal of chemicals.

(d) Conducts regular inspections of the laboratories, preparations rooms, and chemical storage rooms, and submits detailed laboratory inspection reports to administration.

(e) Maintains inspection, personnel training, and inventory records.

(f) Assists laboratory supervisors in developing and maintaining adequate facilities.

(g) Seeks ways to improve the chemical hygiene program.

2. Department Chairperson or Director

(a) Assumes responsibility for personnel engaged in the laboratory use of hazardous chemicals.

(b) Provides the chemical hygiene officer (CHO) with the support necessary to implement and maintain the CHP.

(c) After receipt of laboratory inspection report from the CHO, meets with laboratory supervisors to discuss cited violations and to ensure timely actions to protect trained laboratory personnel and facilities and to ensure that the department remains in compliance with all applicable federal, state, university, local and departmental codes and regulations.

(d) Provides budgetary arrangements to ensure the health and safety of the departmental personnel, visitors, and students.

3. Departmental Safety Committee reviews accident reports and makes appropriate recommendations to the department chairperson regarding proposed changes in the laboratory procedures.

4. Laboratory Supervisor or Principal Investigator has overall responsibility for chemical hygiene in the laboratory, including responsibility to:

(a) Ensure that laboratory personnel comply with the departmental CHP and do not operate equipment or handle hazardous chemicals without proper training and authorization.

(b) Always wear personal protective equipment (PPE) that is compatible to the degree of hazard of the chemical.

(c) Follow all pertinent safety rules when working in the laboratory to set an example.

(d) Review laboratory procedures for potential safety problems before assigning to other laboratory personnel.

(e) Ensure that visitors follow the laboratory rules and assumes responsibility for laboratory visitors.

(f) Ensure that PPE is available and properly used by each laboratory employee and visitor.

(g) Maintain and implement safe laboratory practices.

(h) Provide regular, formal chemical hygiene and housekeeping inspections, including routine inspections of emergency equipment;

(i) Monitor the facilities and the chemical fume hoods to ensure that they are maintained and function properly. Contact the appropriate person, as designated by the department chairperson, to report problems with the facilities or the chemical fume hoods.

5. Laboratory Personnel

(a) Read, understand, and follow all safety rules and regulations that apply to the work area;

(b) Plan and conduct each operation in accordance with the institutional chemical hygiene procedures;

(c) Promote good housekeeping practices in the laboratory or work area.

(d) Notify the supervisor of any hazardous conditions or unsafe work practices in the work area.

(e) Use PPE as appropriate for each procedure that involves hazardous chemicals.

C. The Laboratory Facility

General Laboratory Design Considerations Wet chemical spaces and those with a higher degree of hazard should be separated from other spaces by a wall or protective barrier wherever possible. If the areas cannot be separated, then workers in lower hazard spaces may require additional protection from the hazards in connected spaces.

1. Laboratory Layout and Furnishing

(a) Work surfaces should be chemically resistant, smooth, and easy to clean.

(b) Hand washing sinks for hazardous materials may require elbow, foot, or electronic controls for safe operation.

(c) Wet laboratory areas should have chemically resistant, impermeable, slipresistant flooring.

(d) Walls should be finished with a material that is easy to clean and maintain.

(e) Doors should have view panels to prevent accidents and should open in the direction of egress.

(f) Operable windows should not be present in laboratories, particularly if there are chemical hoods or other local ventilation systems present.

2. Safety Equipment and Utilities

(a) An adequate number and placement of safety showers, eyewash units, and fire extinguishers should be provided for the laboratory.

(b) Use of water sprinkler systems is resisted by some laboratories because of the presence of electrical equipment or water-reactive materials, but it is still generally safer to have sprinkler systems installed. A fire large enough to trigger the sprinkler system would have the potential to cause far more destruction than the local water damage.

D. Chemical Hygiene Plan (CHP)

The OSHA Laboratory standard defines a CHP as ‘‘a written program developed and implemented by the employer which sets forth procedures, equipment, personal protective equipment and work practices that are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace.’’ (29 CFR 1910.1450(b)). The Laboratory Standard requires a CHP: ‘‘Where hazardous chemicals as defined by this standard are used in the workplace, the employer shall develop and carry out the provisions of a written Chemical Hygiene Plan.’’ (29 CFR 1910.1450(e)(1)). The CHP is the foundation of the laboratory safety program and must be reviewed and updated, as needed, and at least on an annual basis to reflect changes in policies and personnel. A CHP should be facility specific and can assist in promoting a culture of safety to protect workers from exposure to hazardous materials.

1. The Laboratory’s CHP must be readily available to workers and capable of protecting workers from health hazards and minimizing exposure. Include the following topics in the CHP:

(a) Individual chemical hygiene responsibilities;

(b) Standard operating procedures;

(c) Personal protective equipment, engineering controls and apparel;

(d) Laboratory equipment;

(e) Safety equipment;

(f) Chemical management;

(g) Housekeeping;

(h) Emergency procedures for accidents and spills;

(i) Chemical waste;

(j) Training;

(k) Safety rules and regulations;

(l) Laboratory design and ventilation;

(m) Exposure monitoring;

(n) Compressed gas safety;

(o) Medical consultation and examination.

It should be noted that the nature of laboratory work may necessitate addressing biological safety, radiation safety and security issues.

2. Chemical Procurement, Distribution, and Storage

Prudent chemical management includes the following processes:

Chemical Procurement:

(a) Information on proper handling, storage, and disposal should be known to those who will be involved before a substance is received.

(b) Only containers with adequate identifying labels should be accepted.

(c) Ideally, a central location should be used for receiving all chemical shipments.

(d) Shipments with breakage or leakage should be refused or opened in a chemical hood.

(e) Only the minimum amount of the chemical needed to perform the planned work should be ordered.

(f) Purchases of high risk chemicals should be reviewed and approved by the CHO.

(g) Proper protective equipment and handling and storage procedures should be in place before receiving a shipment.

Chemical Storage:

(a) Chemicals should be separated and stored according to hazard category and compatibility.

(b) SDS and label information should be followed for storage requirements.

(c) Maintain existing labels on incoming containers of chemicals and other materials.

(d) Labels on containers used for storing hazardous chemicals must include the chemical identification and appropriate hazard warnings.

(e) The contents of all other chemical containers and transfer vessels, including, but not limited to, beakers, flasks, reaction vessels, and process equipment, should be properly identified.

(f) Chemical shipments should be dated upon receipt and stock rotated.

(g) Peroxide formers should be dated upon receipt, again dated upon opening, and stored away from heat and light with tight fitting, nonmetal lids.

(h) Open shelves used for chemical storage should be secured to the wall and contain 3/4-inch lips. Secondary containment devices should be used as necessary.

(i) Consult the SDS and keep incompatibles separate during transport, storage, use, and disposal.

(j) Oxidizers, reducing agents, and fuels should be stored separately to prevent contact in the event of an accident.

(k) Chemicals should not be stored in the chemical hood, on the floor, in areas of egress, on the benchtop, or in areas near heat or in direct sunlight.

(l) Laboratory-grade, flammable-rated refrigerators and freezers should be used to store sealed chemical containers of flammable liquids that require cool storage. Do not store food or beverages in the laboratory refrigerator.

(m) Highly hazardous chemicals should be stored in a well-ventilated and secure area designated for that purpose.

(n) Flammable chemicals should be stored in a spark-free environment and in approved flammable-liquid containers and storage cabinets. Grounding and bonding should be used to prevent static charge buildups when dispensing solvents.

(o) Chemical storage and handling rooms should be controlled-access areas. They should have proper ventilation, appropriate signage, diked floors, and fire suppression systems.

Chemical Handling:

(a) As described above, a risk assessment should be conducted prior to beginning work with any hazardous chemical for the first time.

(b) All SDS and label information should be read before using a chemical for the first time.

(c) Trained laboratory workers should ensure that proper engineering controls (ventilation) and PPE are in place.

Chemical Inventory:

(a) Prudent management of chemicals in any laboratory is greatly facilitated by keeping an accurate inventory of the chemicals stored.

(b) Unneeded items should be discarded or returned to the storeroom.

Transporting Chemicals:

(a) Secondary containment devices should be used when transporting chemicals.

(b) When transporting chemicals outside of the laboratory or between stockrooms and laboratories, the transport container should be break-resistant.

(c) High-traffic areas should be avoided.

Transferring Chemicals:

(a) Use adequate ventilation (such as a fume hood) when transferring even a small amount of a particularly hazardous substance (PHS).

(b) While drum storage is not appropriate for laboratories, chemical stockrooms may purchase drum quantities of solvents used in high volumes. Ground and bond the drum and receiving vessel when transferring flammable liquids from a drum to prevent static charge buildup.

(c) If chemicals from commercial sources are repackaged into transfer vessels, the new containers should be labeled with all essential information on the original container.

Shipping Chemicals: Outgoing chemical shipments must meet all applicable Department of Transportation (DOT) regulations and should be authorized and handled by the institutional shipper.

3. Waste Management

A waste management plan should be in place before work begins on any laboratory activity. The plan should utilize the following hierarchy of practices:

(a) Reduce waste sources. The best approach to minimize waste generation is by reducing the scale of operations, reducing its formation during operations, and, if possible, substituting less hazardous chemicals for a particular operation.

(b) Reuse surplus materials. Only the amount of material necessary for an experiment should be purchased, and, if possible, materials should be reused.

(c) Recycle waste. If waste cannot be prevented or minimized, the organization should consider recycling chemicals that can be safely recovered or used as fuel.

(d) Dispose of waste properly. Sink disposal may not be appropriate. Proper waste disposal methods include incineration, treatment, and land disposal. The organization's environmental health and safety (EHS) office should be consulted in determining which methods are appropriate for different types of waste.

Collection and Storage of Waste:

(a) Chemical waste should be accumulated at or near the point of generation, under the control of laboratory workers.

(b) Each waste type should be stored in a compatible container pending transfer or disposal. Waste containers should be clearly labeled and kept sealed when not in use.

(c) Incompatible waste types should be kept separate to ensure that heat generation, gas evolution, or another reaction does not occur.

(d) Waste containers should be segregated by how they will be managed. Waste containers should be stored in a designated location that does not interfere with normal laboratory operations. Ventilated storage and secondary containment may be appropriate for certain waste types.

(e) Waste containers should be clearly labeled and kept sealed when not in use. Labels should include the accumulation start date and hazard warnings as appropriate.

(f) Non-explosive electrical systems, grounding and bonding between floors and containers, and non-sparking conductive floors and containers should be used in the central waste accumulation area to minimize fire and explosion hazards. Fire suppression systems, specialized ventilation systems, and dikes should be installed in the central waste accumulation area. Waste management workers should be trained in proper waste handling procedures as well as contingency planning and emergency response. Trained laboratory workers most familiar with the waste should be actively involved in waste management decisions to ensure that the waste is managed safely and efficiently. Engineering controls should be implemented as necessary, and personal protective equipment should be worn by workers involved in waste management.

4. Inspection Program

Maintenance and regular inspection of laboratory equipment are essential parts of the aboratory safety program. Management should participate in the design of a laboratory inspection program to ensure that the facility is safe and healthy, workers are adequately trained, and proper procedures are being followed.

Types of inspections: The program should include an appropriate combination of routine inspections, self-audits, program audits, peer inspections, EHS inspections, and inspections by external entities.

Elements of an inspection:

(a) Inspectors should bring a checklist to ensure that all issues are covered and a camera to document issues that require correction.

(b) Conversations with workers should occur during the inspection, as they can provide valuable information and allow inspectors an opportunity to show workers how to fix problems.

(c) Issues resolved during the inspection should be noted.

(d) An inspection report containing all findings and recommendations should be prepared for management and other appropriate workers.

(e) Management should follow-up on the inspection to ensure that all corrections are implemented.

5. Medical Consultation and Examination

The employer must provide all employees who work with hazardous chemicals an opportunity to receive medical attention, including any follow-up examinations that the examining physician determines to be necessary, whenever an employee develops signs or symptoms associated with a hazardous chemical to which the employee may have been exposed in the laboratory. If an employee encounters a spill, leak, explosion or other occurrence resulting in the likelihood of a hazardous exposure, the affected employee must be provided an opportunity for a medical consultation by a licensed physician. All medical examinations and consultations must be performed by or under the direct supervision of a licensed physician and must be provided without cost to the employee, without loss of pay and at a reasonable time and place. The identity of the hazardous chemical, a description of the incident, and any signs and symptoms that the employee may experience must be relayed to the physician.

6. Records

All accident, fatality, illness, injury, and medical records and exposure monitoring records must be retained by the institution in accordance with the requirements of state and federal regulations (see 29 CFR part 1904 and § 1910.1450(j)). Any exposure monitoring results must be provided to affected laboratory staff within 15 working days after receipt of the results (29 CFR 1910.1450(d)(4)).

7. Signs

Prominent signs of the following types should be posted:

(a) Emergency telephone numbers of emergency personnel/facilities, supervisors, and laboratory workers;

(b) Location signs for safety showers, eyewash stations, other safety and first aid equipment, and exits; and

(c) Warnings at areas or equipment where special or unusual hazards exist.

8. Spills and Accidents

Before beginning an experiment, know your facility's policies and procedures for how to handle an accidental release of a hazardous substance, a spill or a fire. Emergency response planning and training are especially important when working with highly toxic compounds. Emergency telephone numbers should be posted in a prominent area. Know the location of all safety equipment and the nearest fire alarm and telephone. Know who to notify in the event of an emergency. Be prepared to provide basic emergency treatment. Keep your co-workers informed of your activities so they can respond appropriately. Safety equipment, including spill control kits, safety shields, fire safety equipment, PPE, safety showers and eyewash units, and emergency equipment should be available in well marked highly visible locations in all chemical laboratories. The laboratory supervisor or CHO is responsible for ensuring that all personnel are aware of the locations of fire extinguishers and are trained in their use. After an extinguisher has been used, designated personnel must promptly recharge or replace it (29 CFR 1910.157(c)(4)). The laboratory supervisor or CHO is also responsible for ensuring proper training and providing supplementary equipment as needed.

Special care must be used when handling solutions of chemicals in syringes with needles. Do not recap needles, especially when they have been in contact with chemicals. Remove the needle and discard it immediately after use in the appropriate sharps containers. Blunt-tip needles are available from a number of commercial sources and should be used unless a sharp needle is required to puncture rubber septa or for subcutaneous injection.

For unattended operations, laboratory lights should be left on, and signs should be posted to identify the nature of the experiment and the hazardous substances in use. Arrangements should be made, if possible, for other workers to periodically inspect the operation. Information should be clearly posted indicating who to contact in the event of an emergency. Depending on the nature of the hazard, special rules, precautions, and alert systems may be necessary.

9. Training and Information

Personnel training at all levels within the organization, is essential. Responsibility and accountability throughout the organization are key elements in a strong safety and health program.

The employer is required to provide employees with information and training to ensure that they are apprised of the hazards of chemicals present in their work area (29 CFR 1910.1450(f)). This information must be provided at the time of an employee's initial assignment to a work area where hazardous chemicals are present and prior to assignments involving new exposure situations. The frequency of refresher information and training should be determined by the employer. At a minimum, laboratory personnel should be trained on their facility's specific CHP, methods and observations that may be used to detect the presence or release of a hazardous chemical (such as monitoring conducted by the employer, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released), the physical and health hazards of chemicals in the work area and means to protect themselves from these hazards. Trained laboratory personnel must know shut-off procedures in case of an emergency. All SDSs must be made available to the employees.

E. General Procedures for Working With Chemicals

The risk of laboratory injuries can be reduced through adequate training, improved engineering, good housekeeping, safe work practice and personal behavior.

1. General Rules for Laboratory Work With Chemicals

(a) Assigned work schedules should be followed unless a deviation is authorized by the laboratory supervisor.

(b) Unauthorized experiments should not be performed.

(c) Plan safety procedures before beginning any operation.

(d) Follow standard operating procedures at all times.

(e) Always read the SDS and label before using a chemical.

(f) Wear appropriate PPE at all times.

(g) To protect your skin from splashes, spills and drips, always wear long pants and closed-toe shoes.

(h) Use appropriate ventilation when working with hazardous chemicals.

(i) Pipetting should never be done by mouth.

(j) Hands should be washed with soap and water immediately after working with any laboratory chemicals, even if gloves have been worn.

(k) Eating, drinking, smoking, gum chewing, applying cosmetics, and taking medicine in laboratories where hazardous chemicals are used or stored should be strictly prohibited.

(l) Food, beverages, cups, and other drinking and eating utensils should not be stored in areas where hazardous chemicals are handled or stored.

(m) Laboratory refrigerators, ice chests, cold rooms, and ovens should not be used for food storage or preparation.

(n) Contact the laboratory supervisor, Principal Investigator, CHO or EHS office with all safety questions or concerns.

(o) Know the location and proper use of safety equipment.

(p) Maintain situational awareness.

(q) Make others aware of special hazards associated with your work.

(r) Notify supervisors of chemical sensitivities or allergies.

(s) Report all injuries, accidents, incidents, and near misses.

(t) Unauthorized persons should not be allowed in the laboratory.

(u) Report unsafe conditions to the laboratory supervisor or CHO.

(v) Properly dispose of chemical wastes.

Working Alone in the Laboratory

Working alone in a laboratory is dangerous and should be strictly avoided. There have been many tragic accidents that illustrate this danger. Accidents are unexpected by definition, which is why coworkers should always be present. Workers should coordinate schedules to avoid working alone.

Housekeeping

Housekeeping can help reduce or eliminate a number of laboratory hazards. Proper housekeeping includes appropriate labeling and storage of chemicals, safe and regular cleaning of the facility, and proper arrangement of laboratory equipment.

2. Nanoparticles and Nanomaterials

Nanoparticles and nanomaterials have different reactivities and interactions with biological systems than bulk materials, and understanding and exploiting these differences is an active area of research. However, these differences also mean that the risks and hazards associated with exposure to engineered nanomaterials are not well known. Because this is an area of ongoing research, consult trusted sources for the most up to date information available. Note that the higher reactivity of many nanoscale materials suggests that they should be treated as potential sources of ignition, accelerants, and fuel that could result in fire or explosion. Easily dispersed dry nanomaterials may pose the greatest health hazard because of the risk of inhalation. Operations involving these nanomaterials deserve more attention and more stringent controls than those where the nanomaterials are embedded in solid or suspended in liquid matrixes.

Consideration should be given to all possible routes of exposure to nanomaterials including inhalation, ingestion, injection, and dermal contact (including eye and mucous membranes). Avoid handling nanomaterials in the open air in a freeparticle state. Whenever possible, handle and store dispersible nanomaterials, whether suspended in liquids or in a dry particle form, in closed (tightly-sealed) containers. Unless cutting or grinding occurs, nanomaterials that are not in a free form (encapsulated in a solid or a nanocomposite) typically will not require engineering controls. If a synthesis is being performed to create nanomaterials, it is not enough to only consider the final material in the risk assessment, but consider the hazardous properties of the precursor materials as well.

To minimize laboratory personnel exposure, conduct any work that could generate engineered nanoparticles in an enclosure that operates at a negative pressure differential compared to the laboratory personnel breathing zone. Limited data exist regarding the efficacy of PPE and ventilation systems against exposure to nanoparticles. However, until further information is available, it is prudent to follow standard chemical hygiene practices. Conduct a hazard evaluation to determine PPE appropriate for the level of hazard according to the requirements set forth in OSHA's Personal Protective Equipment standard (29 CFR 1910.132).

3. Highly Toxic and Explosive/Reactive Chemicals/Materials

The use of highly toxic and explosive/ reactive chemicals and materials has been an area of growing concern. The frequency of academic laboratory incidents in the U.S. is an area of significant concern for the Chemical Safety Board (CSB). The CSB issued a case study on an explosion at Texas Tech University in Lubbock, Texas, which severely injured a graduate student handling a high-energy metal compound. Since 2001, the CSB has gathered preliminary information on 120 different university laboratory incidents that resulted in 87 evacuations, 96 injuries, and three deaths.

It is recommended that each facility keep a detailed inventory of highly toxic chemicals and explosive/reactive materials. There should be a record of the date of receipt, amount, location, and responsible individual for all acquisitions, syntheses, and disposal of these chemicals. A physical inventory should be performed annually to verify active inventory records. There should be a procedure in place to report security breaches, inventory discrepancies, losses, diversions, or suspected thefts.

Procedures for disposal of highly toxic materials should be established before any experiments begin, possibly even before the chemicals are ordered. The procedures should address methods for decontamination of any laboratory equipment that comes into contact with highly toxic chemicals. All waste should be accumulated in clearly labeled impervious containers that are stored in unbreakable secondary containment.

Highly reactive and explosive materials that may be used in the laboratory require appropriate procedures and training. An explosion can occur when a material undergoes a rapid reaction that results in a violent release of energy. Such reactions can happen spontaneously and can produce pressures, gases, and fumes that are hazardous. Some reagents pose a risk on contact with the atmosphere. It is prudent laboratory practice to use a safer alternative whenever possible.

If at all possible, substitutes for highly acute, chronic, explosive, or reactive chemicals should be considered prior to beginning work and used whenever possible.

4. Compressed Gas

Compressed gases expose laboratory personnel to both chemical and physical hazards. It is essential that these are monitored for leaks and have the proper labeling. By monitoring compressed gas inventories and disposing of or returning gases for which there is no immediate need, the laboratory can substantially reduce these risks. Leaking gas cylinders can cause serious hazards that may require an immediate evacuation of the area and activation of the emergency response system. Only appropriately trained hazmat responders may respond to stop a leaking gas cylinder under this situation.

F. Safety Recommendations—Physical Hazards

Physical hazards in the laboratory include combustible liquids, compressed gases, reactives, explosives and flammable chemicals, as well as high pressure/energy procedures, sharp objects and moving equipment. Injuries can result from bodily contact with rotating or moving objects, including mechanical equipment, parts, and devices. Personnel should not wear loosefitting clothing, jewelry, or unrestrained long hair around machinery with moving parts.

The Chemical Safety Board has identified the following key lessons for laboratories that address both physical and other hazards:

(1) Ensure that research-specific hazards are evaluated and then controlled by developing specific written protocols and training.

(2) Expand existing laboratory safety plans to ensure that all safety hazards, including physical hazards of chemicals, are addressed.

(3) Ensure that the organization's EHS office reports directly to an identified individual/office with organizational authority to implement safety improvements.

(4) Develop a verification program that ensures that the safety provisions of the CHP are communicated, followed, and enforced at all levels within the organization.

(5) Document and communicate all laboratory near-misses and previous incidents to track safety, provide opportunities for education and improvement to drive safety changes at the university.

(6) Manage the hazards unique to laboratory chemical research in the academic environment. Utilize available practice guidance that identifies and describes methodologies to assess and control hazards.

(7) Written safety protocols and training are necessary to manage laboratory risk.

G. Emergency Planning

In addition to laboratory safety issues, laboratory personnel should be familiar with established facility policies and procedures regarding emergency situations. Topics may include, but are not limited to:

(1) Evacuation procedures—when it is appropriate and alternate routes;

(2) Emergency shutdown procedures—equipment shutdown and materials that should be stored safely;

(3) Communications during an emergency—what to expect, how to report, where to call or look for information;

(4) How and when to use a fire extinguisher;

(5) Security issues—preventing tailgating and unauthorized access;

(6) Protocol for absences due to travel restrictions or illness;

(7) Safe practices for power outage;

(8) Shelter in place—when it is appropriate;

(9) Handling suspicious mail or phone calls;

(10) Laboratory-specific protocols relating to emergency planning and response;

(11) Handling violent behavior in the workplace; and

(12) First-aid and CPR training, including automated external defibrillator training if available.

It is prudent that laboratory personnel are also trained in how to respond to short-term, long-term and large-scale emergencies. Laboratory security can play a role in reducing the likelihood of some emergencies and assisting in preparation and response for others. Every institution, department, and individual laboratory should consider having an emergency preparedness plan. The level of detail of the plan will vary depending on the function of the group and institutional planning efforts already in place.

Emergency planning is a dynamic process. As personnel, operations, and events change, plans will need to be updated and modified. To determine the type and level of emergency planning needed, laboratory personnel need to perform a vulnerability assessment. Periodic drills to assist in training and evaluation of the emergency plan are recommended as part of the training program.

H. Emergency Procedures

(1) Fire alarm policy. Most organizations use fire alarms whenever a building needs to be evacuated—for any reason. When a fire alarm sounds in the facility, evacuate immediately after extinguishing all equipment flames. Check on and assist others who may require help evacuating.

(2) Emergency safety equipment. The following safety elements should be met:

a. A written emergency action plan has been provided to workers;

b. Fire extinguishers, eyewash units, and safety showers are available and tested on a regular basis; and

c. Fire blankets, first-aid equipment, fire alarms, and telephones are available and accessible.

(3) Chemical spills. Workers should contact the CHO or EHS office for instructions before cleaning up a chemical spill. All SDS and label instructions should be followed, and appropriate PPE should be worn during spill cleanup.

(4) Accident procedures. In the event of an accident, immediately notify appropriate personnel and local emergency responders. Provide an SDS of any chemical involved to the attending physician. Complete an accident report and submit it to the appropriate office or individual within 24 hours.

(5) Employee safety training program. New workers should attend safety training before they begin any activities. Additional training should be provided when they advance in their duties or are required to perform a task for the first time. Training documents should be recorded and maintained. Training should include hands-on instruction of how to use safety equipment appropriately.

(6) Conduct drills. Practice building evacuations, including the use of alternate routes. Practice shelter-in-place, including plans for extended stays. Walk the fastest route from your work area to the nearest fire alarm, emergency eye wash and emergency shower. Learn how each is activated. In the excitement of an actual emergency, people rely on what they learned from drills, practice and training.

(7) Contingency plans. All laboratories should have long-term contingency plans in place (e.g., for pandemics). Scheduling, workload, utilities and alternate work sites may need to be considered.

I. Laboratory Security

Laboratory security has evolved in the past decade, reducing the likelihood of some emergencies and assisting in preparation and response for others. Most security measures are based on the laboratory's vulnerability. Risks to laboratory security include, but are not limited to:

(1) Theft or diversion of chemicals, biologicals, and radioactive or proprietary materials, mission-critical or high-value equipment;

(2) Threats from activist groups;

(3) Intentional release of, or exposure to, hazardous materials;

(4) Sabotage or vandalism of chemicals or high-value equipment;

(5) Loss or release of sensitive information; and

(6) Rogue work or unauthorized laboratory experimentation. Security systems in the laboratory are used to detect and respond to a security breach, or a potential security breach, as well as to delay criminal activity by imposing multiple layered barriers of increasing stringency. A good laboratory security system will increase overall safety for laboratory personnel and the public, improve emergency preparedness by assisting with preplanning, and lower the organization's liability by incorporating more rigorous planning, staffing, training, and command systems and implementing emergency communications protocols, drills, background checks, card access systems, video surveillance, and other measures. The security plan should clearly delineate response to security issues, including the coordination of institution and laboratory personnel with both internal and external responders.

[76 FR 33609, June 8, 2011; 77 FR 17888, March 26, 2012; 78 FR 4325, Jan. 22, 2013]

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- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** Z
- **Subpart Title:** Toxic and Hazardous Substances
- **Standard Number:** 1910.1450 App B
- **Title:** References (Non-Mandatory)

The following references are provided to assist the employer in the development of a Chemical Hygiene Plan. The materials listed below are offered as non-mandatory guidance. References listed here do not imply specific endorsement of a book, opinion, technique, policy or a specific solution for a safety or health problem. Other references not listed here may better meet the needs of a specific laboratory. (a) Materials for the development of the Chemical Hygiene Plan:

1. American Chemical Society, Safety in Academic Chemistry Laboratories, 4th edition, 1985.

2. Fawcett, H.H. and W.S. Wood, Safety and Accident Prevention in Chemical Operations, 2nd edition, Wiley-Interscience, New York, 1982.

3. Flury, Patricia A., Environmental Health and Safety in the Hospital Laboratory, Charles C. Thomas Publisher, Springfield IL, 1978.

4. Green, Michael E. and Turk, Amos, Safety in Working with Chemicals, Macmillan Publishing Co., NY, 1978.

5. Kaufman, James A., Laboratory Safety Guidelines, Dow Chemical Co., Box 1713, Midland, MI 48640, 1977.

6. National Institutes of Health, NIH Guidelines for the Laboratory use of Chemical Carcinogens, NIH Pub. No. 81-2385, GPO, Washington, DC 20402, 1981.

7. National Research Council, Prudent Practices for Disposal of Chemicals from Laboratories, National Academy Press, Washington, DC, 1983.

8. National Research Council, Prudent Practices for Handling Hazardous Chemicals in Laboratories, National Academy Press, Washington, DC, 1981.

9. Renfrew, Malcolm, Ed., Safety in the Chemical Laboratory, Vol. IV, J. Chem. Ed., American Chemical Society, Easlon, PA, 1981.

10. Steere, Norman V., Ed., Safety in the Chemical Laboratory, J. Chem. Ed. American Chemical Society, Easlon, PA, 18042, Vol. I, 1967, Vol. II, 1971, Vol. III, 1974.

11. Steere, Norman V., Handbook of Laboratory Safety, the Chemical Rubber Company Cleveland, OH, 1971.

12. Young, Jay A., Ed., Improving Safety in the Chemical Laboratory, John Wiley & Sons, Inc. New York, 1987.

(b) Hazardous Substances Information:

1. American Conference of Governmental Industrial Hygienists, Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes, 6500 Glenway Avenue, Bldg. D-7, Cincinnati, OH 45211-4438.

2. Annual Report on Carcinogens, National Toxicology Program U.S. Department of Health and Human Services, Public Health Service, U.S. Government Printing Office, Washington, DC, (latest edition).

3. Best Company, Best Safety Directory, Vols. I and II, Oldwick, N.J., 1981.

4. Bretherick, L., Handbook of Reactive Chemical Hazards, 2nd edition, Butterworths, London, 1979.

5. Bretherick, L., Hazards in the Chemical Laboratory, 3rd edition, Royal Society of Chemistry, London, 1986.

6. Code of Federal Regulations, 29 CFR part 1910 subpart Z. U.S. Govt. Printing Office, Washington, DC 20402 (latest edition).

7. IARC Monographs on the Evaluation of the Carcinogenic Risk of chemicals to Man, World Health Organization Publications Center, 49 Sheridan Avenue, Albany, New York 12210 (latest editions).

8. NIOSH/OSHA Pocket Guide to Chemical Hazards. NIOSH Pub. No. 85-114, U.S. Government Printing Office, Washington, DC, 1985 (or latest edition).

9. Occupational Health Guidelines, NIOSH/OSHA. NIOSH Pub. No. 81-123 U.S. Government Printing Office, Washington, DC, 1981.

10. Patty, F.A., Industrial Hygiene and Toxicology, John Wiley & Sons, Inc., New York, NY (Five Volumes).

11. Registry of Toxic Effects of Chemical Substances, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Revised Annually, for sale from Superintendent of documents US. Govt. Printing Office, Washington, DC 20402.

12. The Merck Index: An Encyclopedia of Chemicals and Drugs. Merck and Company Inc. Rahway, N.J., 1976 (or latest edition).

13. Sax, N.I. Dangerous Properties of Industrial Materials, 5th edition, Van Nostrand Reinhold, NY., 1979.

14. Sittig, Marshall, Handbook of Toxic and Hazardous Chemicals, Noyes Publications. Park Ridge, NJ, 1981.

(c) Information on Ventilation:

1. American Conference of Governmental Industrial Hygienists Industrial Ventilation (latest edition), 6500 Glenway Avenue, Bldg. D-7, Cincinnati, Ohio 45211-4438.

2. American National Standards Institute, Inc. American National Standards Fundamentals Governing the Design and Operation of Local Exhaust Systems ANSI Z 9.2-1979 American National Standards Institute, N.Y. 1979.

3. Imad, A.P. and Watson, C.L. Ventilation Index: An Easy Way to Decide about Hazardous Liquids, Professional Safety pp 15-18, April 1980.

4. National Fire Protection Association, Fire Protection for Laboratories Using Chemicals NFPA-45, 1982.

Safety Standard for Laboratories in Health Related Institutions, NFPA, 56c, 1980.

Fire Protection Guide on Hazardous Materials, 7th edition, 1978.

National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

5. Scientific Apparatus Makers Association (SAMA), Standard for Laboratory Fume Hoods, SAMA LF7-1980, 1101 16th Street, NW., Washington, DC 20036.

(d) Information on Availability of Referenced Material:

1. American National Standards Institute (ANSI), 1430 Broadway, New York, NY 10018.

2. American Society for Testing and Materials (ASTM), 1916 Race Street, Philadelphia, PA 19103.

[55 FR 3327, Jan. 31, 1990; 57 FR 29204, July 1, 1992; 61 FR 5507, Feb. 13, 1996]

OSHA LABORATORY STANDARD FACT SHEETS

OSHA® FactSheet

Laboratory Safety OSHA Laboratory Standard

OSHA's Occupational Exposure to Hazardous Chemicals in Laboratories standard (29 CFR 1910.1450), referred to as the Laboratory standard, covers laboratories where chemical manipulation generally involves small amounts of a limited variety of chemicals. This standard applies to all hazardous chemicals meeting the definition of "laboratory use" and having the potential for worker exposure.

Hazardous chemicals present physical and/or health threats to workers in clinical, industrial, and academic laboratories. Hazardous laboratory chemicals include cancer-causing agents (carcinogens), toxins that may affect the liver, kidney, or nervous system, irritants, corrosives, and sensitizers, as well as agents that act on the blood system or damage the lungs, skin, eyes, or mucous membranes. OSHA rules limit all industry exposures to approximately 400 substances.

Elements of the Laboratory Standard

This standard applies to employers engaged in laboratory use of hazardous chemicals.[1]

- "Laboratory" means a facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.
- "Laboratory use of hazardous chemicals" means handling or use of such chemicals in which all of the following conditions are met:
  - Chemical manipulations are carried out on a "laboratory scale" (i.e., work with substances in which the containers used for reactions, transfers, and other handling of substances is designed to be easily handled by one person);
  - Multiple chemical procedures or chemicals are used;
  - The procedures involved are not part of a production process, nor do they in any way simulate a production process; and
  - "Protective laboratory practices and equipment" are available and in common use to minimize the potential for worker exposure to hazardous chemicals.
- Any hazardous chemical use which does not meet this definition is regulated under other standards. This includes other hazardous chemical use within a laboratory. For instance:
  - Chemicals used in building maintenance of a laboratory are not covered under the Laboratory standard.
  - The production of a chemical for commercial sale, even in small quantities, is not covered by the Laboratory standard.
  - Quality control testing of a product is not covered under the Laboratory standard.
- If the Laboratory standard applies, employers must develop a Chemical Hygiene Plan (CHP). A CHP is the laboratory's program which addresses all aspects of the Laboratory standard.
  - The employer is required to develop and carry out the provisions of a written CHP.
  - A CHP must address virtually every aspect of the procurement, storage, handling, and disposal of chemicals in use in a facility.
- Primary elements of a CHP include the following:
  - Minimizing exposure to chemicals by establishing standard operating procedures, requirements for personal protective equipment, engineering controls (e.g., chemical fume hoods, air handlers, etc.) and waste disposal procedures.
  - For some chemicals, the work environment must be monitored for levels that require action or medical attention.
  - Procedures to obtain free medical care for work-related exposures must be stated.

- The means to administer the plan must be specified.
- Responsible persons must be designated for procurement and handling of Material Safety Data Sheets, organizing training sessions, monitoring employee work practices, and annual revision of the CHP.

[1]**Note:** The scope of the Formaldehyde standard (29 CFR 1910.1048) is not affected in most cases by the Laboratory standard. The Laboratory standard specifically does not apply to formaldehyde use in histology, pathology, and human or animal anatomy laboratories; however, if formaldehyde is used in other types of laboratories which are covered by the Laboratory standard, the employer must comply with 29 CFR 1910.1450.

Additional Information

The following OSHA Interpretations of the Laboratory standard provide additional information:

- Labeling Requirements under the HAZCOM and Laboratory standards; use of safe needle devices. (2001, January 11). Available at: www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=23781. Also, for labeling information, refer to the Laboratory Safety QuickCard.
- Coverage of various types of laboratories by the Laboratory standard. (1991, February 8). Available at: www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=20190.
- The Laboratory standard does not apply to a pharmacy operation mixing cytotoxic drugs. (1990, June 22). Available at: www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=20025.

OSHA's Safety and Health Topics Page entitled Laboratories, provides more detailed information about the Laboratory standard and is available at: www.osha.gov/SLTC/laboratories/index.html.

This is one in a series of informational fact sheets highlighting OSHA programs, policies or standards. It does not impose any new compliance requirements. For a comprehensive list of compliance requirements of OSHA standards or regulations, refer to Title 29 of the Code of Federal Regulations. This information will be made available to sensory-impaired individuals upon request. The voice phone is (202) 693-1999; the teletypewriter (TTY) number is (877) 889-5627.

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Laboratory Safety Chemical Hygiene Plan (CHP)

OSHA's Occupational Exposure to Hazardous Chemicals in Laboratories standard (29 CFR 1910.1450), referred to as the Laboratory standard, specifies the mandatory requirements of a Chemical Hygiene Plan (CHP) to protect laboratory workers from harm due to hazardous chemicals. The CHP is a written program stating the policies, procedures and responsibilities that protect workers from the health hazards associated with the hazardous chemicals used in that particular workplace.

Required CHP Elements

1. Standard operating procedures relevant to safety and health considerations for each activity involving the use of hazardous chemicals.
2. Criteria that the employer will use to determine and implement control measures to reduce exposure to hazardous materials [i.e., engineering controls, the use of personal protective equipment (PPE), and hygiene practices] with particular attention given to selecting control measures for extremely hazardous materials.
3. A requirement to ensure that fume hoods and other protective equipment are functioning properly and identify the specific measures the employer will take to ensure proper and adequate performance of such equipment.
4. Information to be provided to lab personnel working with hazardous substances include:
   - The contents of the Laboratory standard and its appendices.
   - The location and availability of the employer's CHP.
   - The permissible exposure limits (PELs) for OSHA regulated substances or recommended exposure limits for other hazardous chemicals where there is no applicable OSHA standard.
   - The signs and symptoms associated with exposures to hazardous chemicals used in the laboratory.
   - The location and availability of known reference materials on the hazards, safe handling, storage and disposal of hazardous chemicals found in the laboratory including, but not limited to, the Material Safety Data Sheets received from the chemical supplier.
5. The circumstances under which a particular laboratory operation, procedure or activity requires prior approval from the employer or the employer's designee before being implemented.
6. Designation of personnel responsible for implementing the CHP, including the assignment of a Chemical Hygiene Officer and, if appropriate, establishment of a Chemical Hygiene Committee.
7. Provisions for additional worker protection for work with particularly hazardous substances. These include "select carcinogens," reproductive toxins and substances that have a high degree of acute toxicity. Specific consideration must be given to the following provisions and shall be included where appropriate:
   - Establishment of a designated area.
   - Use of containment devices such as fume hoods or glove boxes.
   - Procedures for safe removal of contaminated waste.
   - Decontamination procedures.
8. The employer must review and evaluate the effectiveness of the CHP at least annually and update it as necessary.

Worker Training Must Include:

- Methods and observations that may be used to detect the presence or release of a hazardous chemical (such as monitoring conducted by the employer, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released, etc.).
- The physical and health hazards of chemicals in the work area.

- The measures workers can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect workers from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and personal protective equipment to be used.
- The applicable details of the employer's written CHP.

Medical Exams and Consultation

The employer must provide all personnel who work with hazardous chemicals an opportunity to receive medical attention, including any follow-up examinations which the examining physician determines to be necessary, under the following circumstances:

- Whenever a worker develops signs or symptoms associated with a hazardous chemical to which the worker may have been exposed in the laboratory, the worker must be provided an opportunity to receive an appropriate medical examination.
- Where exposure monitoring reveals an exposure level routinely above the action level (or in the absence of an action level, the PEL) for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements, medical surveillance must be established for the affected worker(s) as prescribed by the particular standard.
- Whenever an event takes place in the work area such as a spill, leak, explosion or other occurrence resulting in the likelihood of a hazardous exposure, the affected worker(s) must be provided an opportunity for a medical consultation to determine the need for a medical examination.
- All medical examinations and consultations must be performed by or under the direct supervision of a licensed physician and be provided without cost to the worker, without loss of pay and at a reasonable time and place.

For additional information on developing a CHP, consult the following sources:

- View the complete standard at the OSHA Web site, www.osha.gov.
- Appendix A of 29 CFR 1910.1450 provides non-mandatory recommendations to assist in developing a CHP.

This is one in a series of informational fact sheets highlighting OSHA programs, policies or standards. It does not impose any new compliance requirements. For a comprehensive list of compliance requirements of OSHA standards or regulations, refer to Title 29 of the Code of Federal Regulations. This information will be made available to sensory-impaired individuals upon request. The voice phone is (202) 693-1999; the teletypewriter (TTY) number is (877) 889-5627.

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U.S. Chemical Safety and Hazard Investigation Board

October 2014

Key Lessons for Preventing Incidents from Flammable Chemicals in Educational Demonstrations

Eliminating Flash Fire Hazards by Substituting or Minimizing the use of Flammable Chemicals and Performing an Effective Hazard Review Will Prevent Injuries

Key Lessons Summarized:

- Due to flash fire hazards and the potential for serious injuries, do not use bulk containers of flammable chemicals in educational demonstrations when small quantities are sufficient
- Employers should implement strict safety controls when demonstrations necessitate handling hazardous chemicals — including written procedures, effective training, and the required use of appropriate personal protective equipment for all participants
- Conduct a comprehensive hazard review prior to performing any educational demonstration
- Provide a safety barrier between the demonstration and the audience

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Summary

Educational demonstrations involving flammable materials are often performed at schools or museums to engage students and visitors and stimulate their interest in science. On September 3, 2014, a flash fire[1] occurred during a science demonstration at the Terry Lee Wells Nevada Discovery Museum ("The Discovery") in Reno, Nevada. Thirteen people were injured, including eight children and one adult who were transported to the hospital as a result of the fire. One child was kept overnight for treatment and additional observation.

This incident is one of many the U.S. Chemical Safety Board (CSB) has identified in which lab demonstrations involving flammable materials have resulted in fires and injuries. Methanol, the hazardous chemical involved in The Discovery and two other recent incidents the CSB has investigated, is classified as a highly flammable liquid, and users should adopt strict safety controls.[2] This safety bulletin is intended to provide information about The Discovery incident and other similar incidents, as well as provide safety guidance to prevent future occurrences.

Key Lessons

- *Bulk containers[3] of flammable chemicals should not be in close proximity to potential ignition sources such as open flames.* When planning scientific demonstrations that include flammable chemicals such as methanol, apply the well-established safety concept of the hierarchy of controls,[4] placing top priority on eliminating flash fire hazards. In many demonstrations this can be accomplished by minimizing the amount of flammable chemicals used to the smallest quantity necessary (prohibiting the presence of bulk containers) or substituting a flammable chemical with a less hazardous substance (one that is not highly flammable). For some demonstrations the risks may be deemed too high or the quantity of flammable chemicals cannot be sufficiently reduced, and alternative approaches to eliminating the flash fire hazard (for example, through video demonstrations) should be considered.

- *Employers should implement strict safety controls when lab demonstrators are handling hazardous materials.* Prior to conducting any activity with flammable chemicals, it is the responsibility of employers to ensure that all presenters are sufficiently trained on (1) all hazards involved with demonstrations, (2) safety procedures, and (3) necessary safety precautions.

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[1] A flash fire is a fire that spreads rapidly through a diffuse fuel, such as dust, gas, or the vapors of an ignitable liquid, without the production of significant overpressure. National Fire Protection Association (NFPA) 921. *Guide for Fire and Explosion Investigations*, 2014; Section 3.3.81.

[2] With a flash point of approximately 50°F and a boiling point of approximately 150°F, methanol is a class IB flammable liquid, placing methanol in the second highest Occupational Safety and Health Administration (OSHA) flammability class. Flammability classification is one criteria that should be considered when evaluating for safer alternatives. https://www.osha.gov/dte/library/flammable_liquids/flammable_liquids.html (accessed October 12, 2014). The flash point is the lowest temperature of a liquid at which it gives off vapor at a sufficient rate to support a momentary flame across its surface. National Fire Protection Association (NFPA) 921. *Guide for Fire and Explosion Investigations*, 2014; Section 3.3.82.

[3] For the purposes of this report a bulk container is any container that is larger than the amount needed for a demonstration. In past incidents the bulk container typically was the original container purchased.

[4] The hierarchy of controls is a system widely used in the petrochemical industry to minimize or eliminate hazards.

- *Prior to performing any activity with flammable chemicals, conduct a thorough hazard review.* Take into account all flammability hazards and any other hazards which might possibly occur during the demonstration. Prepare a written procedure that describes all of the activity details and all of the required safety precautions (e.g. minimum personal protective equipment (PPE) requirements, safety barriers, chemical handling requirements, etc.).

- *Provide a safety barrier between any activity involving flammable chemicals and any audience or bystanders.* Preferably, this would be a physical barrier, such as a clear shield. Alternatively, the barrier could be a minimum safe distance between the activity and the audience, established during the hazard review.

- *Any person inside the barrier during a chemical demonstration activity, such as the person performing the activity, must wear all appropriate personal protective equipment.* Examples include gloves, safety glasses with side shields, face shields, and lab coats or clothing made of flame-resistant material.

The Discovery Demonstration Description

A science demonstration called the "Fire Tornado" was regularly performed at The Discovery (Figure 1). The Fire Tornado demonstration is comprised of three smaller demonstrations performed sequentially to produce different colored flame "tornadoes." Each demonstration involves igniting flammable isopropanol (rubbing alcohol) or methanol in the presence of a chemical additive to produce an orange, red, or green colored flame six to twelve inches in height. The green tornado that results from a methanol flame in the presence of boric acid (a common ant and roach killer) is shown in Figure 2. The Fire Tornado demonstration is intended to educate the audience on how tornadoes form and about the chemical properties of the materials involved.

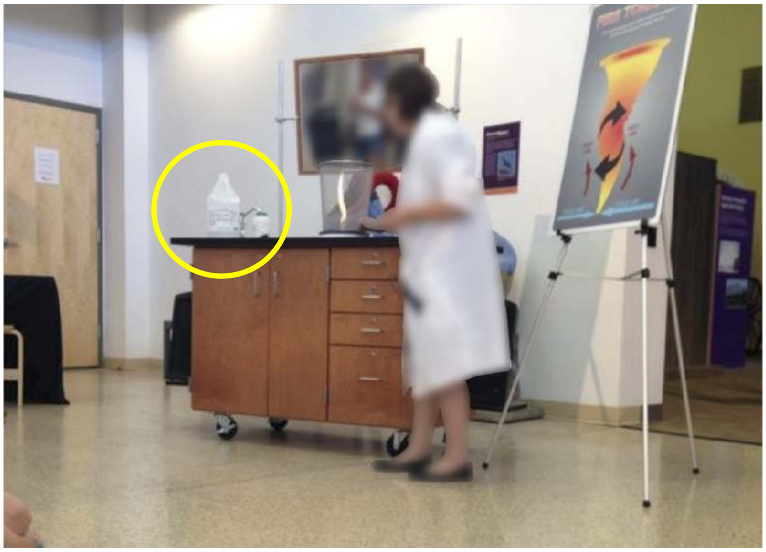

Figure 1. Fire tornado demonstration on the day of the incident[5]. The four-liter bulk methanol container can be seen on the front left corner of the table (circled in yellow).

Figure 2. Boric Acid Fire Tornado with methanol[6]

The basic procedure for all three demonstration variations, described below, is the same. Only the fuel source and color additive are changed.

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[5] http://www.rgj.com/story/news/2014/09/03/explosion-reported-in-reno/15044399/ (accessed September 4, 2014).

[6] http://chemistry.about.com/od/coloredfire/a/Green-Fire-Whirlwind.htm (accessed September 4, 2014).

- *A cotton ball is placed on a glass dish and the fuel (isopropanol or methanol) is added to the dish to saturate the cotton ball;*
- *The color additive (strontium nitrate or boric acid) is added or sprinkled onto the cotton ball;*
- *The dish is placed on a turntable and the cotton ball is ignited using a barbeque-type butane lighter;*
- *The dish and burning cotton ball are covered using a wire mesh waste basket; and*
- *The educator[7] spins the turntable, thus spinning the burning cotton ball and wire mesh basket, creating the tornado effect.*

After each fire tornado is produced, the wire mesh basket is removed, the dish is placed to the side, and a new dish is brought out to repeat the process with new chemicals.

Incident Description

On September, 3, 2014, at approximately 4:00 pm, an educator was performing the Fire Tornado demonstration for a group of visitors consisting primarily of young children. The visitors were seated on the floor approximately 15 feet away from the demonstration. The first two variations of the demonstration were performed without incident. During the third variation, the educator held the lighter flame to the cotton ball, but the expected fuel flame did not rise. The educator realized that methanol fuel had not been added to the cotton ball. The educator attempted to pour a small amount of methanol from a four-liter (about one gallon) bulk methanol container onto the cotton ball. Although there had been no sign of flame from the cotton ball, it is likely that the lighter had actually ignited the cotton, and it was smoldering. The poured methanol ignited immediately, and then flashed back into the methanol container. The methanol inside the container then ignited, resulting in a pressure rise that expelled a large flame from the mouth of the container, causing a large flash fire (Figure 3). The educator dropped the methanol container after it caught fire. The container spilled, and burning methanol spread toward the audience, catching some members of the audience on fire. In response to the fire, two of The Discovery employees acted quickly, extinguishing the fire using a nearby fire extinguisher and fire blanket. The burned remains of the bulk methanol container used can be seen in Figure 4.

Figure 3. Methanol igniting on the day of the incident[8]

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[7] "Educator" is a term used by the museum to describe a museum staff employee whose job duties include visitor interaction and performing demonstrations. The educators do not write the procedures for the demonstrations, they only perform them.

[8] http://www.nbcnews.com/watch/nightly-news/video-shows-dangerous-accident-at-childrens-museum-325405251630 (accessed September 11, 2014).

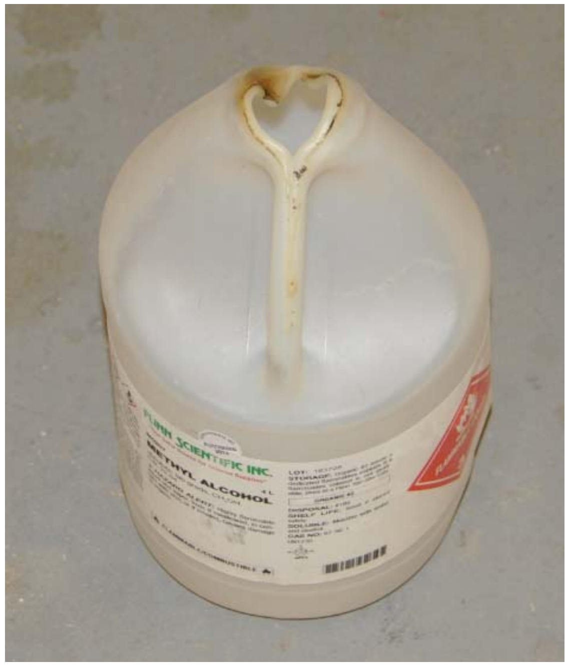

Figure 4. Methanol container following the incident

Demonstration Analysis

The Discovery has approximately 14 demonstrations that its educators perform on a regular basis. Five of these demonstrations involve the ignition of flammable chemicals such as methanol, hydrogen, and methane. To prevent serious injuries, the risks associated with these flammable chemicals should be analyzed and controlled, especially when associated with demonstrations performed in front of an audience. Despite the inherent flammability of methanol, no effective hazard review was ever carried out by The Discovery for any of the demonstrations. The CSB learned that neither The Discovery educators nor their managers had experience or were expected to perform hazard analyses.

As a result of not performing an effective hazard review, the Fire Tornado demonstration procedure lacked sufficient safety precautions. For example, during the initial demonstration training, educators were told verbally to first pour the methanol from the bulk container into a small beaker in a separate room. However, the written procedure for the Fire Tornado demonstration did not contain such a requirement. Had the demonstration procedure included this requirement, the likelihood that the flash fire would have reached the audience would have been substantially minimized, if not eliminated.

The lack of an effective hazard analysis and formal safety procedures resulted in a normalization[9] of the improper use of the four-liter bulk methanol container during the Fire Tornado demonstrations. The

[9] Normalization of deviance is the acceptance of events that are not supposed to happen. Objective outside observers view the given situation as abnormal or deviant, whereas those individuals on the inside become accustomed to it and view it as normal and acceptable. *See* Interview: Diane Vaughan, Consulting Newsline, May, 2008. http://www.consultingnewsline.com/Info/Vie%20du%20Conseil/Le%20Consultant%20du%20mois/Diane%20Vaughan%20(English).html (accessed October 7, 2014).

Discovery has a storage cabinet for flammable chemicals in the basement of the facility where the methanol was intended to be stored. Prior to performing the Fire Tornado demonstration, the methanol was originally brought upstairs to an adjacent room near the demonstration area in order to provide educators more convenient access for filling the beaker. The beaker of methanol was then used in the demonstration and the bulk methanol container remained in the adjacent room. When demonstrations were over, the bulk methanol container would be returned to the basement cabinet.

More recently, some educators began bringing the bulk methanol container to the demonstration to show the audience. These educators stopped transferring the methanol to the beakers and instead soaked the cotton balls directly from the bulk methanol container during the demonstration. In fact, when the educator who performed the Fire Tornado demonstration on the day of the incident received the initial demonstration training, the beakers were not used and the cotton balls were soaked with methanol straight from the bulk methanol container. As a result, this was the practice the educator used on the day of the incident. As previously mentioned, the written Fire Tornado demonstration procedure did not require the use of a beaker for methanol transfer. It provided no warnings about storing the methanol container outside of the flammables cabinet, or about using it directly during the demonstration.

The CSB also learned that the training provided to the educators did not effectively emphasize the inherent methanol flammability hazards. Due to The Discovery staff's lack of understanding and appreciation for the flammable hazards of methanol, the demonstration procedures and training focused primarily on the best ways for educators to interact with the audience and communicate science findings. Insufficient emphasis was placed on the safe use of methanol and other flammable materials during the demonstrations. In fact, periodic evaluations focused on presenting an engaging demonstration rather than ensuring good safety practices during demonstrations. For example, displaying the bulk methanol container to the audience, tone of voice, clear explanation of the science principles, and enthusiasm about the demonstration were highly valued features of the presentation.

The Discovery did not emphasize the importance of the use of a small container with a minimum amount of methanol during the demonstration. However, the CSB determined that only a few milliliters of methanol were actually needed to perform the Fire Tornado demonstration. The quantity of methanol could have been minimized by pre-moistening the cotton balls with methanol prior to the demonstration.

Related Educational Demonstration Incidents

The incident at The Discovery is not an isolated event. Incidents involving demonstrations that use flammable materials and an open flame have occurred across the country. Just recently, the CSB has investigated three methanol demonstration incidents that occurred within 48 days of each other.

In December 2013, the CSB issued a safety message video about a 2006 incident similar to The Discovery incident.[10] Ohio high school students were severely burned when a demonstration called the "Rainbow" experiment resulted in a flash fire. The Rainbow demonstration also used various chemicals and methanol to produce different colored flames. When the flame did not rise as desired, the instructor added methanol directly from a four-liter container and the methanol in the container ignited. More

[10] This video can be found at http://www.csb.gov/videos/ and is entitled *After the Rainbow*.

recently, in January 2014, the same Rainbow demonstration resulted in two New York high school students being burned.[11]

As a result of the continued occurrences of injuries caused by methanol demonstrations, the American Chemical Society issued a Safety Alert to recommend that demonstrations on open surfaces (outside of a chemical fume hood[12]) involving the use of flammable solvents such as methanol should be immediately discontinued due to the "unacceptable risk of flash fire and deflagrations[13] that can cause serious injuries to students and teachers."[14] The ACS Safety Alert also informs recipients of safer demonstration alternatives if it is determined that the demonstrations must be conducted for educational purposes.

On September 15, 2014, only 12 days after the incident at The Discovery, an incident involving a methanol flash fire occurred at the STRIVE Preparatory School ("STRIVE") — a high school in Denver, Colorado. This incident resulted in four students being burned in the flash fire, one seriously. Similar to the other incidents discussed above, a chemistry teacher, a recent college graduate who had just started his teaching career, was giving a demonstration on flammable properties by igniting a small pool of methanol to create a flame in front of students. When the flame did not rise as high as he had hoped, he added additional methanol to the flame from a four-liter bulk container. The small flame flashed back into the bulk methanol container and formed a flash fire that shot out about 12 feet and hit a student in the chest, resulting in serious burn injuries to the student. Three other nearby students were also injured in the flash fire.

The CSB found in its investigation of the STRIVE incident that the school lacked adequate safety procedures and a lab safety training program. Also, the teacher was not aware of the potential for a methanol flash fire and had received no training about the hazards involved with demonstrations involving large quantities of methanol or other flammable materials. School officials acknowledged that training, procedures, and personal protective equipment were not provided, but they believed that the teacher had the appropriate level of training and experience to conduct laboratory experiments based on the fact that the teacher obtained a Bachelors degree in Chemistry and gained some experience supervising college chemistry labs. However, the CSB identified in its investigation of the January 7, 2010, Texas Tech University research lab explosion that graduates of university chemistry programs are often only introduced to limited, basic safety training that may not be effective beyond "cookbook" laboratory work with well-understood and defined risks.[15] As such, employers should not rely on college level experience in lieu of an effective safety management system that ensures effective oversight, hazard assessments, training, and procedures.

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[11] http://newyork.cbslocal.com/2014/01/02/students-treated-for-burns-as-uws-high-school-chemistry-experiment-goes-awry/ (accessed September 12, 2014).

[12] Laboratory safety chemical fume hoods are often the primary control device for protecting laboratory workers when working with flammable chemicals. *See* https://www.osha.gov/Publications/laboratory/OSHAquickfacts-lab-safety-chemical-fume-hoods.pdf (accessed October 15, 2014).

[13] A deflagration is the propagation of a flame at a velocity that is less than the speed of sound. NFPA 921. *Guide for Fire and Explosion Investigations*, 2008.

[14] American Chemical Society (ACS). *Safety Alert Rainbow Demonstration.* http://www.acs.org/content/acs/en/about/governance/committees/chemicalsafety/safety-alert-rainbow-demonstration.html (accessed October 7, 2014).

[15] U.S. Chemical Safety Board (CSB). *Case Study: Texas Tech Laboratory Explosion*. *See* http://www.csb.gov/assets/1/19/CSB_Study_TTU_.pdf (accessed October 17, 2014).

On October 20, 2014, less than five weeks after the incident at STRIVE, three Cub Scouts[16] and one adult were injured during a demonstration at a Cub Scout event in Raymond, Illinois. This incident occurred when methanol[17] was poured from a container onto boric acid near an open flame. Similar to other incidents, the flame propagated back into the bottle and resulted in a flash fire that burned members of the group and seriously injured one Cub Scout. Like The Discovery incident, this demonstration involved burning methanol with boric acid to produce a green colored flame.

Flash Fire Hazard

Flammable liquids such as methanol or other alcohols used in educational demonstrations are capable of igniting and forming a fire that can cause severe burn injuries and property damage. These liquids are often used because of their desired flammable properties. Frequently, however, the educator is not aware that the flammable materials used can cause fires that are much more dangerous than a small flame. One type of fire that is common with methanol lab incidents is a flash fire. A flash fire occurs when the combustion of a flammable gas and air mixture produces a fire that does not last very long but may be large.[18] Also, if a flash fire burns back to its source, such as a large methanol container, a jet fire can form that can spray a long distance (illustrated in Figure 3 above), which is what occurred in both The Discovery and Denver high school incidents. Any educators who perform scientific demonstrations with flammable materials capable of causing a fire in the open atmosphere of a lab should be aware of the hazards and trained in methods to prevent flash fires from occurring.

Safety Programs

Educational chemical demonstrations are valuable in that they help teach important science concepts in ways that make lasting impressions and help inspire students to become involved in science. When performing demonstrations that use hazardous chemicals, care must be taken to make sure these activities are conducted as safely as possible. The hazards involved need to be identified and adequately addressed before demonstrations involving flammable materials are performed in front of children and audiences of any age. A hazard review should be completed prior to performing any chemical demonstrations to identify potential hazards and risk mitigation strategies (Figure 5), such as minimizing bulk material, using a safety barrier, and wearing appropriate personal protection equipment.

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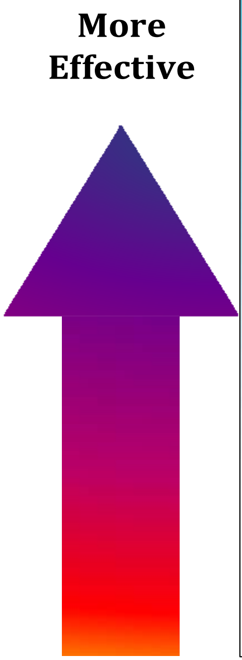
[16] Cub Scouts is a program of the Boy Scouts of America intended for boys aged seven to ten. *See* http://www.scouting.org/scoutsource/CubScouts/FAQS/program.aspx#aa (accessed October 23, 2014).

[17] The source of the methanol was a 12-ounce bottle of HEET®. HEET® is a gas line antifreeze and water remover that is readily available at auto supply stores and contains 99 weight percent methanol. *See* http://www.goldeagle.com/brands/heet and http://complyplus.grainger.com/grainger/msds.asp?sheetid=2986281 (accessed October 23, 2014).

[18] When a flash fire occurs it can expand the cloud volume of the flammable material through combustion heat by a factor of eight. CCPS. *Guidelines for Vapor Cloud Explosion, Pressure Vessel Burst, BLEVE and Flash Fire Hazards, 2nd Edition*, Chapter 5, 2010.



Substitute	Perform demonstrations that do not use hazardous chemicals. Substitute less hazardous chemicals to conduct demonstrations.
Minimize	When handling flammable chemicals, restrict amounts used to the smallest amount necessary for the function.
Administrative Safeguards	Prior to performing any activity with flammable chemicals, conduct a thorough hazard safety review. Prepare a comprehensive written procedure which describes all of the activity details and all of the safety precautions such as minimum personal protective equipment and safety barriers. Train all presenters in all hazards and required safety precautions prior to conducting chemical demonstrations.

Figure 5. Risk reduction examples for science demonstrations involving flammable chemicals

Not all prevention and mitigation strategies offer the same level of protection from an incident. The safety potential of various strategies can be ranked from most to least effective, a concept known as the 'hierarchy of controls'.[19] As depicted in Figure 6, the further left on the hierarchy chain, the more effective the technique is in reducing risk, or ensuring safety. Two highly effective risk reduction techniques on the hierarchy of controls would be to eliminate the flash fire hazards by substituting[20] a less hazardous chemical or minimizing the amount of hazardous chemical used in a chemical demonstration. For some demonstrations the risks may be deemed too high, or the quantity of flammable chemicals cannot be sufficiently reduced and alternative approaches to eliminating the flash fire hazard (for example, through video demonstrations) should be considered. Lower risk reduction actions include administrative safeguards that help prevent or mitigate an incident involving hazardous chemicals such as training, comprehensive procedures, and wearing personal protective equipment. Even if a greater risk-reduction action, such as substitution of a less hazardous chemical, is used, it is still important to maintain other, lower level, administrative controls. This way even if one risk reduction system fails, others are in place to prevent an incident. It is important for managers to ensure that these methods used for safer chemical demonstrations remain in place and are followed.

[19] Prevention and mitigation strategies represent the safeguards designed to eliminate, prevent, reduce, or mitigate a scenario; they are also referred to as barriers, layers of protection, lines of defense, or control measures.

[20] One example for a substitution of the colored flame methanol experiments would be to soak wooden splints in salt solutions and then burn the wooden splints in a Bunsen burner to generate different colored flames.

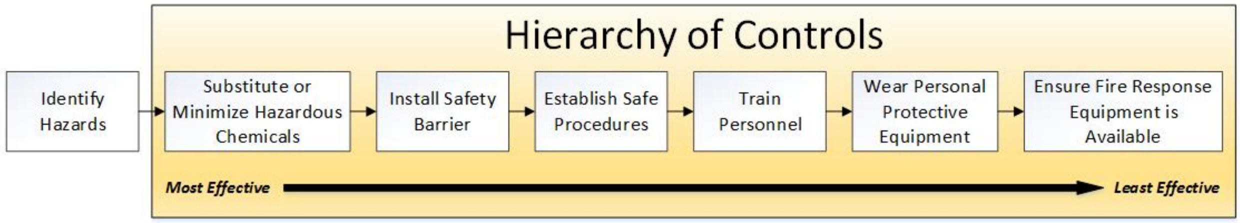


Figure 6. The effectiveness ranking of preventative measures is often referred to as the "Hierarchy of Controls." Schematic developed from concept presented in Kletz, Trevor; Amyotte, Paul. *Process Plants: A Handbook for Inherently Safer Design*, 2nd ed; 2010.

Employers and organizational leaders (e.g, school districts, school principles, museum directors, etc.) are responsible for ensuring strict controls and effective safety programs are in place to prevent incidents. For example, leaders should require and ensure that hazard reviews are performed and that there is an effective safety training program for all personnel conducting demonstrations. Educators performing demonstrations should receive training that details the risks involved in the demonstrations and the proper use of safety precautions to minimize risks. Management should also ensure that comprehensive procedures as well as hazard reviews are updated on a regular basis or as new demonstrations are added. In both The Discovery and Denver high school incidents, if effective safety programs had been in place, the educators and demonstrators would have been aware of the hazards of methanol and also known how to safely perform demonstrations to minimize the risk of creating a large flash fire.

Resources

There are a number of online resources for educators to find safety information for educational demonstrations. The U.S. Department of Health & Human Services has a repository of resources for chemical laboratory safety, K-12 school laboratory safety, and hazard analysis at http://sis.nlm.nih.gov/enviro/labsafety.html. In addition, the National Science Teachers Association has resources for classroom laboratory safety at http://www.nsta.org/safety/. These are only two of many online resources available to educators.

Another resource for educators to learn more about hazards is from flammable chemical manufacturers. The manufacturers are knowledgeable about the flammability hazards and best practices to reduce the risk of incident during educational demonstrations. Educational institutes should contact chemical manufacturers to obtain information about the hazards of chemicals used in educational demonstrations and the best methods available to reduce those hazards.

A number of organizations promote laboratory and classroom safety and should communicate safety lessons and provide guidance to their constituents. These organizations should be proactive about distributing laboratory safety information to their members. These include:

- American Chemical Society: A congressionally chartered independent membership organization which represents professionals in all fields of chemistry and has more than 160,000 members (www.acs.org).

- National Science Teachers Association: The largest organization in the world committed to promoting excellence and innovation in science teaching and learning and has 55,000 members (www.nsta.org).

- National Education Association: America's largest professional employee organization that is committed to advancing the cause of public education and has 3 million members (www.nea.org).

- American Federation of Teachers: A professional employee organization for teachers and has 1.6 million members (www.aft.org).

- National Science Foundation: An independent federal agency that promotes the progress of science (www.nsf.gov).

- Association of Science-Technology Centers: A nonprofit organization of science centers and museums dedicated to furthering public engagement with science (www.astc.org).

- National Parent Teacher Association: A nonprofit association that is a strong advocate for public education, a resource for families and communities, and a voice for children (www.pta.org).

- Association for Science Teacher Education: A nonprofit association that promotes leadership and support for educational professionals, especially science teachers (www.theaste.org).

- American Association of Chemistry Teachers: A professional community by and for K–12 teachers of chemistry (http://www.teachchemistry.org/).

CSB Investigation Reports are formal detailed reports on significant chemical accidents and include key findings, root causes, and safety recommendations. CSB Hazard Investigations are broader studies of significant chemical hazards. CSB Safety Bulletins are short general interest publications that provide new or noteworthy information on preventing chemical accidents. CSB Case Studies are short reports on specific accidents and include a discussion of relevant prevention practices. All reports may contain safety recommendations if appropriate. CSB Investigation Digests are plain-language summaries of Investigation Reports.

The U.S. Chemical Safety and Hazard Investigation Board (CSB) is an independent Federal agency whose mission is to ensure the safety of workers, the public, and the environment by investigating and preventing chemical incidents. The CSB is a scientific investigative organization; it is not an enforcement or regulatory body. Established by the Clean Air Act Amendments of 1990, the CSB is responsible for determining the root and contributing causes of accidents, issuing safety recommendations, studying chemical safety issues, and evaluating the effectiveness of other government agencies involved in chemical safety.

No part of the conclusions, findings, or recommendations of the CSB relating to any chemical accident may be admitted as evidence or used in any action or suit for damages. See 42 U.S.C. § 7412(r)(6)(G). The CSB makes public its actions and decisions through investigation reports, summary reports, safety bulletins, safety recommendations, case studies, incident digests, special technical publications, and statistical reviews. More information about the CSB is available at www.csb.gov.

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