ABSTRACT

Laboratory Health and Safety Compliance Guide for Private Colleges and Universities

by
Gina Marie Ochs

Academic laboratories are presented with the unique challenge of ensuring the health and safety of all people involved in daily activities. The Occupational Safety and Health Administration (OSHA) recently enacted the regulation 29 CFR 1910.1450, "Occupational Exposure to Hazardous Chemicals in Laboratories," which applies to all private employers (including colleges and universities). In this work, a guide is developed to assist private colleges and universities comply with applicable governmental regulations and to ensure the health and safety of all individuals involved with laboratory activities.

Academic laboratories warrant special consideration because of the nature of experimentation (variation in research and classroom activities) and the large turnover in personnel (students). The presented document, "Laboratory Health and Safety Compliance Guide for Private Colleges and Universities" enables each academic institution to select the appropriate material to develop a comprehensive health and safety program tailored to its specific needs. The proper utilization of the guide will not only ensure compliance with applicable governmental regulations, but will also provide a safe environment in which to work, study and learn.

LABORATORY
HEALTH AND SAFETY
COMPLIANCE GUIDE FOR
PRIVATE COLLEGES AND UNIVERSITIES

by
Gina Marie Ochs

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APPROVAL PAGE

**Laboratory
Health and Safety
Compliance Guide for
Private Colleges and Universities**

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This thesis is dedicated to my
parents, brother and
grandmothers

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TABLE OF CONTENTS

Chapter **Page**

Chapter **Page**

Chapter		Page

Chapter **Page**

Chapter	Page

Chapter		Page

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

CHAPTER 1

INTRODUCTION

1.1 Overview of the Occupational Safety and Health Administration

1.1.1 History

"First and foremost, the protection of safety is a moral obligation." (Bretherick 1987, 2) This statement, in theory, should compel employers to protect all employees. However, past experience dictates that reality and theory do not always coincide . The early 1900's was a time period in which most employers did not meet their "moral obligation" to safeguard employees against potential hazards in the work area. Typically, the American worker was subjected to numerous hazards in his or her place of employment; there was minimal, if any, concern given to protect the welfare of employees. The early to mid 1900's was a time period characterized by the rapid advancement of technology. Such a technological advancement brought an extensive array of manufacturing processes, along with an increase in work related accidents and injuries.

Although there were restrictions placed on employers to protect the health and safety of their employees, seldom were these regulations adhered to or enforced. It was not until 1970, that Congress enacted the Occupational Safety and Health Act (OSH Act). The inception of such an act by the government of the United States was a monumental step in ensuring the safety of all citizens in the work force. The responsibility of establishing compliance with the federal law was allocated to the Occupational Safety and Health Administration (OSHA) - which is part of the United States Department of Labor.

1.1.2 Jurisdiction

The safety jurisdiction of the Occupational Safety and Health Act excludes employees of states and their political subdivisions, such as counties or cities. Therefore, the

Occupational Safety and Health Act allows states to submit a state plan [to OSHA] for assuming implementation of the Federal Act and to develop similar state standards (identical or more stringent than the Federal Act) covering occupational safety and health issues. Examples of such a state regulations utilized in New Jersey are the Public Employee Occupational Safety and Health Act (PEOSHA) and the New Jersey Community Right to Know Act. Such regulations extend to all state and county workers in New Jersey.

1.1.3 Other Applicable Regulations

In complying with OSHA regulations, one cannot avoid other aspects of current legislation, such as the standards promulgated by the Environmental Protection Agency (EPA). States may not submit their own environmental compliance plans; employers (public and private) in all states and are subjected to applicable EPA regulations. However, EPA guidelines may vary within each municipality. Therefore, it is essential to determine the specific EPA guidelines governing the particular place of employment.

1.2 Synopsis of Guide

In general, occupational safety and health issues are typically associated with industrial situations and settings. However, it is essential that consideration is given to all potentially hazardous conditions and activities, regardless of job classification or segmentation. OSHA recently promulgated a standard entitled, "Occupational Exposures to Hazardous Chemicals in the Laboratory,"(29 CFR 1910.1450). This standard has had a profound impact not only in industrial laboratories, but also in an often overlooked area of the workforce - academia. The academic laboratory provides a unique and significant challenge to all persons involved.

1.2.1 Purpose

"Experience has shown that the laboratory can be a safe place." (DiBerardinis 1987, 14) However, for a laboratory to achieve this status, it must establish and implement a comprehensive laboratory safety and health program. The objective of this document is to assist private colleges and universities establish and implement a laboratory safety and health plan consistent with applicable OSHA and EPA regulations. The document is written in such a manner to cover a broad range of topics. Therefore, each university or college (private) can select the appropriate material to develop a comprehensive health and safety program tailored to the specific needs of the university or college.

1.2.2 Scope

In the quest to find the best combination of techniques or the best formula for optimal laboratory safety, there are many variables which must be accounted for. Perhaps the two most difficult components to control are daily operations and the exposed personnel (administration, staff, research assistants, students, visitors, maintenance, etc.). These two aspects of an academic laboratory are considerations which tend to change on a daily, if not hourly basis. The "Laboratory Health and Safety Compliance Guide for Private Colleges and Universities" confronts the unique, yet crucial safety and health concerns faced by academic laboratories. The information provided coincides with all applicable federal guidelines as mandated by the Occupational Safety and Health Act of 1970 (focusing on 29 CFR 1910.1450). Additional consideration is given to the legislation of other regulatory agencies, such as the Environmental Protection Agency (EPA), Department of Transportation (DOT) and the National Fire Protection Association (NFPA).

As previously stated - state, government, county and city employees are not covered under the 1970 Occupational Safety and Health Act. The above mentioned employees are protected by individual state regulations. As a result of the variation in state legislation, an analysis of public and county institutions would require a thorough investigation of each state's specific regulations. Therefore, to permit widespread utilization, research was based on the Federal Regulation (OSH Act of 1970) which applies to all private corporations and educational institutions in the United States. Furthermore, the guide was written on a level consistent with laboratory operations for a college or university. The information may be referenced by a grammar or high school, however much of the provided material will be extraneous.

1.3 Compliance Issues

1.3.1 Scope of the OSHA Standard

The scope of the OSHA standard 29 CFR 1910.1450, "Occupational Exposure to Hazardous Chemicals in Laboratories," is limited to "all employers engaged in the laboratory use of toxic substances ...." First, OSHA defines the "laboratory use of toxic substances" as a condition in which all of the following circumstances are met:

1. chemical manipulations are carried out in a "laboratory scale,"
2. multiple chemical procedures and/or chemicals are in use;
3. the procedures involved are not part of a production process, nor in any way simulate a production process; and
4. protective laboratory practices, which may include the use of appropriate equipment, are available and in common use to minimize the potential for employee overexposure to hazardous chemicals.

The term "laboratory scale" is defined as 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. The term "laboratory scale" excludes workplaces that function to produce materials in commercial quantities. Workplaces or activities that do not satisfy the forgoing definitions are not considered to be laboratories, and they will continue to be regulated under existing OSHA standards.

1.3.2 Chemical Hygiene Plan

OSHA has required (effective January 31, 1991) that each employer (including universities and colleges) whose activities fall within the definitions discussed above establish a chemical hygiene plan for protecting employees [including faculty, students, etc.] from health hazards associated with the toxic substances used in the laboratory. The content of the hygiene plan must include the items listed below. This list references chapter numbers of the corresponding section of the document to permit easy access of desired information.

- Identification of personnel responsible for implementation and maintenance of the hygiene plan. (Chapter 3; section 3.2)
- Standard operating procedures (SOPs) for the use, storage, handling and disposal of chemicals. (Chapter 5; section 5.6)
- Standard operating procedures for emergencies. (Chapter 4; section 4.4)
- Monitoring and maintenance of Permissible Exposure Levels (PEL) in all labs. (Chapter 4; section 4.3)
- Criteria to determine the need for, and the nature of, the exposure control strategies to reduce personnel exposures. These strategies include engineering and administrative controls and the use of personal protective equipment. (Chapter 5; section 5.3)
- A requirement that control measures including lab hoods and other local exhaust ventilation, be properly selected, designed, installed, and maintained, along with procedures to ensure satisfaction of the requirement. (Chapter 6; section 6.2)
- Circumstances under which a particular laboratory operation will require approval prior to implementation.
- Additional protective measures for work performed with carcinogenic materials and other particularly hazardous chemicals. (Chapter 7; sections 7.3 - 7.9)
- Information and training procedures covering: (Chapter 3; section 3.3)
  - personal protective equipment care and use;

- health monitoring and records;
- access to MSDS, chemical and personal health data and records; and
- all provisions of the Chemical Hygiene Plan.

- A provision for medical consultation and evaluation. (Chapter 5; section 5.5.2)
- Periodic review and update of the plan. (Chapter 3; section 3.4.2)

The component of the chemical hygiene plan referred to as "circumstances under which a particular laboratory operation will require approval prior to implementation," is not defined in the paper. Each university or college should formulate its own procedures for this area consistent with established school policies and regulations.

1.3.3 Compliance Guidelines

"Most laboratories will find it more practical and realistic to address safety and health issues through a comprehensive program and will find no advantage to the creation of a hygiene plan separate from the overall laboratory health and safety plan." (Bretherick 1987, 6) The "Laboratory Health and Safety Compliance Guide for Private Colleges and Universities" is written in such a manner to cover all aspects of an effective laboratory health and safety plan. The guide was written to allow private educational institutions to evaluate and improve their overall laboratory health and safety program, while incorporating the necessary aspects of the Chemical Hygiene Plan. All applicable material is important to attain a safe and healthy laboratory environment. Therefore, it is recommended that all laboratories upgrade their overall health and safety plan to include the recommended OSHA-required elements (Chemical Hygiene Plan), thus meeting OSHA requirements. The chapters within the text of the document, denoted by "* CHP *" refer to topics which must be included in the chemical hygiene plan (CHP).

1.3.3-1 Statement of Policy

"A clear concise statement of policy is the basis on which a health and safety program should be built." (Slote 1987, 12) All laboratory operators should be able to see and read the commitment the school has made to their safety through safe operating practices and procedures. If such a documented commitment is not established, a relaxed and careless attitude may result. It must be stressed that laboratory supervisors, as well as all university staff and administration are in full support of actions which coincide with procedures of the laboratory safety and health program. The statement of policy should incorporate the following characteristics:

- It should be specific to the location;
- clearly set the safety and health goals and the commitment of the university to ensure these goals are maintained;
- state that all laboratory operators are responsible for optimal safety and health performance;
- identify the technical resources and staff members to whom laboratory operators can turn for assistance in fulfilling their safety responsibilities; and
- should be signed by the President of the University.

Furthermore, the safety and health policy, as well as the program, should reflect various revisions in the University's curriculum. Such revised policy statements, as well as any changes in the laboratory health and safety program, should be appropriately distributed and posted in conspicuous areas of the laboratory.

1.4 DISCLAIMER

The recommendations and procedures outlined are intended solely for guidance purposes. The contents of the document are not intended to serve as the laboratory health and safety program, and therefore should not be used for this purpose. Rather, the provided information should serve as a basis upon which to construe a tailored laboratory health and safety program specific to the particular laboratory operations and needs. As with most government regulations, revisions may have to be enacted. Therefore, the presented information is limited to the standards and regulations of the cited regulatory agencies as of May, 1993. Additional research on all of the discussed regulations is necessary to ensure compliance with potential revisions.

Furthermore, the stated procedures are not intended, nor should they be relied upon, to prosecute any party or parties for non compliance with regulatory standards. Rather, this document is intended to provide the user with a basic understanding of OSHA and EPA rules and regulations, specifically that of "Occupational Exposures to Hazardous Chemicals in the Laboratory," (29 CFR 1910.1450)

CHAPTER 2

GENERAL RECOMMENDATIONS FOR SAFE PRACTICES IN LABORATORIES

2.1 Introduction

A very important part of a laboratory safety and health plan is the description and explanation of safe work practices. These work habits must be followed by all laboratory operators (supervisors, students, visitors, technicians and maintenance personnel) to minimize accidents and injuries which may occur in a laboratory environment. Although it is impossible to design a set of rules that will account for all possible hazards and occurrences, the following guidelines are useful in avoiding accidents and reducing injuries in the laboratory.

One of the most important rules is that everyone involved in laboratory operations must be "safety alert."(Bretherick 1987, 19) To allow safety awareness to become an integral component of everyone's habits, the issue of safety must be discussed repeatedly. Laboratory supervisors and staff members must show a sincere and continual interest in safety while also being perceived as doing so by the students. In turn, each individual student must accept the responsibility for carrying out his or her own work in accordance with good safety practices and should be prepared in advance for possible accidents by knowing what emergency aids are available and how they are used.

The supervisor of the laboratory has the overall safety responsibility and should provide for regular formal safety and housekeeping inspections (at least quarterly) in addition to continuous informal inspections (Fried 1987, 79). Laboratory supervisors have the responsibility to ensure:

- Workers know safety rules and follow them.
- Adequate availability of emergency equipment in proper working order.

- Training is provided in the use of emergency equipment.
- Information is distributed to laboratory workers on special or unusual hazards in non routine work.
- Appropriate safety orientation is given to individuals when they are first assigned to a laboratory space.

Similarly, the laboratory worker should develop good personal safety habits:

- Use eye protection at all times.
- Keep chemical exposure to a minimum.
- Avoid smoking and eating in areas where chemicals are present.

One of the best ways to avoid serious incidents is advanced planning (Bretherick 1987, 25). Before performing any chemical operation, the laboratory worker should plan appropriate protective procedures, correctly position equipment and be prepared to take proper emergency actions. Additionally, laboratory workers should seek information and advice about hazards prior to an accident or emergency.

All laboratory users must be made aware of the consequences of over familiarity with a particular laboratory operation. Such an extensive understanding may lead to an overlooking or underrating of associated hazards. This attitude, in turn, can lead to a false sense of security, which frequently results in carelessness. Additionally, every laboratory worker has a basic responsibility to himself or herself and to others to plan and execute laboratory operations in a safe manner (Martin and Habison 1989, 29). Guidelines to help ensure safe work practices have been separated into three main categories (basic principles, work habits and daily operations) and are further discussed below.

2.2 Basic Principles

Every laboratory worker should observe the following rules (Dux and Stalzer 1988, 253):

- Be aware of the safety rules and procedures that apply to the work that is being completed.

- Determine the potential hazards (e.g., physical, chemical, biological) and appropriate safety precautions before beginning any new operation.
- Know the location of and how to use the emergency equipment in the area, as well procedures.
- Know the types of protective equipment available and use the proper type for each job.
- Be alert to unsafe conditions and actions and call attention to them so that corrections can be made as soon as possible; another person's accident may cause as much damage as an accident the user has.
- Avoid consuming food or beverages or smoking in areas where chemicals are being used or stored.
- Avoid hazards to the environment by following accepted waste disposal procedures. Chemical reactions may require traps or scrubbing devices to prevent the escape of toxic substances.
- Be certain all chemicals are correctly and clearly labeled.
- Post warning signs when unusual hazards, such as radiation, laser operations, flammable materials, biological hazards or other special problems exist.
- Remain out of the area of a fire or personal injury unless it is the lab worker's responsibility to help in the emergency; curious bystanders interfere with rescue and emergency personnel and also endanger themselves.
- Avoid distracting, confusing or startling another worker. Practical jokes or horseplay cannot be tolerated at any time.
- Use equipment only for its designated purpose.
- Position and clamp reaction apparatus carefully, in order to permit manipulation without the need to move the apparatus until the entire reaction is completed. Combine reagents in appropriate order and avoid adding solids to hot liquids.
- Act, think and encourage safety until it becomes a habit.

2.3 Work Habits

2.3.1 Health and Hygiene

Laboratory workers should observe the following health practices (Dux and Stalzer 1988, 255):

- Wear appropriate eye protection at all times.
- Confine long hair and loose clothing.
- Wear shoes at all times in the laboratory - but do not wear sandals, perforated shoes or sneakers.
- Do not use mouth suction for pipeting or starting a siphon; a pipette bulb or an aspirator should be used to provide a vacuum.
- Avoid exposure to gases, vapors and aerosols; use appropriate safety equipment whenever such exposure is likely..
- Wash areas of exposed skin well before leaving the laboratory. However, avoid the use of solvents for washing the skin. Solvents remove the natural protective oils from the skin and can cause irritation and inflammation. Sometimes, washing with a solvent may facilitate the absorption of a toxic chemical.

2.3.2 Food Handling

Contamination of food, drink, cosmetics, chewing gum and smoking materials is a potential route for exposure to toxic substances. Food should be stored, handled and consumed in an area free of hazardous substances. The following guidelines should be followed (DiBerardinis 1987, 47):

- Well defined areas should be established for the storage and consumption of food and beverages. Food should not be stored or consumed outside of this designated area.
- Consumption of food or beverages and smoking should not be permitted in areas where laboratory operations are being carried out.

- Areas where food is permitted should be prominently marked with a posted warning sign (e.g., Eating Area - No Chemicals). No chemicals or chemical equipment should be allowed in such areas.
- Glassware or utensils that have been used for laboratory operations should never be used to prepare or consume food or beverages. Laboratory refrigerators, ice chests, cold rooms and such should not be used for food storage. Separate equipment should be dedicated to their use and appropriately labeled.

2.3.3 Working Alone

If possible, avoid working alone in a laboratory building. Under normal working conditions, arrangements should be made between individuals working in separate laboratories outside of working hours to cross-check each laboratory user periodically. Alternatively, security guards may be asked to check on the laboratory worker.

- Do not work alone in a laboratory if the procedures being conducted are hazardous.
- Special rules may be necessary. The supervisor of the laboratory has the responsibility of determining whether the work requires special safety precautions, such as having two persons in the same room during a particular operation.

2.3.4 Housekeeping

There is a relationship between safety performance and orderliness in the laboratory. When housekeeping standards fall, safety performance deteriorates. Chemicals and equipment should be properly labeled and stored (DiBerardinis 1987, 56):

- Keep the work area clean, uncluttered and free from obstructions. Cleanup should follow the completion of any operation or at the end of each day.
- Wastes should be deposited in the appropriate receptacles.

- Spilled chemicals should be cleaned up immediately and disposed of properly. Disposal procedures should be established and all laboratory personnel should be informed of them.
- Unlabeled containers and chemical wastes should be disposed of promptly, by using the appropriate procedures. Such materials, as well as chemicals, that are no longer needed, should not accumulate in the laboratory.
- Floors should be cleaned regularly; accumulated dust, chromatography adsorbents and other assorted chemicals pose respiratory hazards.
- Stairways and hallways should not be used as storage areas.
- Access to exits, emergency equipment, controls and such should never be blocked.
- Equipment and chemicals should be stored properly - clutter should be minimized.

2.3.5 Personal Protective Equipment

It is imperative that laboratory personnel are trained in the proper storage, inspection and use of appropriate personal protective equipment (Schwope 1987, 22).

- Assure that relevant eye protection is worn by all persons, including visitors, where chemicals are stored or handled.
- Wear appropriate gloves when the potential for contact with toxic materials exists.
- Inspect the gloves before each use, wash them before removal and replace them periodically.
- Use appropriate respiratory equipment when air contaminant concentrations are not sufficiently restricted by engineering controls. Inspect all respirators before use.
- Use any other protective and emergency apparel and equipment as appropriate.
- Avoid use of contact lenses in the laboratory unless necessary. If they are used, inform the supervisor so special precautions can be taken.
- Remove laboratory coats immediately upon significant contamination.

2.3.6 Accident Reporting

Emergency telephone numbers to be called in the event of a fire, accident, flood or hazardous chemical spill should be noticeably posted in each laboratory. In addition, the numbers of the laboratory workers and their supervisors should be posted. These persons should be notified immediately in the event of an accident or emergency.

Every laboratory should have an internal accident-reporting system to help discover and correct unexpected hazards. This system should include provisions for investigating the causes of injury and any potentially serious incident that does not result in injury. The goal of such investigations should be to make recommendations to improve safety, rather than to assign blame for an incident. Relevant federal, state and local regulations may require particular reporting procedures for accidents or injuries.

2.3.7 Unattended Operations

Frequently, laboratory operations are carried out continuously or overnight. It is essential to plan for interruptions in utility service such as electricity, water and inert gas (Haegele 1980, 49).

- Operations should be designed to be safe, and plans should be made to avoid hazards in case of failure.
- Arrangements for routine inspection of the operation should be made, if possible.
- Lights should be left on.
- An appropriate sign should be placed on the door.
- Provide for the containment of toxic substances in the event of failure of a utility service (such as cooling water).

2.4 Daily Operations

2.4.1 Equipment Maintenance

Good equipment maintenance is important for safe, efficient operations.

- Equipment should be inspected and maintained regularly.
- Servicing schedules will depend on both the possibilities and the consequences of failure.
- Maintenance plans should include a procedure to ensure that a device that is out of service cannot be restarted.

2.4.2 Guarding for Safety

All mechanical equipment should be adequately furnished with guards that prevent access to electrical connections or moving parts; careful design of guards is vital. An ineffective guard can be worse than none at all because it can give a false sense of security. Emergency shut - off devices may be needed, in addition to electrical and mechanical guarding.

- Each laboratory worker should inspect equipment before using it to ensure that the guards are in place and functioning.

2.4.3 Shielding for Safety

Safety shielding should be used for any operation which has the potential for explosion such as the circumstances outlined below:

- Whenever a reaction is attempted for the first time.
- Whenever a familiar reaction is carried out on a larger than usual scale.
- Whenever operations are carried out under non ambient conditions.

2.4.4 Accidents and Spills

Corrective measures for accidents and spills vary depending on the form of contact (Martin and Habison. 1989, 88):

- Eye Contact:

  Promptly flush eyes with water for a prolonged period (15 minutes) and seek medical attention.

- Ingestion:

  Encourage the victim to drink large amounts of water.

- Skin Contact:

  Promptly flush the affected area with water and remove any contaminated clothing. If symptoms persist after washing, seek medical attention.

- Clean - Up:

  Immediately clean up spills, using appropriate protective apparel/equipment and proper disposal.

2.4.5 Avoidance of Routine Exposure

Routine exposure should be avoided and/or minimized:

- Develop and encourage safe habits.
- Avoid unnecessary exposure to chemicals by any route.
- Do not smell or taste chemicals.
- Vent apparatus which may discharge toxic chemicals (vacuum pumps, distillation columns, etc.) into local exhaust devices.
- Inspect gloves and test glove boxes before use.
- Do not allow release of toxic substances in cold rooms and warm rooms, since these rooms contain recirculated atmospheres.

2.4.6 Choice of Chemicals

In many instances, hazards can be reduced by the proper selection of chemicals:

- Use only those chemicals for which the quality of the available ventilation system is appropriate.
- Ensure that the combination of chemicals does not cause an adverse chemical reaction.

2.4.7 Equipment and Glassware

Accidents involving glassware are a leading cause of laboratory injuries. Additionally, improper use of equipment can cause serious damage and personal harm (Forsberg and Keith 1988, 96).

- Handle and store laboratory glassware with care to avoid damage.
- Do not use damaged glassware. Damaged items should be repaired or discarded.
- Adequate hand protection should be used when inserting glass tubing into rubber stoppers or corks or when placing rubber tubing on glass hose connections. Tubing should be fire polished or rounded and lubricated, and hands should be held close together to limit movement of glass should a fracture occur. The use of plastic or metal connectors should be considered.
- Glass-blowing operations should not be attempted unless proper annealing facilities are available.
- Vacuum-jacketed glass apparatus should be handled with extreme care to prevent explosions.
- Hand protection should be used when picking up broken glass. Small pieces should be swept up with a brush into a dustpan.
- Proper instruction should be provided in the use of glass equipment designed for special tasks, which can represent unusual risks for the first time user.

- Use extra care with Dewar flasks and other evacuated glass apparatus.
- Shield or wrap equipment that contains chemicals, in the event of an explosion.
- Use equipment only for its designated purpose.

2.4.8 Flammability Hazards

Since flammable materials are widely used in laboratory operations, the following rules should be observed:

- Do not use an open flame to heat a flammable liquid or to carry out a distillation under reduced pressure.
- Use an open flame only when necessary and extinguish it when it is no longer needed.
- Before lighting a flame, remove all flammable substances from the immediate area. Check all containers of flammable materials in the area to ensure that they are tightly closed.
- Notify other occupants of the laboratory in advance of lighting a flame.
- Store flammable materials properly.
- When volatile flammable materials may be present, use only non sparking electrical equipment.

2.4.9 Cold Traps and Cryogenic Hazards

Cryogenics is the branch of physics which deals with very low temperatures. The primary hazard of cryogenic materials is their extreme coldness. They, and the surfaces they cool, can cause severe burns if allowed to contact the skin. Gloves and a face shield may be needed when preparing or using baths. The following rules should be adhered to (Sitig 1985, 107):

- Neither liquid nitrogen nor liquid air should be used to cool a flammable mixture in the presence of air; oxygen can condense from the air, which will lead to an explosion hazard.

- Appropriate dry gloves should be used when handling dry ice.
- Dry ice should be added slowly to the liquid portion of the cooling bath to avoid foaming over.
- Avoid lowering your head to a dry ice chest: carbon dioxide is heavier than air, and suffocation can result.

2.4.10 Systems Under Pressure

The following guidelines should be applied to all operations carried out under any type or amount of pressure:

- Reactions should never be carried out in, nor heat applied to an apparatus that is in a closed system unless the apparatus is designed and tested to withstand pressure.
- Pressurized apparatus should have an appropriate relief device.
- If the reaction cannot be opened directly to the air, an inert gas purge and bubbler system should be used to avoid pressure buildup.

2.4.11 Waste Disposal Procedures

Laboratory management has the responsibility for establishing waste disposal procedures for routine and emergency situations and communicating these procedures to laboratory workers. Workers should follow these procedures with care to avoid any safety hazards or damage to the environment.

2.4.12 Warning Signs and Labels

Laboratory areas that have special or unusual hazards should be posted with warning signs. Standard signs and symbols have been established for a number of special situations, such as: radioactivity hazards, biological hazards. fire hazards and laser operations. Signs should be posted in accordance with the following procedures (Fried 1987, 80):

- Signs must show the locations of safety showers, eyewash stations, exits and fire extinguishers.
- Extinguishers should be labeled to show the type of fire for which they are intended.
- Waste containers should be labeled for the type of waste that can be safely deposited.
- The safety and hazard sign systems should enable a person unfamiliar with the usual route of the laboratory to escape in an emergency.
- Labels on containers of chemicals should contain information on the hazards associated with the use of the chemical. Unlabeled bottles of chemicals should not be opened. Such materials should be disposed of promptly and will require special handling procedures.

2.4.13 Hood Usage

A hood should be used for operations which may result in the release of toxic chemical vapors or dust (Chamberlin and Leahy 1988, 27).

- Use a hood or other local ventilation device when working with any considerably volatile substance with a Threshold Limit Value (TLV) of less than 50 parts per million (ppm.).
- Confirm adequate hood performance before use.
- Keep hood closed at all times except when adjustments within the hood are being made.
- Keep materials stored in hoods to a minimum and do not allow them to block vents or air flow.
- Leave the hood on when it is not in active use, if toxic substances are stored in it or if it is uncertain whether adequate general laboratory ventilation will be maintained when it is off.

CHAPTER 3

PROGRAM ADMINISTRATION

3.1 Introduction

Regardless of how good a program or policy is, it is limited by the manner in which it is executed, in addition to the designated executors. Therefore, one of the most important aspects of a laboratory health and safety plan is the actual administration of the plan. It is crucial that the people who are given the responsibility to carry out such a program are aware of their responsibilities and are properly trained to carry out these responsibilities. An important aspect of administering the program is to maintain written records. All documentation should be kept for evaluation and also for legal purposes. Additionally, emergency procedures must be accounted for in the event of an actual emergency.

The development, implementation and maintenance of a comprehensive laboratory health and safety plan requires the participation of many different people. The prime responsibility of the program rests on the appointed health and safety officer, laboratory supervisor and the laboratory operators. The nature of their respective responsibilities and those of other important persons are discussed below. (Refer to Appendix A of § 1910.1450 for a more complete overview.)

3.2 Responsibilities [*CHP*]

"In the final analysis, laboratory safety can be achieved only by the exercise of judgment by informed, responsible individuals. It is an essential that they learn to work with and accept the responsibility for the appropriate use of hazardous substances."(Anderson 1986, 127) An effective laboratory health and safety plan must clearly and correctly define all responsibilities.

3.2.1 University President

The President has the ultimate responsibility for laboratory health and safety within the university. He or she must, along with other administrators, provide continuing support for a comprehensive laboratory health and safety plan within the University.

3.2.2 Department Supervisors

Each department in charge of a laboratory must appoint a supervisor who is responsible for health and safety in that particular area.

3.2.3 Chemical Hygiene Officer

At least one chemical hygiene officer must be appointed. The two primary responsibilities of the chemical hygiene officer(s) are to monitor all aspects of safety and to serve as the main source of health and safety information. Additionally, the chemical hygiene officer is required to:

- Assist in the development and review of health and safety training plans and programs, conduct training courses and establish safety references.
- Make copies of the approved laboratory health and safety plan available to the technical and support staff.
- Consult, advise and make recommendations on all health and safety matters.
- Aid the laboratory manager in defining hazardous operations, designating safe practices and selecting appropriate protective equipment.
- Obtain, review and approve standard operating procedures, detailing all aspects of proposed laboratory activities that involve hazardous agents.
- Monitor the safety and performance of the staff to ensure that the required safety practices and techniques are being employed.
- Ensure that all personnel obtain medical examinations and the protective equipment necessary for the safe performance of their jobs.

- Develop rules and procedures for safe practices.
- Ensure that technical and support staff receive instructions in procedures dealing with accidents involving test substances.
- Investigate and report in writing to the laboratory supervisor any significant problems pertaining to the operation and implementation of control practices, equipment or the facility.
- Conduct formal laboratory inspections quarterly to ensure compliance with existing laboratory policies and government regulations.
- Arrange for workplace air samples, wipe samples or other tests to determine the amount and nature of airborne and/or surface contamination; use data to aid in the evaluation and maintenance of the appropriate laboratory conditions.
- Become familiar with and maintain compliance with all current legal requirements concerning regulated substances.
- Monitor the procurement, use and disposal of chemicals used in the lab.
- Dispose of unwanted and/or hazardous chemicals and materials.
- Ensure that action is taken to correct work practices and conditions that may result in the release of toxic chemicals.
- Report to the laboratory manager all incidents which: (a) cause personnel to be seriously exposed to hazardous chemicals or materials, such as the ingestion, skin contact with or inhalation of a chemical; or (b) constitute a danger of environmental contamination.
- Investigate accidents and report them to the laboratory manager.
- Seek ways to improve the laboratory health and safety program.

3.2.4 Laboratory Supervisor

The primary responsibility of the laboratory supervisor is to implement the established health and safety plan in the laboratory. The laboratory supervisor is required to:

- Ensure that workers know and follow the health and safety rules.
- Determine the required levels of protective apparel and equipment.
- Provide adequate protective apparel and equipment.
- Perform routine inspections of emergency equipment.
- Provide regular, formal chemical hygiene and housekeeping inspections.
- Be familiar with the current legal requirements concerning regulated substances.
- Assure that all work is conducted in accordance with the health and safety program.
- Prepare procedures for dealing with accidents that may result in the unexpected exposure of personnel or the environment to a toxic substance.
- Select the appropriate control measures for handling hazardous substances.
- Report to the safety officer the location of work areas in which toxic substances and potential carcinogens will be used and ensure that the inventory of hazardous substances is properly maintained.
- Prepare a safety plan for the use of hazardous substances.
- Ensure that facilitates and training for use of any materials being ordered are adequate.

3.2.5 Laboratory Operators

Laboratory supervisors, students, visitors, technicians and maintenance personnel (hereafter referred to as laboratory operators) are required to:

- Gain an understanding of, and act in accordance with, the university health and safety procedures.
- Wear the safety equipment and personal protective equipment necessary to perform each task assigned.
- Report to the laboratory supervisor or the health and safety officer all facts pertaining to every accident that results in exposure to toxic chemicals and any action or condition that may exist that could result in an accident.

3.2.6 Project/Research Director

The project director has the primary responsibility to maintain proper health and safety procedures for the particular operation that he or she oversees.

The above detailed responsibilities must be fulfilled by the respective individuals. Failure to adhere to the guidelines will increase the likelihood of an accident or injury. One important requirement which the chemical hygiene officer and laboratory supervisor are required to complete is to properly train all laboratory operators.

3.3 Training [*CHP*]

3.3.1 Introduction

Laboratory operators may be subjected to various hazards, including biological, chemical, radioactive as well as a fire in the laboratory. All laboratory operators should be familiarized with these hazards and the risks involved. Individuals properly trained in handling hazardous materials are better equipped to minimize the risk of exposure to themselves, their peers and the environment. A comprehensive training program should provide proper orientation in the use of safety equipment and the implementation of related procedures and policies. However, the success of a training program depends on management's support of these programs and the utilization by the laboratory operators of the information developed.

The ultimate responsibility for ensuring a safe working environment rests with the laboratory operator. He or she should assume an active role in maintaining a safe working environment by reporting any problems or noncompliance with policies, to the laboratory supervisor. All laboratory operators are accountable to their peers and, therefore, should fully utilize the information provided during formal and informal training sessions. Any person who does not understand a policy or procedure should consult the health and safety officer (HSO) for clarification.

The HSO should make sure that all operators are aware of hazards in the workplace - the safety measures available, and that they know how to use the safety equipment properly. Laboratory personnel qualified in the areas of health and safety , specifically, the HSO and laboratory supervisor should develop and implement training programs. The laboratory should provide these programs to all new employees and conduct them regularly. The laboratory should also properly document all training sessions, placing records of those attending and subject matter covered in the facility's health and safety files.

Laboratory management should encourage proper training and attitudes toward safety among its employees. As stated in the National Institute of Health (NIH) Guidelines for the Laboratory Use of Chemical Carcinogens:

> Employees should be provided with sufficient information to understand the potential hazards that can affect them personally. Employees should be periodically advised about (1) the possible sources of exposure, (2) adverse health effects associated with exposure, (3) laboratory practices and engineering controls in use and being planned to limit exposure, (4) the use and purpose of any recommended environmental and medical monitoring procedures, and (5) their responsibilities for following proper laboratory practices to help protect their health and provide for the safety of themselves and fellow employees.

In other words, the laboratory operators should utilize the information provided, comply with federal, state and local regulations and report problems to the laboratory manager. The HSO and laboratory supervisor should communicate the potential hazards associated with the work plan, encourage proper training and attitudes toward safety, make sure that all employees are aware of the safety measures available and how to properly use them, provide training on a regular basis and properly document all training sessions and list those who attended.

3.3.2 Training Program Components

Each laboratory should offer a comprehensive employee training program. Such a program should provide training to new employees before work is assigned to them, with additional training, continued throughout their employment. Specific phases of the program should be repeated at least annually, and records should be maintained by the laboratory to indicate whenever an employee has completed a specific training session.

3.3.3 Training Requirements for the Health and Safety Officer

Each laboratory should have a qualified health and safety officer. The level of qualification and time of commitment of the HSO will depend on the size of the laboratory and the complexity of its work. For a laboratory conducting moderate to large scale work with hazardous materials (e.g., an experimental toxicology laboratory performing in vivo work, or a large chemical research location), qualifications should include the following (Manufacturing Chemists Association 1988, 93):

- Bachelor's degree, with a major in chemistry, biology, chemical engineering or a closely related field (a master's degree in industrial hygiene or a bachelor's degree in industrial hygiene with one year of experience is an acceptable substitute).
- At lest two years' experience in occupational health and safety.
- The completion of courses in general occupational health and hazard control indicating the acquisition of greater levels of knowledge regarding industrial hygiene.
- Refreshed training, with additional training at an interval not exceeding eighteen months.

The health and safety officer may have other responsibilities within the organization; however, the amount of time devoted explicitly to health and safety should coincide with the scale of the laboratory operations. Additionally, the HSO is responsible for implementing the laboratory's various training programs.

3.3.4 Training Requirements for all Laboratory Operators

Laboratory operators who are potentially exposed to hazards in the laboratory should be provided with written materials on the nature of the hazards given in addition to a formal training program. This training should be conducted by a qualified safety person and properly documented. It should also provide instruction in handling radio - labeled materials, where applicable.

All Laboratory operators should also receive basic training in fire safety, including:

- Hazard awareness.
- Proper techniques for handling and storing flammable liquids.
- Briefing on the alarm system and emergency evacuation preplanning.
- Hands-on training on the use of fire extinguishers.

Additionally, prior to using any laboratory hood, personnel should be trained in its proper use and monitoring procedures. The operator's education and training should include a daily visual and smoke tube inspection.

Each laboratory must implement a respiratory program that meets the requirements of the Occupational Safety and Health Administration (OSHA:29 CFR 1910.134) and includes a training session in the proper use and limitations of respirators. This training should provide all employees with an opportunity to handle the respirators discussed, to have one fitted properly and tested for fit and to wear the unit in a normal atmosphere for an extended period of time. The program should also include a discussion of engineering controls, respirator selection, the potential health hazards when a respirator is not used and the recognition and handling of emergencies. The laboratory should designate the person who is to be responsible for each program element.

3.3.5 Recommended Outline of Training Program

The following training courses/components should be performed for laboratory operators. However, depending on the nature and extent of the work performed at each particular laboratory, some of the sections may be omitted.

- Respirator protection and fit-testing program:
  - proper selection, use and maintenance of respirators
  - compliance with OSHA 1910.134
  - fit-testing procedures
  - emergency-use
- Handling hazardous chemicals from acquisition to disposal: receiving, transporting within the facility, storage, handling and disposal.
- Fire training - prevention and response.
- Emergency response and evacuation.
- Interpretation of Material Safety Data Sheet (MSDS).
- First aid and CPR.
- Engineering controls.
- General laboratory safety.
- Personal hygiene.
- Protective clothing.

3.3.6 OSHA Hazard Communication Regulation

OSHA adopted a Hazard Communication Regulation (29 CFR 1910.1200) to ensure that employees would be properly informed of the chemical hazards associated with the use of any hazardous materials they handled in the workplace. A comprehensive hazard communication program should be written and implemented to ensure compliance with the OSHA regulation. The program should include: container labeling and other forms of

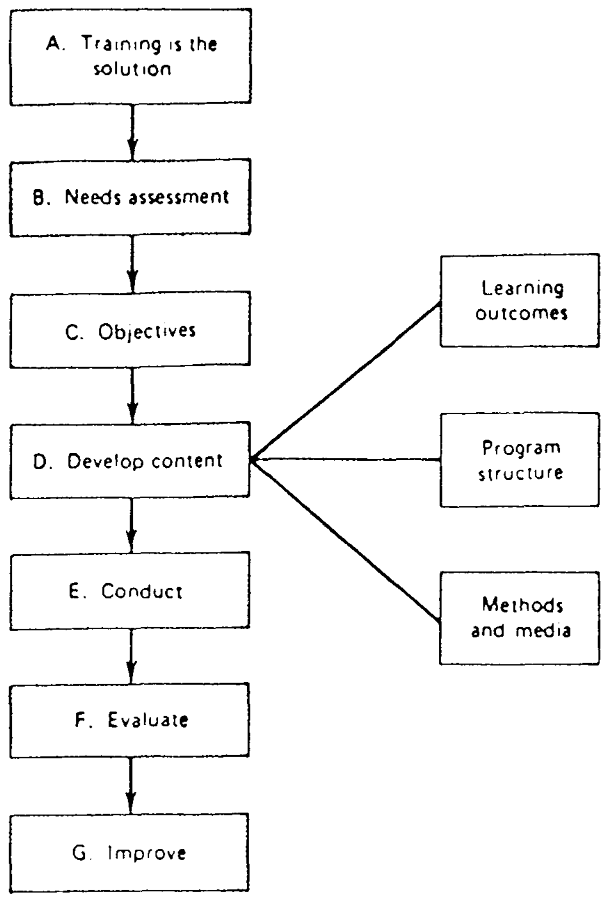


Figure 3.1 Summary of OSHA's Voluntary Training Programs (after Anderson, 1986)

warnings, information on Material Safety Data Sheets (MSDS) and employee training. The Hazard Communication regulation as it applies to laboratory training, states:

> 1910.1200 (h) Employee Information and Training:
> Employers shall provide employees with information and training on hazardous chemicals in their work areas at the time of their initial assignment, and whenever a new hazard is introduced into their work area.
>
> (2) Training
> (i) Methods and observation that may be used to detect the presence or release of a hazardous chemical in the work area.
> (ii) The physical and health hazards of those chemicals.
> (iii) The measures employees can take to protect themselves from these hazards, such as specific work practices, emergency procedures and personal protective equipment.
> (iv) The details of the hazard communication program.

The OSHA Hazard Communication Standard was promulgated in 1984. Previously, OSHA had developed and distributed Voluntary Training Guidelines which were to serve as a basis for meeting training requirements in its standards. OSHA has consolidated these guidelines into seven steps as shown in Figure 3.1. These guidelines may be useful to laboratories in the planning of their training program.

OSHA's Laboratory Standard - § 1910.1450 requires training in two specific areas:

1. Chemical Hazard Protection: Employees are to be trained in the detection of hazardous chemicals, physical and health hazards of chemicals and the measures employees can take to protect themselves.

§ 1910.1450(f)(4)(i)

(i) Employee training shall include:

(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.);

(B) The physical and health hazards of chemicals in the work area; and

(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.

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

3.3.7 Training Recommended

Training should be provided to both employees and supervisors. The following guidelines should be followed:

3.3.7-1 Basic Employee Training Employers shall inform laboratory operators concerning:

- Chemical hazards in their work area.
- Contents of the OSHA Laboratory Standard.
- Location of the Chemical Hygiene Plan.
- PEL's or recommended exposure limits.
- Location of reference material on Hazardous chemicals (refer to § 1910.1450).

3.3.7-2 Supervisor training Supervisors should be trained in the following areas:

- Monitoring of employees for symptoms of exposure to hazardous chemicals
- Appropriate work practices.
- Emergency procedures.
- Personal protective equipment.
- Chemical Hygiene Plan.

3.3.8 Training Resources

There are many sources of health and safety training materials and programs. The following list is not complete, however, it indicates the range of materials available from various sources of audiovisual training aids (Manufacturing Chemists Association 1988, 12).

1. National Audiovisual Center

National Archives and Records Service, General Services Administration, References Section CF, Washington, DC 20409 (301-763-1896)

- "Principles of Physical and Chemical Containment - Unit III"
- "Certification Class II (Laminar Flow)"
- "Effective use of the Laminar Flow Biological Safety Cabinets"
- "Nobody's Perfect"
- "Selecting a Biological Safety Cabinet"
- "Hazard Control in the Animal Laboratory"

2. 3M Hazard Awareness Program

3M Center, St. Paul, MN 55144

- "Fire and Extinguishers"
- "Laboratory Hoods"

3. Office of Continuing Education Harvard School of Public Health

- "Safety, Health and Ventilation Issues in the Laboratory"
- "Certification of Biological Safety Cabinets"
- "Fundamentals of Industrial Hygiene"

4. American Chemical Society

-1155 16th Street, N.W., Washington, DC 20036

- "Chemical Carcinogens"

5. Fischer Scientific Company

711 Forbes Avenue, Pittsburgh, PA 15219

- "28 Grams of Prevention"

6. Other Sources

- BNA Communications Inc. (subsidiary of the Bureau of National Affairs, Inc.), 9439 Key West Ave, Rockville, MD 20850: BNA films

- National Institute of Occupational Safety and Health (NIOSH), 4676 Columbia Pkwy, Cincinnati, OH 4526-1998: Educational Resource Centers
- American Industrial Hygiene Association (AIHA), 175 Wolf hedges Pkwy, Akron, OH 44311-1087: AIHA and NIOSH sponsored courses

3.4 Documentation

"Over the past several years, increases in regulatory activity, environmental health and safety litigation and employee awareness of potential hazards in the workplace have forced employers to maintain accurate records on health and safety programs."(Castegnaro and Sansone 1989, 27). To assure that a documentation program is in place and is accurate and effective, the following items must be accomplished:

- Development of documentation procedures (standard format, sign-off, etc.).
- Distribution of documents - both external and internal.
- Maintenance of documentation program.

As a result of the regulatory and legal environment, documentation programs must extend beyond the maintenance of the proper paper in files. Each laboratory must establish a paper trail that will provide the university, laboratory and regulatory agencies with an accurate representation of how hazardous agents are handled in the facility.

Additionally, all laboratories should develop a standardized format for each type of document, agreed to by all the personnel who will use the form. For example, the worksheet depicted in Figure 3.2 would be useful for documenting a hood monitoring program.

3.4.1 Distribution

The laboratory is responsible for distributing, posting and/or circulating the document to its employees, to management and to state or federal agencies. The laboratory must also make the documents available for agency inspections. A distribution system should include listings of where the documents are and who has signed them, statements that employees have read the documents and notification that individuals or groups have received their copies.

3.4.2 Documentation of Program Maintenance [*CHP*]

Modification of written programs, updates of new monitoring techniques and physical storage of files are key components of a documentation program. An automated system with built in notification for document updated would be advantageous. The use of microfiche for long-term storage of records would also be beneficial.

Retention time for these documents is also an issue. Local, state and federal regulations require a time span from thirty years to indefinite storage of records. Plans for storage should reflect consideration of ways to accommodate any loss of records caused by physical damage (weather, etc.) and access limited to personnel with need-to-know status.

The chemical hygiene plan should tell who will maintain the documentation, describe such documentation, and state the retention policy. Examples of the types of documentation that should be maintained are (Dux and Stalzer 1988, 103):

- Health and safety officer's credentials.
- Health and safety plan.
- Health and safety training (including sign-off statement from project personnel on reading and understanding SOP's and health and safety plan.
- Archival information, such as employee roster, medical surveillance logs, biological monitoring results, air sampling results, ventilation system performance and maintenance records, waste disposal records, respirator fit-testing program and accident incident reports.
- Standard Operating Procedures (SOPs).
- Serious accident/injury records.

- Record of exit/entry to restricted access areas.

Laboratory operators who perform tests and use forms to document the test should sign and date all forms. Also, the user, the HSO, the principal investigator and representatives of laboratory supervisors should review each written program for health and safety plans, respiratory protection provisions, protective clothing and health and safety training. Additionally, the laboratory should maintain a sign-off sheet as part of the file material kept on each written program.

CHAPTER 4

RECOGNITION AND ANTICIPATION OF LABORATORY HAZARDS

4.1 Introduction

The initial step in the development of an overall laboratory health and safety program is to identify the chemical, biological and physical hazards that are present in the facility. This chapter provides a basis for developing a component of the program and shows how to recognize hazards initially and then as components of the working program. Continual use of preliminary surveys, hazardous chemical inventories, material safety data sheets (MSDSs), health and safety packages and annual surveys provide a university's health and safety officer(s) with a methodology for ongoing recognition and anticipation of laboratory hazards. The goal of this section is to help a university construct a hazard evaluation and control program that is based on the proper and timely recognition of hazards.

4.2 Methodology

One of the primary tasks of a comprehensive health and safety program is to identify, evaluate and recognize potential laboratory exposures to all toxic chemicals. Material safety data sheets for all chemicals in each laboratory are useful in the initial recognition of chemical hazards in the workplace (refer to Appendix B for an example of an MSDS). Based on the information they provide, the HSO can perform a preliminary survey to ensure that the proper controls are in place for the safe handling of the chemicals. The MSDSs also assist the HSO in conducting a hazardous chemical inventory and hazard assessment. The HSO can then identify potential chemical, biological and physical agent exposures and conduct a baseline survey to quantify these exposures. Finally, the HSO can develop a health and safety plan based on the results of the surveys.

This chapter outlines a recommended approach to recognizing potential health hazards, utilizing the MSDSs and baseline surveys. A large portion of these programs is based on the requirements found in the Hazard Communication Standard (29 CFR 1910.1200) of the Occupational Safety and Health Administration (OSHA). Figure 4.1 gives the sequence for a generic hazardous chemicals recognition program.

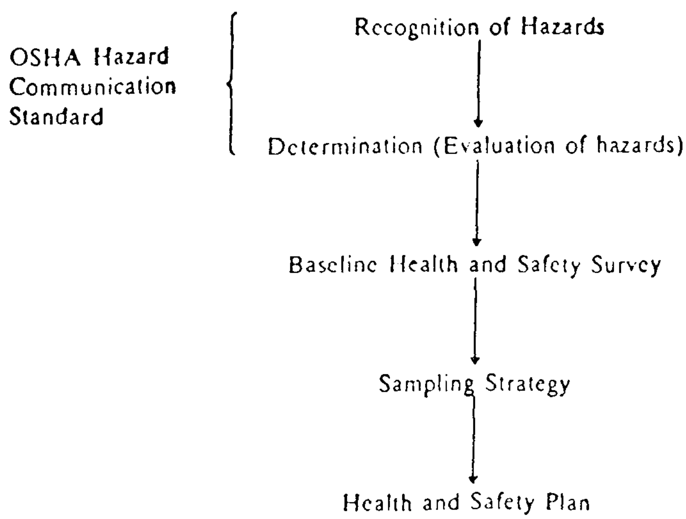


Figure 4.1 Development of a Laboratory Safety and Health Program (after Castegnaro and Sansone, 1989)

4.2.1 Material Safety Data Sheets

The following information is taken from 29 CFR 1910.1200 - Hazard Communications:

1. Chemical Manufacturers and importers shall obtain or develop a material safety data sheet (MSDS) for each hazardous chemical they produce or import. Employers shall have an MSDS for each hazardous chemical which they use.
2. Each MSDS shall be in English and shall contain at least the following:

- The identity used on the label, and, except as provided for on trade secrets: if the hazardous chemical is a single substance, its chemical and common name(s).
- If the hazardous chemical is a mixture which has been tested as a whole to determine its hazards, the chemical and common name(s) of the ingredients which contribute to these known hazards, and the common name(s) of the mixture itself.

- If the hazardous chemical is a mixture which has not been tested as a whole: the chemical and common name(s) of all ingredients which have been determined to be health hazards, and which comprise 1% or greater of the composition, except that chemicals identified as carcinogens shall be listed if the concentrations are 0.1% or greater.
- The chemical and common name(s) of all ingredients which have been determined to be health hazards, and which: comprise less than 1% (0.1% for carcinogens) of the mixture, is evidence that the ingredient(s) could be released from the mixture in concentrations which would exceed an established OSHA Permissible Exposure Limit (PEL) or American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV), or if the chemical could present a health hazard to employees.
- The chemical and common name(s) of all ingredients which have been determined to present a physical hazard when present in the mixture.
- Physical and chemical characteristics of the hazardous chemical (such as vapor pressure, flash point).
- The physical hazards of the hazardous chemical, including the potential for fire, explosion and reactivity.
- The health hazards of the hazardous chemical, including signs and symptoms of exposure and any medical conditions which are generally recognized as being aggravated by the exposure to the chemical.
- The primary routes of entry.
- The OSHA PEL, the ACGIH TLV, and any other exposure limit used or recommended by the chemical manufacturer, importer or employer preparing the MSDS sheet.
- Whether the hazardous chemical is listed in the National Toxicology Program (NTP) Annual Report on Carcinogens (latest edition) or has been found to be a potential

carcinogen in the International Agency for Research on Cancer (IARC) Monographs (latest editions), or by OSHA.

- Any general applicable precautions for safe handling and use which are known to the chemical manufacturer, importer or employer preparing the MSDS, including appropriate hygienic practices, protective measures during repair and maintenance of contaminated equipment, and procedures for clean-up of spills and leaks.
- Any generally applicable control measures which are known to the chemical manufacturer, importer, or employer preparing the MSDS, such as appropriate engineering controls, work practices or personal protective equipment.
- Emergency and first aid procedures.
- The date of preparation of the MSDS or the last change to it.
- The name, address and telephone number of the chemical manufacturer, importer, employer or other responsible party preparing or distributing the MSDS, who can provide additional information on the hazardous chemical and appropriate emergency procedures, if necessary.

If no relevant information is found for any given category on the MSDS, the chemical manufacturer, importer or employer preparing the sheet shall mark it to indicate that no applicable information was found. If complex mixtures have similar hazards and contents (i.e., the chemical ingredients are essentially the same, but the specific composition varies from mixture to mixture), the chemical manufacturer, importer or employer may prepare one MSDS to apply to all of these similar mixtures (Ferrante 1989, 63).

The preparer of the MSDS shall ensure that the information recorded accurately reflects the scientific evidence used in making the hazard determination. If the chemical manufacturer, importer or employer preparing the MSDS becomes newly aware of any significant information regarding the hazards, this new information shall be added to the MSDS within three months.

Mr. John Vendor, Purchasing Manager
XYZ Company
P.O. Box 374
Anywhere, USA

Dear Sir:

On October 8, 1986, VA Facility X received a shipment of hydrochloric acid, shipment 374, manufactured by XYZ Company. We would like to call the following situation(s) to your attention:

Situation 1 – We did not receive a Material Safety Data Sheet (MSDS) with this product shipment and do not currently have an MSDS product for this on file. Please provide us with a current MSDS, or suitable product safety bulletin as soon as possible.

Situation 2 – The MSDS we received with this product shipment was incomplete in the categories noted below:

Note deficiency

Please provide us with a complete MSDS as soon as possible.

It is company policy to request an MSDS for products we purchase from our vendors on delivery, as required by the OSHA Hazard Communication Standard. If you cannot provide us with a completed MSDS, or if you have any questions pertaining to this request, please contact me at (#) or in writing.

We would appreciate your timely response to our request.

Sincerely,

John Doe
MSDS Coordinator

VA Facility X

Figure 4.2 Sample Vendor Letter
(after Dux and Stalzer 1988)

Each facility must ensure that vendors supply MSDSs for the chemicals it purchases. A vendor should make sure that the facility receives the MSDS before, or along with, the first shipment of a newly purchased chemical product. If a vendor delivers a shipment of a new or reformulated chemical without an MSDS, the facility should contact the chemical manufacturer, importer or distributor to obtain one as soon as possible. The OSHA Hazard Communication Standard not only requires manufacturers to supply MSDSs, but also obligates purchasers to actively pursue MSDSs that they need but have not yet received (Dux and Stalzer 1988, 113).

If a facility does not receive an MSDS with the first shipment of a new or reformulated chemical, it should request the vendor to supply one. The facility should make such requests in writing and keep copies on file. Figure 4.2 presents a sample MSDS request letter. A facility is responsible to check all MSDSs for completeness. The vendor should not leave any block on the MSDS blank. At the very least, the vendor should indicate "not applicable" (NA) or "no information available" (ND or No Data) with respect to each category not addressed.

Each facility is responsible for maintaining a file or current MSDSs covering materials used in each work area, and for seeing that these documents are readily available to laboratory operators during laboratory use. In addition, the facility must advise all laboratory users of the location of this information and provide access to it.

4.2.2 Defined Terms

The following list defines selected terms commonly used in MSDSs (Ferrante 1989, 49):

- Carcinogenic: Causing malignant (cancerous) tumors. OSHA, NIOSH and Food and Drug Administration (FDA) consider any tumor to be either a cancer or a precursor of a cancer.
- Oncogenic: Causing tumors.
- Tumorgenic: Causing tumors.

- Mutagenic: Causing a heritable change in the gene structure.
- Embryotoxic: Poisonous to an embryo (without necessarily poisoning the mother).
- Teratogenic: Producing a malformation of the embryo.
- Human Carcinogen: A substance that has been shown by valid, statistically significant epidemiological evidence to be carcinogenic to humans.
- Experimental Carcinogen: A substance that has been shown by valid, statistically significant experimental evidence to induce cancer in humans.
- ACGIH: American Conference of Governmental Industrial Hygienists
- NIOSH: National Institute for Occupational Safety and Health
- LC_{50}: The concentration in air that causes death of 50% of the test animals. The test animal and the test conditions should be specified; the value is expressed in mg/liter, mg/m^3, or ppm.
- LD_{50}: The quantity of material that when ingested, injected or applied to the skin as a single dose will cause death of 50% of the test animals. The test conditions should be specified, the value is expressed in mg/liter, mg/m^3, or ppm.
- ALC: The approximate lethal concentration in air for experimental animals. The test animal and the test condition should be specified, the value is expressed in g/kg or mg/kg of body weight.
- TLV® - TWA: The threshold limit value established by the ACGIH. The time weighted average concentration for a normal 8-hour workday or 40-hour workweek to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.
- PEL: Permissible exposure limits for the workplace, set by regulation and enforced by OSHA. Most of these limit values were originally set by consensus by the ACGIH to assist industrial hygienists in implementing exposure control programs. As law, these are listed in 29 CFR 1910.1000 and subject to revision through the regulatory process.

4.2.3 Guidelines for MSDS Accessibility

The following suggestions describe how a facility can help ensure that MSDSs are readily accessible to employees and made available to interested parties (Ferrante 1989, 60):

- Provide employees with MSDSs for their review before they use any chemical(s).
- Train employees on how to access MSDS files. A facility may post instructions in the workplace, or relay this information to employees verbally, by memorandum or by newsletter.
- Keep MSDSs in notebooks, files, databases or any other convenient medium that remains in, or close to, the immediate work area.
- A facility may provide its employees with MSDSs in documentary form (written operating procedures, manuals, etc.), as long as the material is readily accessible and provides the required information.
- MSDS may be designed to cover groups of hazardous chemicals in the work area if it is more appropriate to address the hazards of a process rather than individual hazardous chemicals. However, the university must ensure that the required information is provided for each chemical and is readily accessible during all scheduled classes and also when students may be conducting independent research and/or experiments.

4.2.4 MSDS Considerations

When reading an MSDS, one should consider the following points:

- An MSDS often outlines only minimum precautions for the safe handling of a chemical, spill or leak procedures, special protection information and special precautions. Therefore, if a facility's policy or the readers own judgment suggests that more stringent procedures are in order, such additional measures should be instituted.
- In the absence of an informed opinion from a designated health professional, always follow the first aid procedure described on the MSDS.

- If the MSDS fails to mention a particular detrimental health effect, it should not be assumed that the substance is hazard-free. The vendor may not have known about recent test results when the MSDS was prepared.
- An MSDS should have no blank spaces. If a facility receives an incomplete MSDS, the supplier should be questioned. As indicated previously, if no data are available, the MSDS should indicate that in the space provided.
- If laboratory operators must travel between laboratory facilities, the MSDS may be kept at a central location at the primary facility. The university must ensure that all laboratory users can immediately obtain the required information in an emergency.

4.2.5 Trade Secrets

One important consideration concerning MSDSs are trade secrets. A supplier may withhold the specific chemical identity, including the chemical name and other specific chemical identity - including the specific identification of a hazardous chemical from the MSDS. However the following criteria must be met (Bretherick 1987, 143):

- Information contained in the MSDS concerning the properties and effects of the hazardous chemicals is disclosed.
- The MSDS indicates that the specific chemical identity is being withheld as a trade secret.
- The specific chemical identity is made available to health professionals, employees, and designated representatives in accordance with the following provisions:

  1. A treating physician or nurse determines that a medical emergency exists and the specific chemical identity of a hazardous substance is necessary for emergency or first aid treatment.
  2. A health professional (i.e. physician, industrial hygienist, toxicologist, epidemiologist or occupational health nurse) in a non-emergency situation must provide medical or other occupational health services to exposed

laboratory operator(s) if a request is in writing and adheres to the criteria outlined in the next section.

A written request to obtain a trade secret chemical identity must describe with reasonable detail one or more of the following occupational health needs:

- To assess the hazards of chemicals which employees will be exposed.
- To conduct pre-assignment or periodic medical surveillance of exposed employees.
- To provide medical treatment to exposed laboratory users.
- To select or assess appropriate personal protective equipment for exposed laboratory operators.
- To design or assess engineering controls for exposed employees.
- To conduct studies to determine the health effects of exposure:

4.2.8 Preliminary Health and Safety Survey

A preliminary health and safety survey serves as two purposes: to identify potential health hazards and to collect relevant operational, environmental and personal background information for the future assessment of those health hazards. At a minimum the surveyor(s) must collect the following information in a preliminary walk-through survey (Myers: Liddle and Hill 1987, 525).

- A list of potentially hazardous materials, including toxic chemicals and biological and physical agents that may cause harm to a facility's employees (as defined by OSHA's Hazard Communication Rule-29 CFR 1910.1200. The minimum information required for each chemical agent consists of material name, frequency of use and amount of use.
- Descriptions of operations and tasks involved in the handling, storage and disposal of hazardous materials and their by-products. Additionally a description of operations that use hazardous physical agents or stresses.

The following information and factors are required for the initial determination of potential health hazards:

- Type of operation and specific operational characteristics that may influence the presence and/or degree of a hazardous exposure:

  - narrative of operation including documented written procedures;

  - type of equipment used;

  - physical/chemical factors of the operation (temperature, pressure, chemical reactions); and

  - specific task performance by employees.

- Frequency and duration of the operation and potential exposure of employees to a hazard.

- Number of personnel, both male and female.

- Description of control measures (e.g., type of personal protection equipment, engineering controls and administrative controls-such as training and rotation of personnel).

- Rudiments of each operation. For example, are chemicals being heated with or without combustion? Are dry materials being dumped or mixed? Are liquids being sprayed? How often is each operation being run?

- Obvious signs of exposure, including:

  - airborne dust, smoke or mist;

  - accumulation of dust, liquid, or oil on machines, on the floor, and/or the ledges;

  - odors from solvent vapors or gasses;

  - unusual taste;

  - burning or throat/nose irritation;

  - hazardous operations being performed during unsupervised times or special tasks being performed by maintenance personnel;

Table 4.1 Physical Constraints/Hazardous Agents in Toxicological Laboratories (after Myers; Liddle and Hill 1987)

Operation	Physical Constraints/ Agent/Exposure	Operation	Physical Constraints/ Agent/Exposure	Operation	Physical Constraints/ Agent/Exposure
Receiving	Lifting, twisting Solvents Test chemical Positive controls	Histology	Glacial acetic acid Mercuric oxide Hematoxylin Basic fuchsin Metanil yellow Trypan blue stain Geimsa stain Repetitive motion, eye strain	Engineering/maintenance	Welding: Ultraviolet radiation Oxides of nitrogen Fluorides Flux fumes Ozone Solvents Glues Pesticides Noise Cleaning fluids/ disinfectants Test chemical Positive controls Lifting, twisting Asbestos (insulation)
Storage	Lifting Solvents Positive controls				
Dose preparation	Test chemical Lifting, repetitive motion Noise (mixing) Radiation (trace) Solvents (e.g., alcohol, DMSO) Biological agents Positive controls	Analytical chemistry	Solvents Reagents Repetitive motion Radiation (ionizing, nonionizing)		
		Cagewash	Aerosols (bedding) Biological agents Test chemical Positive controls Noise Heat stress Lifting, twisting		
Dose administration	Lifting, repetitive motion Dilute test chemical Radiation Biological agent				
Histology	Hydrochloric acid Picric acid 27–40% Formaldehyde 95% Alcohol 10% Formalin xylene Paraffin Eosin stain	Boiler plant	Sodium hydroxide Phosphates Sulfuric acid Chlorine Heat stress Lifting, twisting Asbestos (insulation) Noise		

- presence of procedures for responding to emergencies, such as chemical spills, leaks, explosions and fires.
- complaints of employees about such symptoms as skin rash or dermatitis, coughs, tightness of the chest, difficulty in breathing, stuffy noses and persistent colds, headaches, dizziness, or lightheadedness, loss of appetite, fatigue, nausea and numbness of the fingers, hands, arms or legs;
- persistence of symptoms or improvement when people are away from the university; or
- high turnover rate on certain jobs.

The facility HSO should collect the background information listed above, with the assistance of other laboratory personnel. Table 4.1 presents an example of hazardous agents found in operational areas of toxicological laboratories. Additional agents may also be present in the areas, and the checklist should include them as well.

A preliminary survey may also prove useful in compiling a list of all workplace chemicals. As required by the federal Hazard Communication Regulation (29 CFR1900.1200(e)), a facility is responsible for developing a list of hazardous chemicals to be included as part of its written hazard communication program. In addition to a preliminary survey of all purchasing and inventory records should be reviewed. Each inventory listing should be kept in its respective work area. An example of a hazardous chemical inventory questionnaire is provided in Figure 4.3.

Once a facility has completed its chemical inventory, it should cross reference its contents with the MSDSs received to date. If an MSDS states that the chemical listed is not hazardous under the OSHA Hazardous Communication Rule, the facility may consider dropping the chemical from its list. A laboratory may also discover that chemicals identified in the inventory list lack an MSDS. It then must be determined if the chemical is hazardous (in which case an MSDS is required).

Additionally, some state's have enacted right-to -know laws and have prepared lists of hazardous chemicals which facilities should consult in their attempts to comply with state requirements for the listing of hazardous chemicals.

CHEMICAL NAME________________ STORED AT______
MATERIAL/INVENTORY CONTROL NUMBER__ SUPPLIER______
is used in this department.
FROM: DEPARTMENT______________________
BY: NAME____________________ DATE______
Complete one sheet for each material and for each supplier and send it to the facility HazCom Coordinator.

CHARACTERISTICS OF MATERIALS TO LOOK FOR:

Gas	Liquid	Solid
Pressurized	Poisonous	Corrosive
Toxic	Carcinogen	Flammable
Combustible	Nuclear	Alkaline
Oxidizer	Pyrophoric	Infectious solvent
"Reactive hazard"	"Housekeeping supply"	Very dusty
Heavy mist	Fume problem	Strong odor

Incompatible with__________________
Sensitive to: heat light shock pressure

Frequency of Use: ____________
Amount of Use: ____________
Total Quantity: ____________

Figure 4.3 Material Inventory Questionnaire (after Myers; Liddle and Hill, 1987)

4.3 Hazard Assessment [*CHP*]

The OSHA standard lists approximately 600 hazardous chemicals in its Hazard Communication standard. It is very important that the HSO or a hazardous materials coordinator assesses the hazard upon receipt of a chemical and MSDS. Several measures to help determine the danger of chemicals are discussed below.

4.3.1 Methods To Assess Hazards

A facility should use all available sources of health and physical information to appraise the potential hazards that a chemical may possess. These sources include, but are not limited to (Castegnaro and Sansone 1989, 196):

- Information on the physical-chemical properties, toxicological data and human health effects, as well as environmental fate and effects data.
- All adequate health and safety information obtained from the supplier.
- Primary resources used for hazard evaluation:
  1. National Library of Medicine
     - On-line computerized medical literature analysis and retrieval system (MEDLARS).
     - Immediate access to more than 2.5 million references on more than 50,000 chemicals
  2. Dialog
     - More than 200 databases
     - More than 90 million records
     - A wide variety of subject matter, including chemistry, medicine and biosciences, as well as science technology data.
  3. Lexis/Nexis: Federal and state regulatory/legal data.

A chemical is considered to constitute a physical hazard if there is scientifically valid evidence that it is a combustible liquid, a compressed gas, an explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive), or water reactive as defined by Section C of the OSHA Hazard Communication Standard.

4.3.2 Health Hazard Determination

To determine whether a chemical is a health hazard, a facility should evaluate the data to establish whether:

- there is statistically significant evidence, based on at least one study conducted in accordance with scientific principles that acute or chronic health effects may occur in employees exposed to it;
- it meets any of the health hazard criteria as defined by the OSHA standard that would make it a carcinogen: a corrosive, highly toxic irritant, a sensitizer, a toxic material or an agent that could harm any organ and/or system of the body, human or animal;
- it is listed in OSHA Regulation 29 CFR1910 Subpart Z, ACGIH threshold limit values for chemical substances and physical agents in the workplace;
- it is listed in the IARC monographs or the (NTP), Annual Report on Carcinogens (a listing in any these documents, will be considered as conclusive evidence of its carcinogenicity); or
- the results of any studies that were designed and conducted according to established scientific principles indicate statistically significant evidence that the chemical possesses a potential health hazard.

In assessing whether or not a health hazard exists for a mixture, a facility should evaluate to determine:

- Whether the mixture has been tested as a whole. If so, the health hazard determination and the ingredients that contributed to this condition are indicated on the MSDS.
- Whether the mixture has not been tested as a whole for a health hazard. In this case, the health hazard determination for component chemicals is used in the evaluation of any components of the mixture that comprise 1% or greater ($\geq$ 0.1% for carcinogens).
- Whether it is determined that a component (< 1%, or < 0.1% for a potential carcinogen) present in the mixture could be released in atmospheric concentrations that would exceed the established OSHA or ACGIH exposure limit for the component, or would present a health hazard at these concentrations, then the mixture would be considered hazardous.

A facility or workplace may contain common consumer products, such as household detergents and cleansers, soap and type correction fluid. These items may be excluded from the hazard assessment, provided they are used in the same manner and in the same approximate quantities as would be expected in their typical consumer applications. If, for example, a commercial sodium hypochlorite solution (e.g., Clorox®) is used regularly to disinfect work surface for microbial contamination, it should be included in the program.

4.3.3 Sampling Procedures

The main types of sampling techniques are described below (Forsberg and Keith 1988, 135):

- Personal Sampling: a pump device placed directly on a person that will collect possible air contaminants during an 8-hour work shift. The contaminant is trapped on a medium and then analyzed. This type of sampling will give a good idea of what the person has been exposed to during the day. The use of dosimetry is also being used to determine chemical exposure. The person would wear the badge for a specified time and then the medium is analyzed to determine what and how much of the substance the person was exposed to.
- General Area Sampling: a pump collection device is placed in the laboratory and operated for a specified period of time and then analyzed. The disadvantage of the area sampling is that it does not give an accurate reading of an individual's exposure. The laboratory operator may not have worked a long period of time in the area and also could have been exposed to other substances in other areas.
- Grab Sample: involves collecting a sample of air in an empty bag, flask, bottle, etc.. The sampling is immediate and does not take more than a few minutes. The samples are analyzed for air contaminants. This type of sampling is similar to general area sampling and does not provide for individual exposures.

- Integrated Sampling: a known amount of air is passed through a medium that traps the air contaminant. The medium is then analyzed to determine quantity and what the substance is. This sampling is usually done over a period of time and will provide information on individual exposures.
- Equipment Used for Sampling: selecting the proper sampling equipment will depend on the type of air contaminant to be tested for. Vendors of monitoring equipment (Appendix C) often provide critical and insightful assistance in the selection of appropriate sampling equipment. Two basic contaminants often found in laboratories are: gases/vapors and particulates. The equipment for gases and vapors are detector tubes, badges or direct reading instruments. For particulates - filter devices, cyclones and direct reading instruments should be used.

Laboratories may often encounter a number of problems in their chemical exposure assessments. These may include, but are not limited to, the following:

- sampling equipment calibration errors;
- sample contamination;
- varying environmental conditions;
- lack of sample homogeneity;
- adsorption of abalyte onto sample container walls;
- use of improper sampling medium;
- incomplete evaluation of analyte sampling medium;
- channeling of analyte on the collection medium;
- degradation of analyte prior to analysis;
- mechanical defects in sampling equipment;
- partial vapor pressure effects of gases;
- reactivity of the analyte with sampling medium;
- volumetric errors and sampling rate errors;
- temperature and pressure effects during sampling;

- analytical errors; and
- calculation errors.

The person conducting the sampling should be sure to consider all problems for the specific chemical monitoring technique being employed. However, it is best to use the service of a professional industrial hygienist to design detailed sampling and analysis procedures.

After the samples have been successively collected, they are analyzed to see what the substance is and how much of the item is present in the workplace. Once these items are determined, the results are compared to establish standards to see if concentrations have exceeded established limits (TLV's, PEL's and Short Term Exposure Limits (STEL's)). If the sampling results indicate exposures within acceptable limits and the results representative of employee exposures, the results should be reported to the affected employees and documented and filed for future reference (OSHA regulations require retention of exposure evaluation records).

If the sampling results indicate exposures above acceptable levels, the laboratory should implement both immediate and long term control measures. In cases of highly toxic compounds, the laboratory should consider shutting down the operation until exposure-reducing controls can be implemented. In situations involving compounds of a less toxic nature, the laboratory should implement personal protection and engineering controls of various types to provide both immediate and long-term protection for employees. The laboratory should inform employees of all sampling results and of steps being taken or planned to reduce exposures. After implementing permanent controls, the laboratory should conduct further sampling to verify their effectiveness.

4.3.4 Baseline Health and Safety Survey

The baseline health and safety survey constitutes the implementation of the sampling strategy plan. The baseline survey should include the quantitative monitoring of agents, the evaluation of personal protective equipment, and the evaluation and verification of the effectiveness of engineering controls. In addition to these technical issues, the survey should address the management of industrial hygiene programs.

Figure 4.4 below summarizes the proper order to conduct a hazard recognition program:

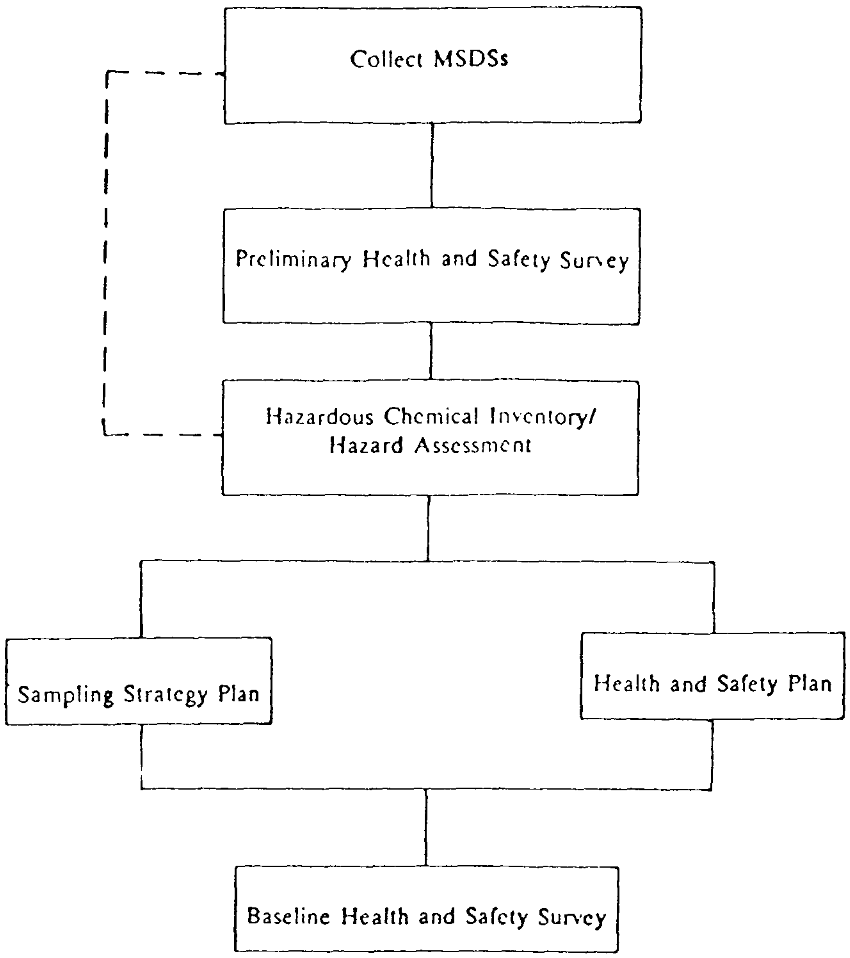


Figure 4.4 Proper Order for Hazard Recognition Program (after Forsberg and Keith, 1988)

4.4 Emergency Procedures [*CHP*]

It is very important that all employees of a laboratory understand and are trained in the procedures that must be followed in the event of a fire, explosion, toxic chemical release or accident. Every laboratory should have a comprehensive emergency plan ready for implementation during such events. An employee should never have to "second guess" the first priority. Additionally, employees should not have to hesitate if deciding in determining if and when they can safely shed their personal protective equipment in the avoidance of exposure to a dangerous chemical.

4.4.1 Emergency Response

The procedures recommended in the event that a chemical carcinogen or toxic material is spilled are as follows (Manufacturing Chemists Association 1988, 21):

- Leave the room immediately, and if any chemical has contacted the eyes or skin, wash thoroughly using the eyewash and/or shower, as necessary. Discard any protective clothing that may have been contaminated.
- Notify personnel in the immediate area to evacuate and post the area with warning signs.
- When a person is contaminated, it is necessary to notify either the Poison Control Center and/or laboratory management.
- Before returning to the spill area, all laboratory operators should be made aware of the neutralization process for the specific compound spilled. Persons not wearing the appropriate personal protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.
- The minimum personal protective equipment that should be worn during cleanup consists of:
    (a) respirator, with the appropriate cartridge or self contained breathing apparatus;
    (b) disposable Tyvek® jumpsuit;
    (c) disposable Tyvek shoe protectors and Tyvek head cover;
    (d) safety glasses; and
    (e) disposable gloves (at least two dissimilar pairs, with the inner pair taped to the sleeve cuff of a Tyvek jumpsuit).

- No one is to enter the spill area alone. Only when accompanied by another appropriately dressed individual may a person enter the spill area. If no one else is available, a person desiring to enter is to remain immediately outside the room, dressed in protective equipment and ready to provide assistance in case of problems.

4.4.1-1 Cleanup of Solid Chemical Spills The following procedures should be observed in the cleanup of solid chemical spills:

- Cover the solid material with wet paper towels (using water or appropriate solvent). Avoid spreading the compound as much as possible. Do not dry sweep.
- If the material is flammable, remove all sources of ignition.
- Ventilate the area of the spill.
- Carefully pick up the bulk of the material in one of the scoops provided with the spill kit.
- Again, with wet paper towels, wipe up any small traces of material still present.
- Follow the neutralization process appropriate for the spilled material to decontaminate the area.
- Dispose of the residue according to the recommended hazardous waste disposal procedure.

4.4.1-2 Cleanup of Liquid Chemical Spills The following procedure should be observed in cleaning up liquid chemical spills:

- Ventilate the area of the spill.
- If the material is flammable, remove all sources of ignition.
- Surround the area with an absorbent materials (Solusorb, paper towels, sodium bicarbonate, sand or vermiculite). Solusorb is available in spill kits sold commercially.

- Carefully spread more absorbent material onto the chemical, and try to avoid creating aerosols. Allow enough time to soak up the liquid.
- Carefully pick up the bulk of the material in one of the scoops provided with the spill kits.

4.4.2 Means of Egress

In planning for a timely and efficient evacuation in case of an emergency, a means of egress must be considered and planned. The principal reference, which has been widely adopted by many states and municipalities, is the National Fire Protection Association Standard 101, "Code for Safety to Life from Fire in Buildings and Structures." It addresses such topics as type and number of exits, measurement of travel distance to exits and emergency lighting. Referral to this standard should be made for more specific information.

4.4.3 Alarm Systems

An integral part of an emergency response plan is a reliable, well-designed alarm system. Principle components of such a system include (Ferrante 1989, 106):

- a control unit;
- initiating device circuitry, with appropriate connections (to manual pull-box stations, detectors, water flow alarms, etc.);
- indicating device circuiting, with appropriate connections (to belts, speakers and off premises alarms, etc.); and
- primary and secondary power supplies.

There is a great variety of systems available ranging from local alarms to central station alarm systems. In considering an alarm system for a specific site, details on the design, installation, inspection and maintenance of the different types of system can be found in various documents published by the National Fire Protection Association (NFPA).

4.4.4 First Aid

First aid recommendations supplied with chemical specific handling documents (e.g., MSDSs) typically assume that a physician, ambulance or emergency medical service is available within five to fifteen minutes. They reflect an out of hospital situation and are thus designed to cover only the initial period while awaiting for professional help. First aid assistance should be provided only by trained individuals. The following general guidelines are typically used (Dux and Stalzer 1988, 136):

- If the victim is convulsing or unconscious do not induce vomiting. Inducing vomiting in an unconscious person is likely to aspirate the chemical into the lungs, thus spreading it and causing other complications. Assure that the victims' airway is open and lay the victim on his or her side with the head lower than the body. Immediately transport the victim to a hospital.
- If the chemical ingested is an irritant, corrosive or volatile substance, do not induce vomiting. Inducing vomiting with chemicals of these types is also likely to aspirate the chemical into the lungs and may harm or destroy other tissues in the throat or mouth, thus spreading it and causing other complications. Usually, the best advice is to dilute the chemical by having the victim drink one or two glasses of water until the care of a physician or paramedic has been obtained. If the chemical is very toxic, the victim may be advised to drink a slurry of activated charcoal to adsorb the chemical while awaiting medical help.
- If the chemical ingested is not an irritant, corrosive or volatile but is very toxic (i.e., the quantity sufficient of induce death is about one teaspoon or less), then, because of the high toxicity of the chemical, consider undertaking the risk of inducing vomiting. Ipecac syrup or salt water may be used in such an emergency.

- If the chemical ingested is not an irritant, corrosive or volatile and is low in toxicity (this covers the majority of organic and inorganic compounds), give one or two glasses of water to dilute the chemical while awaiting medical help.
- If the chemical ingested is a concentrated acid, give the victim several glasses of very cold water to dilute it. This is because the heat of dilution, which is released when concentrated acids are diluted.
- If the chemical ingested is a dilute acid, give the victim several glasses of cold water and also

  Maalox®, milk of Magnesia or aluminum hydroxide gel to neutralize it. Avoid all carbonated beverages, since these will release the carbon dioxide in the stomach.
- If the chemical ingested is either concentrated or a dilute base, give the victim several glasses of cold water to dilute it.
- If the chemical ingested is a known or suspected carcinogen, determine from a physician whether long term monitoring is recommended. The specific compound, exposure route and exposure level will determine the physician's recommendation.
- If the chemical is spilled on the skin, immediately wash it off with soap and water. If it is not very toxic, corrosive, or an irritant, and is not readily adsorbed by the skin, contact a physician if any symptoms such as redness or spots develop. If the chemical is a corrosive or an irritant, in which case symptoms such as redness or spots are likely to develop quickly, contact a physician. If the chemical is toxic and readily adsorbed by the skin, contact a physician immediately because there may not be any distinguishable symptoms on the skin.
- If the chemical is splashed in the eyes, flush the eyes immediately for about twenty minutes. If the chemical is not an irritant, not corrosive and not very toxic, contact a physician if any symptoms such as redness or irritation of the eyes occur. If the chemical is an irritant, corrosive or toxic, contact a physician immediately. Symptoms usually develop quickly in such cases.

- If the chemical is inhaled, see that the victim leaves the area immediately and breathes fresh air. If the chemical is not an irritant, not corrosive and not very toxic, contact a physician if any symptoms such as coughing or shortness of breath occur. If the chemical is an irritant, corrosive or toxic, contact a physician immediately; symptoms are likely to develop quickly.

Several supplies should be available in the event of an emergency:

- Ipecac syrup or table salt to induce vomiting;
- activate charcoal for making a slurry to drink;
- Maalox®, milk of magnesia, or aluminum gel to neutralize dilute acids;
- appropriate respirators; and
- eyewash stations to flush the eyes.

CHAPTER 5

CONTROL MEASURES FOR PERSONAL EXPOSURE

5.1 Introduction

All chemicals can be potentially hazardous. The risk of being exposed to hazardous substances can be reduced or eliminated by recognizing, evaluating and controlling the hazard. A person should be able to recognize what the hazards are and how they exist. One should be able to evaluate the degree of the hazard that exists. Finally, all persons who perform any type of laboratory work should be able to control the hazard with environmental, physical or engineering methods to reduce the exposure. Any person can protect themselves effectively if they understand what they are exposed to. This knowledge will allow them to minimize the risks associated with working with chemicals by taking proper protective measures. By using the appropriate protective controls, one can effectively reduce the amount of exposure to a hazardous substance. The following chapter will discuss the various control measures which should be implemented to reduce potential laboratory hazards.

5.2 The Source of the Chemical

Various methods to control hazards at the source are discussed below. (DiBerardinis 1987, 69)

- Substitution: Substituting a less toxic material for a highly toxic one is a very effective control method. The employee will be affected to a lesser degree by this method. To ensure that this technique is effective it is important to recognize that new hazards are not introduced by the substitution method.
- Process Change: Processing operations or processing equipment may be modified to reduce exposure to contaminants. Examples of this would be: using low speed

grinding equipment to reduce dust in air or using dipping or brushing of coatings instead of using sprays to keep mists down. The major auto manufacturers used process change in undercoating and painting of all vehicles. Instead of spraying the cars, they now dip them in large reservoirs of paint, thus keeping the airborne particulate mists to a minimum.

- Isolation: Isolation of toxic chemicals may be used by enclosing the system in self contained rooms, such as a spray paint booth. By using this method, employees may enter the area with proper protective equipment and work in a safe environment.
- Wet Method: To keep dust and particulates from being put into the air, water or some wetting agent is used to control them.
- Local Exhaust: Air contaminants can be removed at the source by the use of local exhaust systems such as fume hoods or flexible ducts. Using this method during welding operations will reduce the amount of metal oxides that are put into the air. The one problem faced with this type of ventilation is that it is not effective on highly toxic substances.

Additionally, proper housekeeping is an important way to minimize hazards. This includes cleaning up spills as soon as they happen. Leaving a substance on the floor will only allow it to evaporate and increase the amount of contaminant in the air. When a spill is cleaned, place the adsorbents, rags, etc. in a closed container to avoid the substance from being put into air. Using the proper decontamination procedures when leaving the work area will limit exposure. It is very important that all laboratory operators leaving to go to lunch, do not wear contaminated clothing - this will only increase the exposure level through inhalation and ingestion.

5.3 Employee Control Measures [*CHP*]

5.3.1 Introduction

There are several crucial control measures which an employee can take into account for laboratory hazards (Forsberg and Keith 1988, 86):

- Education/Training: Through developing and conducting various training and education programs, effective control measures can be achieved in reducing exposure to hazardous materials in the workplace. Employees can be assured that proper conditions exist once they know what to look for.
- Rotation of the Workers: Limiting the amount of time an employee is exposed to a chemical is an effective measure to reduce exposure.
- Monitoring Procedures: Using the various personal and area monitoring programs should keep the possibility of over exposure to a minimum.

One very important employee control a person can take to minimize hazards is the use of personal protective equipment. The varying and complex nature of this topic, warrants special attention. Therefore, the next section of this chapter is dedicated to the correct selection, training, use and maintenance of personal protective equipment.

5.4 Personal Protective Equipment

5.4.1 Introduction

Laboratory operations frequently involve a risk of clothing or skin contact with toxic materials. It is often necessary to augment engineering and administrative controls with personal protective equipment (PPE). The use of PPE should be implemented as a last resort. Unless workers select, use and maintain equipment properly, they may not receive the intended protection. Additionally, the user may have a false sense of security and therefore be at a higher risk of injury or illness than if they had used no protective clothing at all.

Laboratory facilities often adopt procedures requiring workers to don protective garments before entering a potentially contaminated area and then remove them when exiting. This restricts the flow of any contamination that may have been picked up in one specific area. The conditions under which protective equipment is used in a laboratory depend on the type of work being done, the chemical, biological or physical agents being used, in addition to the potential for exposure (Schwope 1987, 23). This section is concerned with the use of protective equipment to minimize hazards presented by skin and clothing contact Respiratory protection against inhalation hazards will be addressed separately.

5.4.2 Protection of Face and Eyes

Many of the hazards for which protective clothing is required are chemical. The object of protective clothing is to form an impenetrable barrier between the user and the hazard. Unlike engineering controls, which enclose or otherwise affect the source of the hazard, one may think of protective clothing as enclosing the user against the hazard (Schwope 1987, 23).

Direct contact of the skin or the mucous membranes with a chemical substance, or with clothing soaked with a chemical, will typically result in one of the following adverse outcomes:

- Inorganic acids and bases can cause primary irritation, ranging from minor reddening to ulceration and corrosion.
- Organic solvents can cause defatting of the skin, with resultant cracking and dermatitis.
- Some systematic toxins can be adsorbed into the blood across the skin.
- With some substances, a sensitization reaction may occur. In such cases, a much smaller exposure to the same substance at a later date can cause the reaction to occur again.

The most commonly used pieces of equipment for protection of the face and eyes are illustrated in Figure 5.1. Of these, the equipment most frequently used in laboratories is safety glasses. Safety glasses are available in many different configurations and styles, and can be fitted with prescription lenses for those who need them. Safety glasses can be equipped with side shields for greater protection.

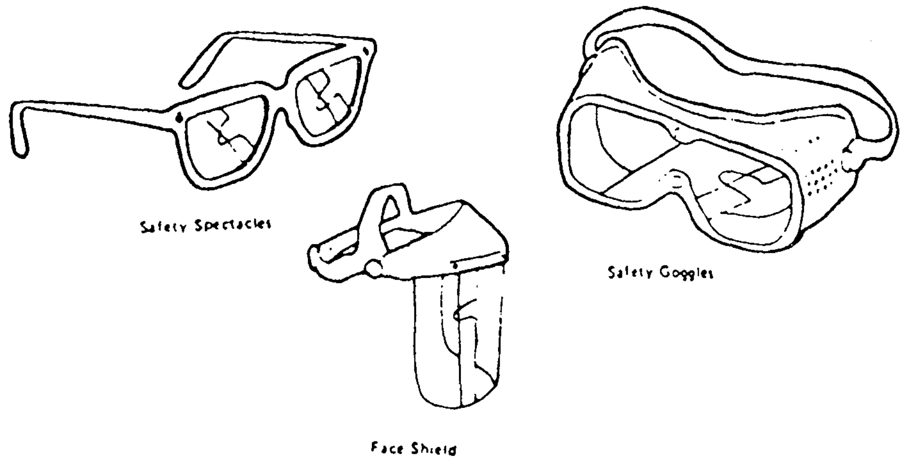


Figure 5.1 Personal Protective Equipment for the Protection of the Face and Eyes (after Schwope, 1987)

Both glasses and goggles are available in tints and shades that permit their use for welding, burning or for exposure to non - ionizing radiation. In the case of lasers, the frequency of the radiation must be known, since the adsorbing media are frequency-specific. In environments in which a splashing liquid or rapidly moving airborne particulate exist, clear plastic goggles that completely enclose the eyes will provide superior protection. In addition, goggles that can be worn over non safety prescription glasses allow the use of regular eye glasses in the lab.

A face shield provides protection for the nose and mouth areas of the face in addition to the immediate area of the eye. Clear shields are available for protection from splashing chemicals or rapidly moving particulate, such as one might encounter when using a grinding wheel. Finally, if total protection of the face, head and neck is necessary,

Table 5.1 Selected Suppliers of Personal Protective Equipment (after Schwope, 1987)

Supplier/Manufacturer	Air-Purifying Respirators	Air-Supplied Respirators	SCBA	Safety Glasses	Goggles	Face Shields	Hard Hats	Hearing Protection	Disposable Clothing	Reusable Clothing	Gloves
Abanda by Disposables, Inc.									✓	✓	
American Allsafe Company	✓			✓	✓	✓	✓	✓			
American Optical Company	✓		✓	✓	✓	✓	✓	✓			
Bilsom, International					✓		✓	✓			
H. L. Bouton Company				✓	✓	✓					
Brahma Glove Company									✓	✓	✓
E. D. Bullard Company	✓					✓	✓				
Charkate									✓	✓	✓
Daffin Disposables	✓								✓	✓	✓
Durafab									✓	✓	
EAR Division, Cabot Corporation								✓			
Edmont									✓	✓	✓
Glendale Protective Technologies	✓			✓	✓	✓	✓	✓			
Magid Glove & Safety Company	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Mine Safety Appliance Company	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
North Safety Equipment	✓	✓	✓	✓	✓	✓	✓				
Peltor, Inc.						✓	✓	✓			
Racal Airstream, Inc.	✓							✓			
Rainfair, Inc.									✓	✓	✓
Scott Aviation	✓	✓	✓								
Survivair	✓	✓	✓								
3M Company	✓	✓						✓			
Titmus				✓	✓						
U.S. Safety, Cecso Service Company	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Willson Safety Products	✓	✓		✓	✓	✓	✓	✓	✓		✓

one may use a full hood with a clear visor. Table 5.1 lists several leading suppliers and manufacturers of protective equipment for the eye and face. For a more comprehensive listing of manufacturers of a specific item, refer to the Thomas Registry.

5.4.3 Hard Hats and Hearing Protectors

Although hard hats are not often seen in laboratories, in some applications such protection may be necessary. For example, many pilot operations require hard hats. Hard hats are available in several models designed for different applications. Some hats are not appropriate for use near electrical wires, and others are only light duty "bump caps," designed for use in low hazard environments.

Another form of personal protective equipment are earplugs and earmuffs, which are available in a number of different types, sizes, shapes and colors. As with all safety equipment, a qualified professional should select them and direct their use. A hearing conservation program is necessary in a work environment which equals or exceeds a time weighted average of 85 dBA over an eight hour day. Additionally, the use of hearing protection is mandatory as one meets or exceeds the OSHA PEL of 90 dBA (over an 8 hr. time weighted average).

5.4.4 Types of Protective Clothing

Laboratory employees often wear protective clothing because there can be a high risk of spill or splash in laboratory operations. The protective clothing chosen must be appropriate to the hazard against which protection is required. Employees must use it according to the manufacturer's directions (with respect to disposal, donning, cleaning). Disposable laboratory coats, jumpsuits and gloves are often used in laboratories to protect from hazards (Schwope 1987, 97).

Protective clothing articles are made from a wide variety of natural and synthetic materials. Neoprene, nitrile and natural rubbers, polyvinyl chloride and polyethylene are a few examples of common protective clothing materials. Protective clothing designs also vary. One can purchase full body suits, jackets, gloves, sleeves, aprons as well as many other pieces of equipment. The selection of appropriate equipment to specific needs is discussed below:

5.4.1-1 Disposable Laboratory Garments Three basic types of fabric are in common use in industrial and laboratory disposable garments. The most prevalent is Tyvek®, a spun-bonded polyolefin fabric made by du Pont. One drawback of Tyvek®, is that is impermeable to air and moisture, and can therefore be hot and uncomfortable. Manufacturers have developed a second class of breathable fabrics to address this problem. These fabrics, which include Gore-tex®, and Kimberly-Clark's Kleenguard®, fabric, are able to "breathe."(Ferrante 1989, 232) In other words, they will permit the passage of air and moisture and thus minimize the retention of body heat. Such breathable garments may, however, also allow penetration of toxic agents. The laboratory should permit the use of such garments only after careful consideration of the protective requirements.

A final category of fabric is coated Tyvek, which features a layer of impermeable plastic. An example of the coating material used is Saranex®, which is manufactured by Dow. All of these fabrics are used to produce a wide variety of garments. The choice of the right garment requires a knowledge of the hazards involved and the protection required. Although one can assemble a complete protective ensemble by wearing several different garments at once, it is desirable to use as few different garments as possible to achieve the desired coverage. Whenever multiple garments are used, the possibility of chemicals entering the interior of the suit between layers is increased, therefore, one can minimize this risk (penetration of chemical through protective layers) by wearing single garments.

Table 5.2 Physical Properties for Glove Use
(after Forsberg and Keith 1988)

Property	Neoprene	Python Neoprene	Coated Work Gloves: Ripple Texture	Coated Work Gloves: Multi-purpose	Coated Work Gloves: Utility	Coated Work Gloves: Flexible Vinyl Plastic	Coated Work Gloves: Super-flexible Vinyl Plastic	Molded Handwear: Natural Latex Gloves	Molded Handwear: Latex Nitrile Gloves	Molded Handwear: Synthetic Bayprene® Rubber Gloves	Molded Handwear: Baytex® Gloves
Abrasion resistance	G	G	G	E	E	E	E	G	E	G	G
Cut resistance	E	E	E	NR	NR	NR	NR	E	E	E	E
Snag resistance	E	E	E	G	G	G	G	E	E	E	E
Heat resistance	G	G	E	F	F	F	F	E	G	G	E
Low temperature resistance	E	E	E	G	F	G	E	E	E	E	E
Flexibility	G	G	F	E	E	E	E	G	G	G	G
Dry grip	E	G	E	E	E	E	E	E	E	G	E
Wet grip	F	E	E	E	F	E	G	E	G	E	E

* G = good, E = excellent, F = fair, NR = not recommended.

5.4.4-2 Gloves After the face and eyes, the hands are the most vulnerable part of the body, and are most likely to be affected by spills, cuts, accidental injections or contact with temperature extremes. To mitigate each of these hazards, laboratory operators should wear protective gloves. The selection of the right glove for the job requires a knowledge of the manual tasks to be performed, as well as an understanding of the physical and chemical risks to which the wearer may be exposed. Table 5.2 shows how one glove supplier categorizes its gloves with respect to physical properties.

5.4.5 Selection and Use of Chemical Protective Clothing

Since there is such a wide variety of chemical protective clothing available, and since the performance of the various types against a particular hazard can differ greatly, the selection and use of chemical protective clothing must be carefully considered and administered. Consequently, chemical protective clothing must be selected by an individual who is knowledgeable in the types of uses of such gear. Among the issues that must be considered are permeability, functional compatibility, record keeping and maintenance.

5.4.5-1 Permeability The extent to which a particular substance penetrates a glove material is called its permeability. In general, permeation of a substance through a glove or clothing material depends on at least four factors (Forsberg and Keith 1988, 181):

1. Temperature: The permeation rate increases with increasing temperature.
2. Thickness: The time required to permeate a material increases with the increasing thickness of a material.
3. Solubility: The permeability of a liquid is generally higher if the chemical is soluble in the protective garment material. However, the solubility cannot always be used as a predictor of permeability.

4. Multicomponent liquids: The rate at which a substance permeates can be accelerated in the presence of another, more rapidly permeating component.

Although qualitative permeation data are available from many manufacturers, relatively few have conducted any in-house quantitative experiments. However, more permeability data are becoming available from both manufacturers and testing laboratories. It must be remembered that no material is 100% impermeable to anything, and no one chemical will form a satisfactory barrier against all substances. Therefore, one must evaluate the performance of barrier materials against various chemicals on a substance-by-substance basis.

5.4.5-2 Functional Compatibility When prescribing various pieces of personal protective equipment for simultaneous use, it is useful to recall that if one kind of equipment is worn, the use of certain equipment may be unnecessary or impossible. For example, the use of a full face respirator may preclude the need to use a face shield in some applications. Conversely, the use of prescription eye-glasses would preclude the use of a full-face respirator, since the temple bars would interfere with the sealing surface of the respirator. Finally, utilization of encapsulating suits, by definition, would require an alternative source of respirable air. In the selection of protective clothing, one must consider the hazards inherent in the work to be done. As an example, anyone who plans to work near an open flame or torch should wear flame-retardent garments.

5.4.6 Recordkeeping and Administration

The incorrect use of safety equipment may place workers at a higher risk of injury or illness. Those who assume themselves to be protected from a particular hazard when in fact they are not may take chances or fail to adopt a sufficiently cautious attitude (Bretherick 1987, 209). The result might be an injury that could have been avoided. For this reason, standard operating procedures should clearly describe the proper use of personal protective equipment. In addition, the laboratory should train all laboratory operators who use PPE in the proper use, limitations, maintenance and procedures to follow in the event of a failure.

Furthermore, a laboratory must maintain complete records of employee training. A laboratory can use well-kept records to schedule annual refresher training, limit access to regulated areas and regulate issuance of protective clothing for a particular task.

5.4.7 Recommendations for Protecting Clothing

The protective equipment requirements for any laboratory must be tailored to the operations and hazards found in the lab. The following information is meant to provide a few examples of protective equipment programs suitable for specific types of facilities.

Ancillary operations in toxicological laboratories (necropsy, tissue trimming, and histological operations) facilitate the need for laboratory operators at a minimum to wear a single pair of disposable gloves, a laboratory coat and safety glasses (Anderson 1986, 121).

In working with carcinogens, mutagens or teratogens, a worker should wear a disposable laboratory suit, safety glasses or goggles, gloves, disposable boots or shoe covers, sneakers or rubber boots, and a disposable head covering. The handling of toxic materials necessitates the need for a disposable full-body suit over work clothing, as well as safety glasses, gloves and shoe covers. Laboratory operators should not wear disposable over clothing out of the laboratory or repository where neat chemicals are handled (Anderson 1986, 125). They should remove work clothing upon exit form the laboratory. In laboratory operations that do not involve the handling of well packaged hazardous chemicals (chemical analysis, histology, tissue trimming, necropsy), all laboratory operators should wear a single pair of disposable gloves, a laboratory coat and safety glasses.

5.5 Respiratory Protection

5.5.1 Introduction

Typically, laboratory operators do not require respiratory equipment. However, in the event that respiratory protection is necessary - OSHA guidelines should be followed. The OSHA standard for respiratory protection (29 CFR 1910.134) is very specific in what an employer (university) must do to protect all affected persons.

- Employer must provide laboratory operators with a medical-physical and lung function test;
- Train in respirator use;
- "Fit test" for proper performance;
- Supply the laboratory operator with the respirator; and
- Conduct periodic inspections of the equipment.

A respiratory protection program must be established when respiratory protection is needed. OSHA defines the necessity of respiratory equipment as [§ 1910.134 (2)]:

> Respirators shall be provided by the employer when such equipment is necessary to protect the health of the employee. The employer shall provide the which are applicable and suitable for the purpose intended. The employer shall be responsible for the establishment and maintenance of a respiratory protective program which shall include the requirements outlined in paragraph (b) of this section.

The respiratory protection program should include the minimum requirements listed below; although the specific order of importance may vary for each application. For a more comprehensive overview of each aspect of the program refer to § 1910.134.

1. administration;
2. knowledge of respiratory hazards;
3. assessment of respiratory hazards;
4. control of respiratory hazards;
5. selection of proper respiratory equipment;

NAME AND ADDRESS OF COMPANY
SEEKING RECOMMENDATION ______________________

____

____

NAME OF INDIVIDUAL ______________________
HIS PHONE NUMBER ______________________

1. Material—
   a. Chemical Name ______________________
   b. Trade Name ______________________
   c. Formula ______________________
   d. TLV or TWA   OSHA 1910.1000 ________ Current ACGIH ______
2. Form in which it will be used—
   a. Liquid? ________ b. Solid? ________ c. Gaseous? ________
   d. If gaseous, is it an organic vapor? ________ or acid gas? ________
   other? ______________________
3. Maximum expected concentration—
   a. ______________ parts per million, or
   b. ______________ milligrams per cubic meter
4. Will material be heated? ______________
   a. If so, to what temperature? ____________ °F.
5. What is the odor threshold of the material? ______________
6. At what concentration is the material considered to be immediately dangerous to life or health? ______________
7. Can the substance be absorbed through the skin? ______________
8. Irritant to eyes? ________ respiratory tract? ________ skin? ________
9. At what concentration is it an irritant? ______________
10. If the substance is known to be flammable, what are the lower and upper flammable limits, in per cent by volume? ______________
11. What is the vapor pressure of the material? ______________
12. Will material be mixed with other chemicals? ________ If so, give details
    ____
    ____
    ____
13. Any possibility of oxygen deficiency? ______________
14. Can good ventilation of the area be maintained? ______________
15. Will exposure be continuous? ________ or intermittent? ________
16. Will the respiratory device be used for routine exposures, or will it be used as an escape device? ______________

Figure 5.2 Questionnaire for gas mask and respirator recommendations (after National Safety Council, 1988)

6. training;
7. inspection, maintenance and repair of equipment; and
8. medical surveillance.

The above stated minimal requirements of a respiratory protection program must first start with an assessment of the inhalation hazards present in the laboratory. The initial step involves gathering the necessary toxicological, safety and research data on the substance or substances in the atmosphere. A sample questionnaire (as shown in Figure 5.2) can be used to assist in gathering pertinent information about the air contaminant and the exposure conditions.

The OSHA methods of compliance require the use of engineering or work practice controls to reduce exposures to the PEL (or below). However, if such controls cannot get exposure down to the permissible limit, they still must be used to reduce the exposure to the lowest possible level. At this point, the controls can be supplemented by respirators. The OSHA regulation states that respirators are the least satisfactory means of exposure control, because they only provide good protection if they are properly selected, properly fitted, worn by employees and replaced when their service life is over. Additionally, some employees may not be able to wear a respirator.

Despite the several listed difficulties, respirators are the only form of protection available:

- during the interval necessary to install or implement feasible engineering and work practice controls;
- in work operations, such as maintenance and repair activities and other activities for which engineering and work practice controls are not feasible;
- in work situations where feasible engineering and work practice controls are not yet sufficient to reduce exposure to or below the PEL; and
- in emergencies.

OSHA § 1910.1000 lists respiratory protection equipment for various concentrations of a substance. This is called the Respiratory Selection Guide .Additionally, the ANSI Standard Z88.2-1980 is a source of protection factors for the various types of respirators. Protection factors are used in the selection process to determine the maximum use concentration for the respirator. The maximum use concentration is determined by multiplying the TLV by the protection factor. The recommended protection factors should only be used a respirator program meeting the requirement of 29 CFR 134 and if satisfactory fit-testing has been performed. To provide additional protection, an employer must always select a respirator prescribed for concentrations higher than those found in the laboratory. The employer may not use respirators that are not listed. All respirators must be approved by NIOSH-Mine Safety and Health Administration (MSHA) or carry a Bureau of Mines approval tag which is still valid under a grandfather clause.

5.5.2 Medical Surveillance [*CHP*]

It is impossible to asses and identify potentially adverse health effects of exposures occurring away from the workplace. Standard exposure monitoring cannot account for the effects of habits, such as smoking or drinking, nor of metabolic factors, such as variations in breathing rate, lung volume or individual sensitivities. Medical surveillance and biological monitoring can help make the laboratory health and safety program more comprehensive.

Biological monitoring involves monitoring chemicals, or metabolites of those chemicals, that have passed from the working environment into the biological or internal environment of the laboratory operator. Medical surveillance involves monitoring the health status of laboratory operators, with particular emphasis on the adverse health effects that may be caused by exposure to chemicals in the workplace.

Table 5.3 OSHA Medical Surveillance Requirements for Selected Chemicals (after Pepitone, 1989)

Chemical	Requirements
Asbestos	Pulmonary function tests, chest X-rays
Carcinogens (13)	Complete medical history (see 29 CFR 1910, 1003–1910, 1016), including genetic and environmental factors, review for immunologic status, medical treatments, pregnancy smoking history
Vinyl chloride	Complete physical exam, liver studies
Inorganic arsenic	Complete medical history and exam, chest X-ray, sputum cytology
Inorganic lead	Complete medical history and exam, detailed blood studies, including blood lead and zinc protoporphyrin levels
Coke oven emissions	Complete history, chest X-ray, pulmonary function tests, sputum cytology, urine cytology
Cotton dust	Complete medical history, standardized respiratory questionnaire, pulmonary function tests
1,2-Dibromo-3-chloropane	Complete medical and reproductive history, examination of genitourinary tract, serum specimen for radioimmunoassay
Acrylonitrile	Complete medical history and exam, detailed exam of peripheral and central nervous system, gastro-intestinal system, skin, and thyroid; chest x-ray; fecal occult blood screening for all workers over 40 years.

Biological monitoring can be defined as the "analysis of exhaled air, analysis of some biological fluid, such as urine, blood, teats or perspiration; or analysis of some body component, such as hair or nails, to evaluate past exposure to a chemical." Medical surveillance also involves the analysis of bodily fluids or other components, but its fundamental purpose is to evaluate the pathological effects of past exposure. The objective is to reduce the level mortality attributed to the development of the subject disease in the population being monitored. The focus of medical monitoring is on establishing the probability of a disease being present, rather than on confirming the diagnosis of the disease. Therefore, the tests that are conducted in a medical surveillance program tend to be simpler, less expensive, less invasive and more comfortable than the diagnostic test procedures.

The regulations promulgated by OSHA consist of chemical-specific medical surveillance and biological monitoring (examples which are given in Table 5.3).

Additionally, OSHA has issued specific medical surveillance requirements for workers who wear respirators (refer to § 1910.134) and within chemical specific regulations (such as § 1910.1001, on asbestos). These regulations require a periodic review of the medical status of respirator users to assure that they are physically able to perform their jobs while wearing the equipment. OSHA has also issued requirements for record keeping (29 CFR 1910.20, record keeping) specifically distinguishing between exposure records and medical records. These distinctions are very important for preserving the confidentiality of medical records.

5.5.3 Program Implementation

Before implementing a program, several issues must be addressed. The organization and administration of the plan must be accounted for as well as legal and ethical issues and the selection of analytical techniques.

It must first be decided whether or not a program is actually necessary. For example, if there are no exposures, or if the environmental monitoring is providing sufficient data for evaluating exposure, biological monitoring may not be necessary. However, there are many uses for biological monitoring data. For example, periodic biological monitoring may identify unsuspected exposures from intermittent sources or exposure routes (adsorption or ingestion) which traditional air monitoring techniques cannot detect. Since biological monitoring is a more direct measure of the dose received than is environmental monitoring, biological monitoring can confirm and document levels of exposure estimated from area or personal sampling. Medical personnel can use biological monitoring and medical service data to confirm exposure and guide the choice of therapeutics. Such data may also be used to identify unusual sensitivities or metabolic abnormalities.

If a laboratory decides that monitoring or surveillance may be necessary, it must decide who to include in the program, and it must establish the frequency of surveillance. Due to cost constraints, a laboratory may choose to monitor or survey only the laboratory operators whose exposure exceeds certain thresholds (e.g., 50% of the TLV).

A laboratory must next decide what is to be measured. It must be determined if the chemical itself should be monitored, some metabolite or a pathological event. Once the laboratory decides what substance it wants to monitor, it must decide the kind of sample to take (e.g., blood, urine, breath hair, nails) and specify the kind of analysis it wants (e.g., colorimetric, chromatographic, spectrophotometric). The sampling process of collecting blood requires special skill and procedures, both for sampling and processing, and may meet resistance. Other types of data, such as from the analysis of urine or breath, are relatively easy to collect because they require no invasive techniques. However, since the analysis is based on excretory samples, they are less accurate as a quantitative estimate of internal exposures.

The choice of analytical techniques varies from simple colorimetric dipstick tests to tests that require sophisticated equipment. Selection of a method depends on (1) the methods the laboratory has evaluated and considers to be acceptable, and (2) the availability of resources for in-house or commercial analysis (Pepitone 1989, 49).

After the analysis has been performed, the results must be interpreted. The laboratory must determine whether an exposure to the substance in question has occurred and, if so, whether the level of exposure falls within acceptable bounds. However, the precision of biological monitoring and medical surveillance is frequently no better than $\pm$ 20%. Also, the interpretation of results can be difficult because individuals vary widely in their metabolic functions, dietary habits, work and other exposures. Experienced occupational health professionals should be used to help design the program and to interpret the results. These results should be communicated to all laboratory operators and should be treated as confidential information.

5.6 Standard Operating Procedures for Chemical Procurement, Distribution, Storage and Disposal [*CHP*]

A very important aspect of a laboratory safety and health program is standard operating procedures for the procurement, distribution, storage and disposal of all chemicals. The achievement of safe handling, use and disposal of hazardous substances begins with the people who requisition such substances and those who approve their purchase orders. These people should be aware of the potential hazards of the substances being ordered, know whether or not adequate facilities and trained personnel are available to handle such substances and should ensure that a safe disposal route exists.

5.6.1 Procurement of Chemicals

Before a new substance that is known or suspected to be hazardous is received, information concerning its proper handling methods, including proper disposal procedures, should be given to all those who will be involved with it. If the distribution system involves receiving room or storeroom personnel, they should be advised that the substance has been ordered. It is the responsibility of the laboratory supervisor to ensure that the facilities are adequate and that those who will handle any material have received proper training and education to do so safely.

The U.S. Department of Transportation (DOT) requires that shippers furnish and attach department-prescribed labels on all shipments of hazardous substances. These labels indicate the nature of the hazard of the substance shipped and thus provide some indication to the receiving room, storeroom and stockroom personnel of the type of hazard received. However, this label should not be relied on after the container has been opened (Verschueren 1986, 29).

It is preferred that all substances are received at a central location for distribution to the storerooms, stockrooms and laboratories. Central receiving is also helpful in monitoring substances that may eventually enter the waste disposal system. An inventory of substances kept in the storerooms and stockrooms can serve to alert those responsible for disposal as to what they may expect regarding the quantity and nature of substances they may be required to handle.

No container of a chemical or cylinder of a compressed gas should be accepted that does not have an identifying label. For chemicals, it is desirable that this label correspond to ANSI Z129 which requires at a minimum, the following components:

- identification of contents of the container;
- signal word and summary descriptions of any hazard(s);
- precautionary information-what to do to minimize hazard or prevent an accident from occurring;
- first aid in case of exposure;
- spill and cleanup procedures; and
- if appropriate, special instructions for physicians.

Receiving room, storeroom and stockroom personnel should be knowledgeable about or trained in the handling of hazardous substances. Such training should include the physical handling of containers of chemicals so that they are not dropped, bumped, or subject to crushing by being piled one upon another. Information should be provided about environmental and hazard-initiating exposures that must be avoided. Some of the more common items with which receiving room, storeroom and stockroom personnel need to be familiar include the following (Gatson 1987, 187):

- the use of proper material handling equipment, protective apparel and safety equipment;
- emergency procedures, including the cleanup of spills and the disposal of broken containers;
- the dangers of containing chemicals by skin absorption, inhalation or ingestion;
- the meanings of the various DOT labels on shipping packages;
- the proper methods of material handling and storage, especially the incompatibility of some common substances, the dangers associated with alphabetic storage, and the sensitivity of some substances to heat, moisture, light and other storage hazards;
- the special requirements of heat-sensitive materials, including those shipped, refrigerated or packed in dry ice;
- the problems associated with compressed gasses, including unique situations, such as the construction of an acetylene cylinder;
- the hazards associated with flammable liquids (especially the danger of their vapors catching fire a distance from the container) and explosives and of toxic gases and vapors and oxygen displacement.
- substances that react with water, giving rise to hazardous conditions (e.g., alkali, metals, burning magnesium, metal hydrides, acid chlorides, posphides and carbides);
- the federal and state regulations governing controlled substances such as radioactive materials, drugs, ethyl alcohol, explosives and needles and syringes;

- chemicals that have offensive smells; and
- packages that exhibit evidence that the inside container has broken and leaked its contents.

5.6.2 Procedures for Storing Chemicals in Storerooms and Stockrooms

There is a wide range of possibilities for storing chemical substances. The arrangements made will depend on the size of the organization, the quantities handled and the nature of the problem. Lack of sufficient storage space can create hazards due to overcrowding, storage of incompatible chemicals together and poor housekeeping. Adequate, properly designed and ventilated storage facilities should be provided to ensure the safety of all laboratory operators and the protection of the university property.

Many laboratories often find it necessary to maintain a reserve of supplies in excess of the amounts that can be kept safely in the laboratory. If the quantities are large or the volumes of the individual containers are such that repackaging is necessary, then a safe place is needed to store these containers and to perform these functions. Depending on the needs, this could be a stockroom or storeroom for the laboratory.

Stored chemicals should be examined at periodic intervals (at least annually). At this time, those that: have been kept beyond their appropriate shelf life or have deteriorated, have questionable labels, are leaking, have corroded caps or have developed any other problem should be disposed of in a safe manner. Shelved chemicals can be prevented from falling off their shelf by placing retaining stock cords or similar restraining devices across the open face of the shelf or by raising the forward face of the shelf about one-quarter inch (Gatson 1987, 207).

5.6.3 Stockroom Design

Stockrooms should not be used as preparation areas because of the possibility that an accident will occur and thereby unnecessarily contaminate a large quantity of materials. Preparation and repackaging should be performed in a separate area.

Stockrooms should be conveniently located and open during normal working hours so that all laboratory operators do not have to store excessive quantities of chemicals in their laboratories. Procedures must be developed for the operation of any stockroom that places the responsibility for its safety and inventory control in the hands of one person. Stockrooms should be well ventilated. If storage of opened containers is permitted, extra local exhaust ventilation and the use of outside storage containers or spill trays are necessary. The following storage guidelines should be followed when applicable (Manufacturing Chemists Association 1988, 127)

5.6.3-1 Flammable Liquids Flammable liquids should be contained in the following manner:

- centralized storage an dispensing room (separate from the main building)- control measure for associated fire hazard;
- if necessary locate the storage/dispensing room in the main building in a cutoff area (separated from other areas by fire rated construction) on the at-grade level having at least one exterior wall;
- never locate on a roof, below grade level, upper floor or in the center of the building;
- the walls, ceilings and floors should be constructed of materials having at least a 2-hour fire resistance and there should be self-closing Class B fire doors;
- adequate mechanical ventilation controlled by a switch outside the door and explosion proof lighting, switches; and
- burning tobacco and lighted matches should be forbidden.

5.6.3-2 Drum Storage The storage of drums, regardless of contents, is very important. The described rules should be applied to:

- 55 gallon metal drums are permitted by OSHA to be stored in the laboratories of universities and colleges.
- It is not safe to dispense from sealed drums exactly as they are received. The bung should be removed and replaced by an approved pressure and vacuum relief vent to protect against internal pressure buildup in the event of fire or if the drum might be exposed to direct sunlight.
- Drums should be stored on metal racks placed such that the end bung openings are toward an aisle and the side bung openings are on top.
- Drums as well as racks should be grounded with a minimum length of American gage 10 wire.
- Dispensing from drums should be performed with an approved hand operated rotary transfer pump. Such pumps have metering options and permit immediate cutoff control to prevent overflow and spillage.

5.6.3-3 Toxic Substances Toxic substances should be stored in the following manner:

- Segregate from other substances and store in well-defined area that is cool, well ventilated and away from light, heat, acids, oxidizing agents and moisture.
- Storerooms should be equipped with exhaust hoods or equivalent local ventilation devices in the event of an emergency or spill.
- Opened containers should be closed with tape or other sealant before being returned to the storeroom.

5.6.3-4 Water Sensitive Chemicals Chemicals of this type present a special hazard and should be handled accordingly.

- Construct storage areas which prevent accidental contact with water (eliminate all sources of water)
- Do not use automatic sprinkler systems.
- Storage facilities should be of fire-resistant construction.
- Other combustible materials should not be stored in the same area.

5.6.3-5 Compressed Gases Storerooms must be very careful in the storage of compressed gases. The following suggestions should be strongly considered:

- Store in well-ventilated, dry areas.
- If possible, storage rooms should be of fire-resistant construction and above ground.
- Cylinders may be stored outdoors, but some protection must be provided to prevent corrosion of the cylinder bottom; air circulation must not be restricted.
- Do not store near sources of ignition or corrosive chemicals or vapors.
- Do not store where heavy objects may strike or fall on them (near elevators, service corridors and unprotected platform edges).
- The cylinder storage area should be posted with the names of the gases stored.
- If gases of different type are stored at the same location, the cylinders should be grouped by type of gas (e.g., flammable, toxic or corrosive).
- Full and empty cylinders should be stored in separate portion of the storage area - the older stock should be used first with minimal handling of other cylinders.
- Do not place cylinders in an area where they can become overheated (e.g., near radiators, steam pipes, or boilers).
- Store cylinders in an upright position where they are unlikely to be knocked over.

5.7 Distribution of Chemicals from Stockrooms to Laboratories

The method of transport of chemicals between stockrooms and laboratories must reflect the potential danger posed by the specific substance. The guidelines given below should be adhered to minimize all risks (Gatson 1987, 149).

5.7.1 Chemicals

- Hand carried: place in an outside container to protect against breakage and spillage.
- Wheeled cart: cart should be stable under the load and have wheels large enough to negotiate uneven substances without tipping or stopping suddenly.
- If possible, transport on freight elevators only (as opposed to passenger elevators).

5.7.2 Cylinders of Compressed Gases

- Do not subject to rough handling or abuse.
- To protect the valve during transportation, the cover cap should be left screwed on hand tight until the cylinder is in place and ready for actual use.
- Never roll or drag cylinders.
- The preferred transport is by a suitable hand truck with the cylinder strapped in place.

5.7.3 Procedures for Storing Chemicals in Laboratories

Local regulations and insurance requirements sometimes dictate the quantities of certain chemicals (e.g., toxic, flammable or highly reactive) a laboratory is permitted to store. A laboratory must first determine if such compliance is mandatory and regulate storage accordingly.

5.7.3-1 General Considerations To minimize hazards, the outlined recommendations should be followed (Manufacturing Chemists Association 1988, 253):

- Every chemical in the laboratory should have a definite storage place and should be returned to that location after each use.
- The storage of chemicals on bench tops is undesirable. In such locations (bench top) chemicals are unprotected from potential exposure to fire and are also more readily knocked over.
- Storage in hoods is inadvisable because this practice interferes with air flow in the hood, clutters up the working space and increases the amount of materials that could become involved in a hood fire.
- Storage trays or secondary containers should be used to minimize the distribution of material should a container break or leak.
- Care should be taken in the laboratory to avoid exposure of chemicals to heat or direct sunlight and to observe precautions regarding the proximity of incompatible substances.
- Laboratory refrigerators are to be used for the storage of chemicals only. All containers placed in the refrigerator must be properly labeled (identification of contents and owner, date of acquisition or preparation and the nature of any potential hazard). Flammable liquids should not be stored in laboratory refrigerators unless the unit is approved and explosion-proof.
- Chemicals stored in the laboratory should be inventoried periodically and unneeded items should be returned to the stockroom or storeroom.
- Chemicals that have illegible labels or appear to have deteriorated should be disposed of.
- On termination, transfer, graduation or such, of any laboratory personnel, those personnel and the laboratory supervisor should arrange for the removal or safe storage of all hazardous materials those persons have on hand.

5.7.3-2 Flammable Liquids OSHA regulations for the laboratory storage of flammable and combustible liquids are not based on fire prevention and protection principles but rather address the types and sizes of containers allowable

- Whenever feasible, quantities of flammable liquids greater than one liter should be stored in metal containers. Portable approved safety cans are one of the safest methods. However, such cans must be properly labeled to identify their contents.
- Small quantities should be stored in ventilated storage cabinets made of 18-gage steel and must have riveted and spot-welded space between the inner and outer walls. Such cabinets are of double-wall construction and have a 1.5 inch air space between the inner and the outer walls. The door is two inches above the bottom of the cabinet and the cabinet should be liquid tight. If , for reasons of cost or space limitations, storage cabinets must be constructed of wood, they should be built according to NFPA Standard 30.
- Ensure that: aisles and exits are not blocked in the event of a fire, contact with strong oxidizing agents such as chromic acid, perangates, chlorates and peroxides is not possible, and source of ignition are excluded.

5.7.3-3 Toxic Substances It is important that toxic substances are considered:

- Store in ventilated storage areas in unbreakable chemically resistant secondary containers.
- Minimum working quantities should be present in the work area.
- Storage vessels should contain a label such as the following: CAUTION: HIGH CHRONIC TOXICITY or CANCER-SUSPECT AGENT.
- Storage areas for substances that have high acute or chronic toxicity should exhibit a warning sign of the hazard, have limited access and be adequately ventilated.
- An inventory should be maintained.

- Chronically toxic materials designated as regulated carcinogens are required by federal and state regulations to maintain an inventory.
- Adequate ventilation is very important for hazardous materials that have a high vapor pressure (such as bromine, mercury and mercaptans).

5.7.3-4 Compressed Gases Similar to toxic substances, compressed gases should also be handled very carefully. The guidelines below should be followed; for more specific information refer to OSHA

§ 1910.106 and NFPA No. 30.

- Cylinders of compressed gases should be securely strapped or chained to a wall or bench top to prevent being knocked over accidentally.
- Keep compressed gases capped when they are not in use.
- Keep away from heat or ignition.

5.8 Procedures for Disposing of Chemicals in Laboratories

The disposal of chemicals from instructional laboratories is a special problem. Students in such laboratories are usually inexperienced and the quantities of wastes may require special precautions. However, the proper disposal of substances used in a laboratory is an important responsibility of all laboratory users. Arrangements for disposal may vary from laboratory to laboratory, depending on the facilities and the types of substances used. However, the basic principle is that substances must be disposed of in ways that avoid harm to people and the environment. Wastes should be transferred in a form that is safe and acceptable to the people involved in disposal operations. It is also important to consider the future fate of the waste substance.

5.8.1 General Considerations

- If practical, very hazardous substance should be converted to less hazardous substances, rather than being placed directly in containers.
- All persons using chemicals in the laboratory should be generally aware of the toxic properties of the substance(s) used, including consideration of the toxic properties of possible reaction products. If the toxic properties of the possible products are unknown, the products should be treated with respect and the disposal method should take account of the uncertain hazards.
- Educate students about how to handle chemicals and dispose of them safely as an integral part of their laboratory training.

5.8.2 Disposal to the Sewer System

Sewer systems operate in various ways. Some systems may be harmed or present hazards for people and the environment when some chemicals are added directly to them. Local regulations usually define exactly what can be added to the sewer system. The laboratory supervisor should be aware of these regulations and inform laboratory operators so they can conform to these regulations. All sewer systems that discharge into waterways are limited by federal regulations in the disposal of certain toxic chemicals. The following rules regarding disposal into a sewer system should be followed (Bretherick 1987, 137):

- Only water-soluble substances should be disposed of in the laboratory sink. Solutions of flammable solvents must be sufficiently dilute so they will not pose as a fire hazard.
- Strong acids and bases should be diluted to the pH3-11 range before they are poured in the sewer system. Acids and alkalis should not be poured into the sewer drain at a rate exceeding the equivalent of 50 ml of concentrated substance per minute.
- Highly toxic, malodorous or lachrymatory chemicals should not be disposed of down the drain. Laboratory drains are generally interconnected; a substance that goes down one sink may well come up as a vapor in another. Additionally, there is a hazard of

chemicals from two sources contacting one another with the potential for disastrous consequences.

- Small amounts of some heavy compounds may be disposed of in the sink, but large are a hazard for the sewer system and water supply.

5.8.3 Disposal of Solid Chemical Wastes

- Procedures should be set for the collection and distribution of such wastes. These procedures should include a clear understanding as to who is in charge and what the responsibilities of the laboratory workers are with respect to the identification of hazards that may be encountered.
- The people responsible for disposal must know what to do in case of a spill.
- The solid chemical wastes should be placed in a container provided for that purpose.
- All wastes must be adequately labeled.
- All persons involved with such waste must be aware of the hazards and the importance of segregating incompatible materials.

5.8.4 Disposal of Liquid Chemical Wastes

The requirements are the same as outlined above for solid chemical wastes, but also include the following guidelines:

- Waste solvents that are free of solids and corrosive or reactive substances may be collected in a common bottle or can. Segregation into two or three types of waste is often useful (e.g., chlorinated solvents, hydrocarbons) as is the use of completely separate bottles for wastes that may be special difficulties.
- When large quantities of a solvent are involved, consideration should be given to recycling rather than disposal.

5.8.5 Disposal of Especially Hazardous Wastes

This class of chemical wastes includes very toxic substances, strong carcinogens, mutagens, nerve gases, explosives and substances in tanks and other sealed containers.

- Wherever possible, undertake a chemical reaction which produces a less hazardous substance.
- For chemicals regulated as carcinogens, EPA disposal rules must be followed (Resource Conservation and Recovery Act (RCRA).
- Personnel working with such substances should have contingency plans, equipment and materials available for coping with potential accidents.

5.8.6 Spills

Preplanning procedures should be developed to prepare for the accidental release of chemicals. Such procedures will minimize the exposure of personnel and property. The procedures may range from having a sponge mop and bucket available to having an emergency spill-response team with protective apparel, safety equipment and materials on call to contain, confine, dissipate and clean up the spill. The preplanning should include consideration in the following areas (Verschueren 1986, 154):

- The potential location of the release (e.g., outdoors vs. indoors, in a laboratory, corridor, or storage area, on a table, hood, or on the floor).
- The quantities of the material that might be released and whether the substance is a piped material or a compressed gas.
- The chemical and physical properties of the material (e.g., its physical state, vapor pressure, and air or water reactivity).
- Hazardous properties of the material (its toxicity, corrosivity and flammability).
- The types of personal protective equipment that might be needed.

There should be supplies and equipment on hand to deal with the spill, consistent with the hazards and spilled quantities of the substance. The cleanup supplies should include neutralizing agents (such as sodium carbonate and sodium bisulfate) and adsorbents (such as vermiculite and sand). Paper towels and sponges may also be used as absorbent-type cleanup aids, although this should be done cautiously. For example, paper towels used to clean up a spilled oxidizer may later ignite. Commercial spill kits are available that have instructions, adsorbents, reactants and protective equipment. These kits may be located strategically around work areas, similar to fire extinguishers.

If a spill does occur, the following general procedures may be used, but should be tailored to individual needs (Verschueren 1986, 193):

- Attend to any persons who may have been contaminated.
- Notify persons in the immediate area about the spill.
- Evacuate all non essential laboratory operators from the spill area.
- If the spilled material is flammable, turn off ignition and heat sources.
- Avoid breathing vapors of the spilled material; if necessary, use a respirator.
- Leave on or establish exhaust ventilation, if it is safe to do so.
- Secure supplies to effect cleanup.
- During cleanup, wear appropriate apparel.
- Notify the safety coordinator if a regulated substance is involved.

5.8.6-1 Handling of Spilled Liquids If a liquid spills, the procedures below should be followed:

- Confine or contain the spill to a small area - do not let it spread.
- For small quantities of inorganic acids or bases, use a neutralizing agent or an absorbent mixture (e.g., soda ash or diatomaceous earth). For small quantities of other materials, absorb the spill with a non reactive material (such as vermiculite, dry sand or towels).
- For larger amounts of inorganic acids and bases, flush with large amounts of water (providing the water will not cause additional damage). Flooding is not recommended

in storerooms where splattering may cause additional hazards in areas where water-reactive chemicals may be present.

- Mop up the spill, wringing out the mop in a sink or a pail equipped with rollers.
- Carefully pick up and clean any cartons or bottles that have been splashed or immersed.
- Vacuum the area with a vacuum cleaner approved for the material involved. However, remember that the exhaust of a vacuum cleaner can create aerosols and, thus, should be vented to a hood or through a filter.
- If the spilled material is extremely volatile, let it evaporate and be exhausted by the mechanical ventilation system (provided that the hood and associated mechanical system is spark proof).
- Dispose of residues according to safe disposal procedures.

5.9 Caution Signs

The hazards in all laboratories and rooms and the person responsible for the area should be posted on a sign on the main hall door. If additional information is requested, the room supervisor listed may be questioned. The stickers which appear on the door can indicate the potentially hazardous materials and/or equipment located in the room. The warning does not mean entry into this room is hazardous, but that there are a number of materials or equipment in the room which, if used improperly, may cause harm. Refer to Appendix D for a list and description of the various warning signs which are commonly used.

CHAPTER 6

LABORATORY FACILITY

6.1 Introduction

Perhaps the single most important consideration of a laboratory is the facility itself. It is imperative that a laboratory accounts for the actual design (ventilation, human factors considerations and emergency shower facilities), emergency power, fire protection and overall classroom safety. If these fundamental aspects of a laboratory facility are not accounted for, many dangers can exist, regardless of other precautionary measures. The dangers resulting from improper laboratory design considerations have the potential to be more hazardous simply because they usually are not expected or apparent.

6.2 Laboratory Design [*CHP*]

6.2.1 Introduction

A design methodology is presented in Figure 6.1. Designers can modify the scheme for laboratories of different types, based on the operations and personnel who will be utilizing this space. Therefore, the first step in the design process is to perform a needs assessment to gain an understanding of both the user and project activities. Once this has been accomplished, the design team can define the functional requirements of the laboratory, which in turn permits the application of the functional requirements, the worker protection plan and risk assessment to the design criteria.

In designing a general laboratory, the risk assessment should be a qualitative process review to identify any hazardous operations that should not be performed in a general-use laboratory. Once the design criteria have been agreed on, the designers should execute several alternative designs before arriving at the final choice. Worker protection and risk assessments must be defined by health and safety professionals who are familiar with the evaluation and control practices for handling chemical, biological and radiological agents, as well as fire protection.

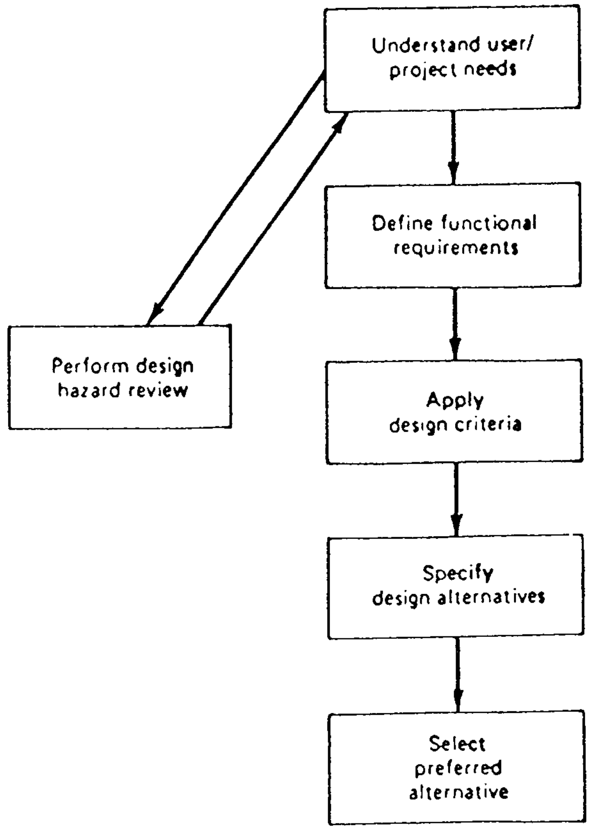


Figure 6.1 Laboratory Design Process
(after DiBerardinis, 1987)

6.2.2 Design Hazard Review

After the operations and chemicals have been identified and understood, designers can address the assessment of risk to personnel and worker protection. The type of review is known as a design hazard review (DHR). For general laboratories, a DHR should be performed for the laboratory as a whole and for specific projects if they add additional hazards to the laboratory and cannot be handled by existing engineering and personal protective equipment measures. After the initial DHR, laboratory management should initiate a subsequent DHR only if, in their judgment, the hazards associated with any new

Table 6.1 Design Considerations
(after Gibbons and Savies 1988)

- 1.0 Laboratory layout
  - 1.1 Personnel entry and egress
  - 1.2 Laboratory furniture locations
    - Benches
    - Aisles
    - Desks
    - Work surfaces
  - 1.3 Location of fume hoods
  - 1.4 Location of equipment
  - 1.5 Handicapped access
- 2.0 Laboratory heating, ventilation, and air conditioning (HVAC)
  - 2.1 Temperature control
  - 2.2 Laboratory pressure relationship
  - 2.3 Laboratory ventilation systems
    - Comfort ventilation supply air for laboratory modules
    - Recirculation of laboratory room air
  - 2.4 Exhaust ventilation for laboratory modules
    - Exhaust of general room ventilation air from laboratories
    - Air rates for laboratory hoods and other local exhaust air facilities
    - Chemical fume hoods
  - 2.5 Exhaust fans and blowers
    - Exhaust air cleaning for laboratory effluent air
    - Exhaust ducts and plenums
- 3.0 Loss prevention and occupational safety and health protection
  - 3.1 Emergency considerations
    - Emergency fuel gas shutoff
    - Groud fault circuit interuppters
    - Master electrical disconnect switch
    - Emergency blowers
    - Emergency eyewash
    - Chemical spill control
    - Emergency cabinet
  - 3.2 Construction methods and materials
  - 3.3 Control systems
  - 3.4 Alarm systems for experimental equipment
  - 3.5 Hazardous chemical disposal
  - 3.6 Chemical storage and handling
  - 3.7 Compressed gas cylinder racks
  - 3.8 Safety for equipment

project(s) warrant it. The following information belongs in the DHR (Gibbons and Savies 1988, 467):

- description of the process;
- list of raw materials and products;
- size ant type of equipment; and
- statement of potential hazards.

Laboratory designers can construct a series of design criteria, based on the design review and user needs assessment. A comprehensive list of important elements of design for general laboratories can be developed from Guidelines for Laboratory Design. As presented in Table 6.1, the designer must address all of these considerations in the DHR and needs assessment.

Additionally, examples of other design criteria are given below (DiBerardinis 1987, 280):

- Worker Protection: The laboratory must minimize the risk of worker exposures. Therefore, ventilation systems must be adequate in number and operational characteristics, there must be suitable changing and storage area, eyewash and emergency showers must be available. The design must also consider the risk of re - entrainment of contaminated air by air handling equipment serving either the lab itself or other nearby space.
- Traffic Flow: The lab must be designed with consideration for the patterns of movement of people and material within the laboratory. Minimization of the transport of hazardous materials from its point of receipt to storage, and from storage to working area is preferred. The use of pass through to allow the delivery of a material and dispensing of prepared dilute samples can be desirable as it minimizes the need for laboratory entry. However, these pass - throughs can be potential points of inadvertent chemical emission if not properly designed.

- Maintainability: Methods are needed for assuring that critical mechanical systems are functional and for facilitating routine maintenance. For example, hood airflow alarms and filter pressure drop sensors are among the design features that should be considered.
- Decontamination: Within each working space, it will be important to provide sufficient hood space so that all work can be conducted within hoods, further confining potential contamination. All surface finish (floors, walls, ceiling) must be made of materials that are readily cleaned and that resist reaction or adsorption of chemicals. For this reason, a widely used finish in laboratories is epoxy.
- Fire Protection: The laboratory should be designed with an integral fire protection system. This requires consideration for the use of sprinklers (and specifications for system design), detectors, alarms and signaling mechanisms.
- Emergency Response: The laboratory should be designed to facilitate emergency response. Means of egress and entrance should be considered, as well as visual accessibility to response teams.
- Storage: Provisions must be made for chemical storage within the laboratory. The need of some materials for storage at sub ambient temperatures must be considered, as should the need for limited exposure to light. The storage area must be secure from exposure to fire and should provide protection against other types of foreseeable accidents (e.g., explosion in an adjacent area).
- Economic Feasibility: In designing a laboratory, it is possible to build redundancy upon redundancy and minimize risks at great expense. While risk control is of utmost importance, one must also consider the costs of alternative design features and consider cost effectiveness in design.
- Ergonomic Considerations: The principles of human factors engineering (ergonomics) must be applied to laboratory design. In a relatively small laboratory, the efficient use

of space is important. It is also important to provide a comfortable work environment that minimizes stress, thereby helping to reduce the likelihood of accidents.

6.2.3 Human Factors Considerations

The analysis of tasks for the purpose of human factors engineering evaluation addresses four characteristics of each task in question:

- range of motion and reach requirements;
- exertion and strength requirements;
- dexterity and fine motor control requirements; and
- frequency and duration.

The range and motion required to perform a task must be compatible with the physical and anthropometric dimensions of the worker. The reach distance from the normal working position, can be compared to established data for working populations. The design criteria are created to establish horizontal and/or vertical reach requirements so that 95% of the population from which workers are drawn can comfortably perform the task (Mond 1987, 12). If the task in question requires a reach, or range of motion, that is at or beyond the maximum for the working population, increased effort will be required to perform the task. This may lead to articles being dropped, increased fatigue or inappropriate task performance.

Many laboratory tasks require dexterity and fine motor control. Tenseness, eye strain, stiffness and other complaints often accompany close attention and relative immobility. Special consideration must be paid to the work station and other aspects of the work environment.

Another aspect of task analysis is consideration of the duration of the task and the frequency with which it must be performed. The harmful effects from repetitive activities that require significant physical effort, or close attention, can accumulate over time. Therefore, the worker should be given opportunities to pause and rest when necessary.

Table 6.2 Standards for Laboratory Furniture (after Gibbons and Savies 1988)

Laboratory Furniture	Standards
Fume Hoods	
Interior	Stainless steel
Width	2.44 m (8 ft)
Height	Vertical with "infinitely" adjustable sashes
Face Velocity	30 ± 6 m/min (100 ± 20 fpm)
Lab Bench	
Height	5.0 cm below worker's elbow (2 in.)
Recording area	30.48 cm wide × 30.48 cm deep (12 in. wide × 12 in. deep)
Chair (adjustable)	
Height (assuming table height = 63.5 cm (25 in.)	38.1–50.8 cm (15–20 in.)
(Assuming table height = 96.52 cm (38 in.)	71.12–83.82 cm (28–33 in.)
Fabric	Vinyl
Seat area	38.1 cm wide × 40.64 cm deep (15 in. wide × 16 in. deep)
Angle between seat pan and backrest (fore/aft adjustability)	105 degrees
Backrest height	17.78–25.4 cm (7–10 in.)
Backrest area	20.32–25.4 cm height × 35.56 cm width (8–10 in. height × 14 in. width)
	Convexly shaped (50.8 cm radius or 20 in. radius)

Table 6.3 Standards for Design of Storage Area (after Gibbons and Savies 1988)

Storage Areas	Standard
Drawers and cabinets	Flush to the furniture
	Design for predicted use and projected expansion
	Proper damping and padding for drawers holding glassware
Shelving for storage closets	
Below waist height	Shelf depth should not exceed 45.7 cm (18 in.)
Above shoulder height	Shelf depth should not exceed 30.48 cm (12 in.)
Between waist and shoulder	Shelf depth should not exceed 60.96 cm. (24 in.)
Barrels	Grounded and bonded

Since personal capabilities and limitations vary from one employee to the next, the frequency of the need for rest should be reviewed by the health and safety officer.

6.2.3-1 Furniture and Fixtures Another important, often overlooked consideration are the furniture and fixtures used in a laboratory. Laboratory fixtures should be designed so that occupants can use them with ease and comfort for the entire time they are in the lab. Table 6.2 presents criteria for the design of ergonomically correct laboratory furniture, while Table 6.3 lists criteria for drawers, shelves and other storage areas in laboratories.

6.2.3-2 Comfort Indices Comfort indices are another important consideration. The amount and nature of the light provided in a laboratory can significantly affect the ease with which work can be accomplished. The amount of glare, the provision of too much or too little light and the effects of fluorescent versus incandescent bulbs are all important considerations. Standards for the quantity and nature of light for laboratory environments are presented in Table 6.4. Additionally, criteria for temperature and noise are shown in Table 6.5. The noise level recommended for laboratories is 65dBA, which is 20 dBA lower than the action level of 85dBA prescribed by OSHA. This noise level will provide a quiet environment in which work can be performed. If noise levels exceed 85dBA, certain control measures, as described in the OSHA Noise Standard (29 CFR 1910.95), may be necessary.

The temperature of a laboratory may be of particular importance if persons working in the area are in poor physical condition and/or must use chemical protective clothing. Since protective garments tend to accumulate body heat, persons wearing protective clothing will become uncomfortable more quickly in warm environments. Additionally, the use of a respirator may further contribute, adding to heat retention and raising the anxiety level of the user. The use of personal protective clothing in warm and/or humid environments by persons in poor physical conditions or with low tolerance

Table 6.4 Standards for Laboratory Illumination
(after DiBerardinis 1987)

Noise	
Desirable levels	65 dBA
devices to help achieve goal	Intercoms
	Telephone near entrance
Temperature	70°F: demanding visual and motor tasks
	72°F: secondary tasks
	78°F: showering

Table 6.5 Guidelines for Noise and Temperature in Laboratory Facilitates
(after DiBerardinis 1987)

Environmental Parameter	Standard
LIGHTING	
Intensity	Soft white lighting is preferable
Main lab area	500 lux (50 fc)
Isolation room	500 lux (50 fc)
Benchtop work surface	100–1,000 fc
Work surface under hood	100–1,000 fc
Interior entryway	100 lux
Corridors of main lab	300 lux
Viewing corridors	100–200 lux
Personnel pass-through	200 lux
Changing area	500 lux
Shower stall	200 lux
Restroom/grooming center	200 lux
Luminaire Spacing	2.5 ft from the wall to the center of the luminance
Reflectance	
Ceilings	60–90%
Walls	50–85%
Windows	15–45%
Furniture	30–40%
Floors	15–35%

for heat, is a serious issue. All personnel assigned to wear respirators must be medically approved.

6.2.3-3 Tools and Instrumentation The operation of tools and instrumentation in a laboratory environment may require a higher degree of risk if extremely hazardous or toxic substances are being handled or if the use of gloves and personal protective equipment interferes with the ability of the operator. For this reason, careful consideration should be given to the interaction of the operator and the tool, and special accommodations made where advisable. This may include the redesign of buttons and switches for compatibility with gloves, or the implementation of other changes to enhance the reliability and simplicity of the operation.

Another aspect of operating laboratory instrumentation is the manner in which information is provided to the operator. Guidelines have been established for illumination and contrast of signs and gauges and are presented in Table 6.6. Additionally, the issue of video display terminal (VDT) safety has been given close scrutiny as well. A summary of human factors issues for laboratories in a simple checklist form is provided in Appendix E.

6.2.4 Safety Showers and Eyewash Stations

A laboratory must locate safety showers and eyewash stations throughout the facility. The equipment should be located close to where laboratory users may be using potentially hazardous materials. The equipment used and its placement must meet local, state and federal regulations.

Current standards of OSHA discuss eyewash stations and safety showers only in general terms. OSHA suggests that personal protective equipment in a laboratory include an easily accessible drench-type safety shower and an eyewash station within the work area. OSHA has also addressed basic recommendations for maintenance labeling and

Table 6.6 Standards for Visual Displays
(after Mond, 1987)

Display Type	Standard	
Warning Lights		
Color selection	Red: danger, warning, fire Yellow: caution Green: go ahead; systems OK Flashing light: extreme danger	
Signs		
Factors to consider	Shape Conspicuousness Width-to-height ratio of 1:6 Contrast between characters and background	
Color contrast yielding greater visual efficiency	*Characters*	*Background*
	Black	White
	Black	Yellow
	White	Black
	Dark blue	White
	White	Dark red and green
	Dark green and red	White
Dials and Gauges		
Format type	Rectangular	

training in the use of this equipment. Applicable sections of OSHA standards for eyewash stations and safety showers are summarized below.

29 CFR 1910.151(c)

Where the eyes or body of any person may be exposed to injurious corrosive materials, suitable facilities for quick drenching or flushing of the eyes and body shall be provided within the work area for immediate emergency use.

29 CFR 1910.94(d) (9)(vii)

Near each tank containing a liquid that may burn, irritate or otherwise be harmful to the skin if splashed upon the worker's body, there should be a supply of clean, cold water. The water pipe (carrying a pressure not to exceed 25LB) shall be provided with a quick opening valve and at least 48 in. of hose not smaller than three-fourths in., so that no time may be lost in washing off liquids from the skin or clothing. Alternatively, deluge showers and eye flushes shall be provided in cases where harmful chemicals may be splashed on parts of the body.

Additionally, the America National Standard Institute (ANSI) has published a more detailed voluntary industry standard, which covers physical features, location and maintenance for this equipment. This document - ANSI Z358.1-1981 presents design and performance requirements for six different types of emergency eyewash and shower equipment. Table 6.7 reviews ANSI Z 358.1-1981.

6.2.4-1 Types of Eyewash Stations and Safety Showers Eyewash stations and safety showers are available in several different types. ANSI has grouped the eyewash and shower appliances that may be used in a laboratory into the following categories:

- Emergency Shower: "A unit that enables the user to have water cascading over the entire body."
- Plumbed and self-contained eyewash: A plumed unit is "an eyewash unit permanently connected to a source of potable water." A self contained eyewash is one "that is nor permanently installed and must be refilled or replaced after use." Self contained eyewashes must have at least a 15-minute water supply.

Table 6.7 ANSI Z358.1-1981; Standards for Emergency Eyewash and Shower Equipment (after American National Standards Institute, 1981)

Type of Equipment	Physical Specifications	Laboratory Location	Maintenance	Training
Emergency showers	Water column between 82 and 96 in. with 20-in. minimum diameter column at 60 in. above surface; should deliver 30 gal/min (gpm); enclosures, if used, require minimum 34-in. unobstructed diameter	Accessible within 10 seconds and not more than 100 ft from hazard	Activated weekly to flush lines and verify operation	Required for all employees who might be exposed to a chemical splash
Plumbed and self-contained eyewashes	Flow rate of 0.4 gpm for 15 minutes required; water nozzles 33–45 in. above floor	Accessible within 10 seconds and not more than 100 ft from hazard	Plumbed units activated weekly to flush lines and verify operation; self-contained units treated in accordance with manufacturer's instructions	Required for all employees who might be exposed to a chemical splash
Personal eyewashes	Not addressed	Not specified, but recommended to be placed in immediate vicinity of potentially hazardous areas	Tested, refilled, disposed, and maintained in accordance with manufacturer's instructions; activated weekly to flush lines and verify operation	Required for all employees who might be exposed to a chemical splash

- Personal Eyewash: "A supplementary eyewash that supports plumbed units, self contained units, or both, by delivering immediate flushing for less than 15 minutes."
- Eye-face wash: "A device used to irrigate and flush both the face and the eyes.
- Hand-held drench hose: "A flexible hose connected to a water supply and used to irrigate and flush eyes, face and body areas.
- Combination Unit: "A unit combining a shower with an eyewash or eye/face wash, or with a drench hose, or with both, into one common assembly.

6.2.4-2 Location The effectiveness of any eyewash station or safety shower depends on its accessibility. The first 15 seconds after an injury occurs are critical, therefore a laboratory should place the emergency shower and/or eyewash station close to the hazardous site. ANSI recommends accessibility within 10 seconds and placement at a distance no greater than 100 feet. ANSI also suggests that the laboratory place eyewash fountains and safety showers near the laboratory entrance. Selection of a location should also be a function of the traffic patterns, the specific contaminants, the number of students performing hazardous operations, the specific hazards to be protected against and whether protective equipment is worn. Also, laboratory operators should have easy access to the eyewash station or safety shower, without intervening partitions or obstructions. The laboratory should pay particular attention of the proximity to electrical outlets and the length of any shower pull chains in a walkway. Finally, the laboratory should store a blanket close to either an eyewash or safety shower to prevent shock and provide privacy.

6.2.4-3 Water Supply To satisfy general requirements, laboratory operators should flush contaminants with "copious" amounts of water. An eyewash station or safety shower should, therefore, deliver a slow stream of water for at least 15 minutes (Russell 1986, 96). A slow or spent stream of water is preferable, since high pressure in a eyewash may drive particulate hazards into the eyes. ANSI Z358.1-1981 recommends a pressure of

30psi in an eyewash and provides other guidelines for ensuring water flows. Laboratory workers should be able to operate the eyewash with push-to-operate activation valves that will remain open until manually closed. Such valves free the hands and allow the injured person to hold back the eyelids for a thorough flushing.

A laboratory should provide only potable water in its safety stations, and the temperature of the water should be kept within a comfortable range (60-95^{O}F) to prevent shock and to encourage usage. Temperatures above 100^{O}F are not desirable because they increase circulation and may increase the absorption of the chemical. Water temperatures above 120^{O}F may cause first degree burns. A laboratory should see that any outdoor showers and eyewashes provide tempered water, which may require the addition of a heated holding tank

If self-contained eyewash units are used, a program of frequent water replacement must be adopted. Harmful microorganisms have been shown to grow in these units and the introduction of contaminated water into the eye can cause infection, and in severe cases, loss of sight. Additionally, a laboratory should activate its plumbed eyewashes and safety showers weekly to flush the lines and permit observation of proper pressurization levels. It should also conduct a documented inspection of water pressure on a monthly basis, testing its portable units and checking that the fill level is in accord with the manufacturer's instructions (ANSI Z358.1-1981, 78).

6.2.4-4 Use and Training Although it is important that a laboratory supply proper eyewash stations and safety showers, it is equally important that the laboratory train all laboratory operators in their proper use. The laboratory should document emergency procedures in writing and should properly label safety equipment. Also, it should be ensured that all laboratory users are familiar with the controls and operating devices, as well as procedures involved in assisting an injured person. Very often an injured person cannot flush his or her own eyes, and two people are needed; one to hold open the victim's eyes and the other to restrain the victim, who may be in pain. The laboratory should introduce the proper methods involved in such an emergency. Also, it should clearly label its safety showers and eyewash stations, similar to all safety equipment.

6.2.4-5 Manufacturers and Suppliers The 1992 Thomas Register lists the following manufacturers and suppliers of eyewash and safety shower equipment:

- Bradley Corporation, Menomonee Falls, Wisconsin
- Eastoo Industrial Safety Corporation, New York, New York
- Guardian Equipment, Chicago, Illinois
- Haws Drinking Faucet Company, Berkely, California
- Intest, Inc., Newport News, Virginia
- Ogontz Corporation, Willow Grove, Pennsylvania
- Safety Equipment Company, Tallahassee, Florida
- Safety Services, Inc., Kalamazoo, Michigan
- Sargent-Sowell, Inc., Grand Prairie, Texas
- Sipco Products, Inc., Peoria, Illinois
- Speakman Company, Wilmington, Delaware
- Water Saver Faucet Company, Chicago, Illinois
- Western Drinking Fountains, Emergency Equipment Division, Glen Riddle, Pennsylvania

6.2.5 Ventilation Flow

Laboratories that use chemicals vary from spacious well-designed facilities to those that consist of a single room that has been designated as a laboratory and has little or no provision for ventilation. The need for ventilation flow in these different types of laboratories will vary from the provision of simple comfort for the occupants to control of highly toxic volatile substances. Concentration will focus on ventilation flow for the control of toxic substances. However, the overall performance of laboratory workers will also benefit from ventilation flow systems that control the temperature, humidity and concentration of odoriferous materials in the laboratory. Typically, there is a tendency for laboratory workers to associate odor with toxicity. This tendency may result in over concern for a substance which emits an odor and a lack of concern for highly toxic substances that have little or no odor.

The steady increase in the cost of energy in recent years has resulted in a conflict between the desire to minimize the costs of heating or cooling and dehumidifying laboratory air and the need to provide laboratory workers with improved ventilation flow as a means of protection from toxic gases, vapors, aerosols and dusts. However, although the energy costs associated with tempering the input air for laboratories are often substantial, cost considerations should never take precedence over ensuring that laboratories have adequate ventilation systems to protect workers from hazardous concentrations of airborne toxic substances. Therefore, any changes in overall laboratory ventilation systems to conserve energy should be instituted only after thorough testing of their effects has demonstrated that laboratory workers will still have adequate protection. An inadequate ventilation system can be worse than none at all, because it is likely to give laboratory workers an unwanted sense of security that they are protected from airborne toxic substances. Many ventilation systems are poorly designed. The next section will discuss the proper design of ventilation systems.

6.2.5-1 Design of Ventilation System The design of an efficient ventilation system is technically complex. All designs should be developed or approved by a registered professional engineer or a certified industrial hygienist. The design process requires detailed familiarity with the range of tasks for which protection is required, as well as the variety of biological and chemical agents to be used in the system. The following are guidelines which should be considered when designing a system:

- When designing a local exhaust ventilation (LEV) system for a variety of applications, be sure that it will be protective enough for the least easily controlled operation and the most toxic biological or chemical agent.
- Locate hoods in a manner that minimizes the amount of traffic that can disrupt the flow patterns of the hood.
- Enclose as much of the operation or process as possible. Not only does this increase the effectiveness and reliability of control, but it also reduces the amount of air that has to be handled. Equip the enclosure with horizontal or vertical sashes, so that the hood opening can be minimized when in use and shut completely when not in use.
- Avoid placing the hood near doors, windows or air diffusers that can create cross-drafts at the hood face .
- Be sure that any makeup or auxiliary air introduced at the hood face flows in the same direction as the induced draft into the hood.
- Be certain that the volume of air exhausted from the hood is sufficient to achieve a capture velocity of 100 $\pm$ 20 ft/min of the hood opening. If the operation in the hood results in a certain volume of contaminated gas or vapor, the exhaust volume should be large enough to accommodate that volume.
- Design the duct connection to the hood to avoid sharp angles of introduction of other branches to within six duct diameters of the hood. This will reduce turbulent air patterns inside the hood.
- Round the front edge or lip of the hood opening to reduce turbulence.
- Use air-cleaning equipment that is appropriate for the type of containment. The equipment should be located so that filters can be easily changed or monitored. Locate differential pressure gauges in the laboratory so that pressure drops, indicative of the need to replace filters, can be easily determined.
- Locate the fan outside the building (on the roof), to permit the maintenance of the negative pressure in the duct carrying containment air from the hood to the fan.

Locate air-cleaning equipment ahead of the fan to reduce deterioration of fan parts caused by the action of contaminants.

- Place exhaust stacks above there roof line and away from air supply equipment.

6.2.5-2 Hood Monitoring and Inspection Programs The performance criteria listed below reflect quantitative and qualitative assessments of ventilation system performance and condition. Any system used to protect personnel or the environment from toxic or hazardous substances should be rigorously tested before being put into service, and also frequently thereafter. In evaluating the performance of a given system, the following criteria should be considered (Alden and Kane 1987, 113):

- non - disruptoive interior and exterior air patterns, including those in the hood or cabinet, as well as those from the room environment into the blood;
- adequate and appropriate capture velocities and airflow volumes;
- absence of leaks from plenums, sashes, hoods, or from the gloves in a glove box;
- adequate routine and preventive maintenance;
- use of pressure gauges and alarms to determine the pressure drop across the air-cleaning devices; and
- good housekeeping.

All laboratories performing work involving hazardous materials, where exhaust ventilation is used for primary control of personnel exposures, should operate according to a regularly scheduled ventilation system monitoring and maintenance program. Such a program should be designed and directed by qualified health and safety personnel. Because of the wide variety of laboratory hoods (chemical fume hoods, biological safety cabinets, vented enclosures) and other local exhaust ventilation, the monitoring program for each piece of exhaust equipment should reflect the manufacturer's recommended operating practices. As described below, each monitoring program should include daily visual inspections, quarterly inspections, annual maintenance and testing, and user training.

6.2.5-3 Daily Inspection Checklist

1. Exhaust slots: Adjustable rear exhaust slots in laboratory hoods should be checked periodically for proper balance. When the exhaust inflow and down flow are unbalanced in a biological laminar flow cabinet, the potential exists for contaminated air to be pushed outside the hood face.
2. Airflow check: When the exhaust system is operating, a tissue paper check should be performed to ensure that the exhaust is functional: tape a small piece of tissue paper at the hood opening and observe whether it reflects a directional airflow. For a glove box, tissue paper should be placed inside at the exhaust slots (but it should not be allowed to escape into the exhaust system, as it might block the filter and reduce airflow).
3. Smoke test: All exhaust enclosures should be smoke-tested to demonstrate the effective capture of contaminates generated during normal operating procedures. The smoke test is conducted by placing a smoke generator inside the enclosure and observing whether all the generated smoke is captured. If smoke leaks out of the enclosure, contaminated air could peak out during normal conditions.
4. Pressure gauges: All pressure gauges should be checked to see that they indicate pressure levels with a predetermined safe operating range. This range should be initially determined for both the enclosure static pressure and the HEPA filter pressure drop by a qualified safety and health professional. The precise range may vary between systems, and thus it should be defined on a system by system basis.
5. Housekeeping: Any material blocking the hood opening or exhaust parts should be removed. If evidence of turbulence has been found during the check of the hood, one explanation may be clutter in the hood. Hoods are not designed to be chemical storage cabinets.

Laboratory ____________________
Investigator ____________________
Telephone No. ____________________

Model ____________________
Serial No. ____________________
Date ____________________

Supply blower speed
control setting ____________________

Magnehelic gauge
reading ________" w.c.

Supply Velocity

High ____ Low____ Average Work Surface______

Air Curtain

Access Opening ____________________

Exhaust Velocity

Ducted ______

Not Ducted ____
Size ________

High __ Low__ Average__

CFM _____ _____
Calculated Air Intake ________

REMARKS:____
____
____
____

Testing Technician ________

Figure 6.3 Sample Velocity Profile from Bilological Safety Cabinet (after Mond 1987)

6.2.5-4 User Training The daily visual inspections and smoke test tubes should be an important aspect of a hood operator's education and training. Before a person begins using any laboratory hood, he or she should be trained in its proper use and become familiar with monitoring programs. The results of these tests for all types of exhaust equipment should be recorded and the records kept in an accessible location so that users can refer to them when suspected hood malfunctions occur.

6.2.5-5 Routine Maintenance In addition to the periodic monitoring, an overall annual maintenance procedure should be established. These procedures should be performed by a qualified personnel. Documentation of these tests should be maintained by laboratory supervisory personnel. Figure 6.3 is an example of a hood monitoring form.

The following general maintenance procedures should be performed annually on exhaust equipment. More specific information for special hoods and enclosures is presented in the National Sanitation Foundation Standard for Class I Biohazard Cabinets, NSF 49.

- Exhaust for Maintenance: The fan manufacturer should recommend necessary maintenance, including lubrication, belt checking, fan blade deterioration, and speed check recommendations. Lubrication of the fan and fan motor may be required more frequently, depending on the operating conditions.
- Ductwork check: All the ductwork between the hood or exhaust opening should be checked for corrosion, deterioration and buildup of liquid or solid condensate. Any dampers used for balancing the system should be lubricated and checked for proper operation. Unused ductwork or old hood installations should be removed.
- Air cleaning equipment: In-line exhaust charcoal or HEPA filters should be monitored for containment buildup. Mechanical or adsorbent filters not equipped with differential pressure gauges, or audible alarms, should be leak-checked annually.

Absorbent or absorbent filters for gas and vapors can be leak-checked by the release of halogen gas inside the hood and a halogen meter monitoring the filter outlet airstream.

During these maintenance procedures, extra precaution should be taken to protect personnel from any of the toxic contaminants in the hood, ductwork or filters. Any excess contaminated material or filters removed from the hood system should be disposed of according to the facility's approved toxic waste disposal practices.

6.3 Emergency Power

The interruption of utility service to a laboratory facility can cause major adverse effects. Interruptions can be caused by storms, earthquakes, vandalism, maintenance outages and equipment breakdowns. Each facility should have a comprehensive plan that outlines its response to a loss of utilities. Even if the loss does not create an emergency by itself, it will render the facility more vulnerable to an emergency situation. Therefore, a utility interruption contingency plan should be included as part of a facility's plan for emergency operations.

6.3.1 Implications of Power Outages

Loss of electricity is more likely than loss of water pressure, and the effects on a laboratory could be more widespread and more serious. In considering the implications of an interruption in electricity, each facility must examine the measures necessary to protect the laboratory, its occupants and the integrity of any experiments being run.

There should be auxiliary backup power for all emergency equipment. Exit signs, lighting, evacuation alarms and other emergency equipment must not be disabled at a time when they are most necessary. Frequent operational checks must be conducted where backup batteries are used to ensure a content state of readiness. If a system-wide backup generator is used, it must be designed to provide power immediately, without a time delay.

In addition, equipment to be used by emergency personnel in the event of a power outage must be available.

Equipment used to control employee exposure to hazardous materials should be kept operating during a power outage. It is desirable to equip air-moving and air-cleaning devices critical to personal safety and health with backup power. In addition, if the effectiveness of the ventilation system could be compromised by a power outage, the rate at which air contaminants are generated must be minimized. Therefore, shutdown procedures should be established for key pieces of equipment and experiments.

If auxiliary power is used to maintain the ventilation system, the characteristics of the system running on auxiliary power must be evaluated. Any change in airflow between rooms, or any operational parameter of the ventilation system, must be recognized. The impact of changes in the safety and health of personnel must be assessed, and evacuation and emergency response plans adjusted accordingly.

It is desirable, to the extent possible, to provide auxiliary power to ensure the integrity of the experiments in progress. Backup power must be provided to all refrigerated areas, and a continuos source of power must be ensured for the computers being used. Any interruption of utilities may have adverse consequences that place a facility, its employees, its students, and the surrounding community at an elevated risk. In addition, the substantial investment in ongoing experiments could be placed in jeopardy. It is the responsibility of the laboratory managers to foresee these consequences and to make adequate preparations to minimize them.

6.3.2 Maintenance and Testing Considerations

A maintenance program is required for all emergency power systems. The maintenance program should include regular testing of emergency equipment (generators, batteries, etc.) as recommended by the manufacturer. The testing program should be documented and described.

The emergency procedures to be followed in case of power outage should be regularly reviewed and regularly exercised. Regular emergency drills help to ensure that laboratory staff will be familiar with equipment shutdown, staff notification and evacuation procedures on the relatively rare occasions when the procedures are used.

6.4 Fire and Explosion Protection

6.4.1 Introduction

The potential for fire and/or explosion is always present in laboratories. While the probability and consequences associated with such events vary as a function of laboratory design and operations, steps can be taken to minimize potential losses. There are four classes of fires, all of which can occur in the laboratory environment (Ferrante 1989, 123):

1. Class A fires in ordinary combustible materials, such as wood, cloth, paper, rubber and some plastics;
2. Class B fires in flammable liquids, oils, greases, tars, oil-based paints, lacquers, and flammable gases;
3. Class C fires that are engendered by energized electrical equipment; and
4. Class D fires in combustible metals, such as magnesium, titanium, zirconium, sodium, lithium and potassium.

It is important to recognize the differences among these classes, and to understand the types of fire hazard present in an individual laboratory facility. The class(es) of fire hazard present strongly influence the choice of fire detection and suppression equipment.

6.4.2 Portable Fire Extinguishers

Fire extinguishers should be conspicuously located where they will be readily accessible and immediately available in the event of fire. The specific type and size of extinguisher should be selected with consideration for the hazards to be protected and the strength of the personnel who might use the extinguishers.

6.4.2-1 .Extinguisher Selection Type Extinguisher selection should be based on the class of hazards to be protected as follows:

- Class A: Hazards should be protected with extinguishers of the following types: water, multipurpose dry chemical, bromochlorodifluoromethane (Halon 1211®), and foam or aqueous film forming foam (AFFF).
- Class B: Hazards should be protected with extinguishers of the following types: dry chemical, carbon dioxide, bromochlorodifluoromethane (Halon 1211®), or bromotrifluoromethane (Halon 1301®), foam or (AFFF).
- Class C: Hazards should be protected with extinguishers of the following types: dry chemical, carbon dioxide, bromochlorodifluoromethane (Halon 1211®), or bromotrifluoromethane (Halon 1301®).
- Class D: Hazards should be protected with extinguishers and extinguishing agents that are approved for use on the specific combustible metal hazard. Examples include, G-1® powder for magnesium fires and Lith-X for lithium fires.

6.4.2-2 Extinguisher Selection Size For the majority of laboratory applications, water and AFFF extinguishers should have a capacity of 2.5 gal. Dry chemical, carbon dioxide, bromochlorodifluoromethane (Halon 1211®), bromotrifluoromethane (Halon 1301®), and foam extinguishers should hold 20-30 lbs. Site selection should reflect consideration of both the hazards and the strength of the personnel who might use the extinguisher.

6.4.2-3 Extinguisher Location and Installation Locate extinguishers conspicuously, where they will be readily accessible in the event of a fire. The travel distance should be a maximum of 30 ft, and located along normal paths of travel, including exits from an area (Dux and Stalzer 1988, 120). Preferably, extinguishers should be located close to any known hazard. The top of the extinguisher is to be installed no more than 5 ft. above the floor. The clearance between the bottom of the extinguisher and the floor should be no less than 4 inches. Place operating instructions on the front of the extinguisher.

6.4.2-4 Inspection and Maintenance Conduct inspection of fire extinguishers regularly to ensure that they have been properly placed and are operable. Inspectors should determine that an extinguisher:

- is in its designated place;
- is conspicuous;
- is not blocked in any way;
- has not been activated and become partially or completely emptied;
- has not been tampered with;
- has not sustained any obvious physical damage or been subject to an environment that could interfere with its operations (e.g., corrosive fumes); and
- shows conditions to be satisfactory, if equipped with a pressure gauge and/or tamper indicators.

Inspections should be made at least once a month and documented, with records retained for review. Maintenance of extinguishers involves a complete and thorough examination, which should include the mechanical parts, the amount and condition of the extinguishing agent, and the condition of the agent's expelling device. Maintenance techniques vary, and inspections should be performed by qualified personnel. Formal maintenance activities should be conducted at least once each year.

In addition to routine maintenance, hydrostatic testing must be performed on extinguishers subject to internal pressures to protect against failure caused by (Dux and Stalzer 1988, 132):

- internal corrosion from moisture;
- external corrosion from atmospheric humidity or corrosive vapors;

- damage from routine handling;
- repeated pressurization's;
- manufacturing flaws;
- improper assembly of valves or safety relief discs; and/or
- exposure to abnormal heat (e.g., fire).

6.4.3 Detection Systems

There are many factors to consider when selecting and implementing a fire detection system. The following sections account for such important considerations.

6.4.3-1 Types of Detection Systems Although heat, smoke, flame, and combustible gas detection systems are not required by laws or regulations in most laboratory facilities, they can be important to protecting the facility and its contents. There are many types of detection systems, and the choice of a system must be tailored to the facility and the hazards present. The following types of detector are often found in laboratory facilities (DiBerardinis 1987, 143):

- Heat Detectors: These devices respond to the convected thermal energy of a fire. They are activated when the detecting element reaches a predetermined fixed temperature, or when a specified rate of temperature change occurs. The former are called fixed-temperature detectors; the latter are rate-of-rise detectors. Some detectors combine both features.
- Smoke detectors (both ionization and photoelectric types): Ionization detectors typically respond faster to flaming fires, which produce smaller smoke particles. The larger smoke particles generated by smoldering fires are typically detected faster by photoelectric detectors.

- Flame detectors: These detectors respond to radiant energy from flames, coals or embers. There are two types: infrared and ultraviolet flame. The major difference is in the sensitivity of the latter to sunlight.
- Combustible gas detectors: These units detect the presence of flammable vapors and gases. They give a warning when concentrations in the air approach the explosive range.

6.4.3-2 Detection System Selection and Installation The selection of a detector should be based on the anticipated hazard(s) and the environment to be protected. Criteria include type and amount of combustibles, possible ignition sources, environmental conditions and property values. Heat detectors are used most effectively to protect confined spaces or the areas immediately contiguous to a particular hazard. This is because the heat from a fire can dissipate quite rapidly over a larger area, allowing further propagation of fire before the device is tripped. The operating temperature of a heat detector is typically 25^{o}F above the maximum ambient conditions (DiBerardinis 1987, 140).

Smoke detectors typically respond to fire more quickly than heat detectors and can be used effectively in large, open spaces. Photoelectric devices are preferable if smoldering fires are anticipated, while ionizing devices are more effective at detecting flaming fires. Prevailing air currents, as well as ceiling and room configurations, are a key consideration in placement. Flame detectors are typically installed in high hazard areas where rapid fire detection is critical. Since, infrared flame detectors can experience interference from solar radiation - however, concern for false trips is important. Furthermore, since flame detectors are line-of-sight devices, an unobstructed view of the flame must occur for detection.

Combustible gas detectors are selected and calibrated for the specific substances to be detected. They are typically located close to the hazard and are set to activate an alarm when a certain percentage of the lower flammable limit is reached. Additional details on automatic fire selection and installation can be found in NFPA Standard 72E, "Automatic Fire Detectors."

6.4.3-3 Inspection and Maintenance Inspection and maintenance of detection systems and their components are keys to reliable operation. These activities also help reduce the number of false alarms. It is optimal if such actions are performed regularly and are documented for review. It is also desirable to test detection systems periodically to assure that they are in proper working order.

6.4.3-4 Types of Sprinkler Systems Sprinkler systems automatically provide water or other fire extinguishing agent to extinguishing fires. There are water systems, dry chemical systems, Halon systems, carbon dioxide systems and foam systems (DiBerardinis 1987, 259).

1. Water Systems: Water systems can be further segregated into the following categories:

- Wet pipe systems. These are characterized by the presence at all times of water in the lines under pressure. The water will flow through any sprinkler head(s) that fuse (i.e., the closure melts) in a fire environment. Sprinkler heads are available with a variety of operating temperatures and should be installed and replaced only by qualified personnel.
- Dry pipe systems: These are characterized by the pressure of air in the sprinkler lines under pressure. The air will flow through nay head(s) that fuse in a fire environment. This allows water to flow into the lines. Water then flows through the fused head(s).
- Precaution systems: These have air in the lines and have a fire detection system. The detection system operates a valve that allow a water to flow into the lines. The system then operates like a traditional sprinkler system when a head fuses.

- Deluge systems: These feature continuously open sprinkler head(s). There is also a fire detection system which operates a valve, allowing water to flow into the lines and then out the open head(s) when a fire is detected.

2. Dry Chemical Systems: Dry chemicals are powders that are effective in extinguishing Class A, B and/or Class C fires. Advantages include quick knockdown capability and absence of electrical conductivity. Disadvantages include slight corrosivity and difficulty in cleanup. A fixed dry chemical system consists of the agent, an expelling gas, a means to activate the system (e.g., a flame detectors) and fixed piping and nozzles. Designs include both total flooding and local application types.
3. Halon Systems: Halon 1301® is a halogenated hydrocarbon, bromotrifluoromethane, which is effective in extinguishing Class B and C fires. Extinguishment is accomplished by a chemical reaction. An important advantage is that Halon leaves no residue after application. Disadvantages include possible toxic effects when agent concentrations exceed 7%, and from the products of decomposition. A Halon 1301® system consists of the agent, a release mechanism, a means to activate the system (e.g., heat detector), fixed piping and nozzles. Designs include both total flooding and local application types. In both cases the installation must be in an enclosed area, or the agent must be liquefied gas.
4. Carbon Dioxide Systems: Carbon dioxide is effective in extinguishing Class B and C fires. Extinguishment is accomplished by reducing the oxygen content of the atmosphere until it will no longer support combustion. This gas can also extinguish a fire by cooling. Advantages of carbon dioxide include its own pressure for discharge and the lack of residue after use. Disadvantages include need for retention of the extinguishing atmosphere and inherent danger (through oxygen displacement) when used in areas occupied by personnel. A carbon dioxide system consists of the agent, a means to activate the system (e.g., heat detection), fixed piping and nozzles. Designs

include both total flooding and local application types. An enclosure is mandatory in the former and preferable in the latter.

5. Foam systems: Several different types of foams are used to suppress fires and/or vapors from spills of flammable or combustible chemicals. Foams are denied by their expansion ratio, or their foam value compared to their original foam solution volume before adding air. There are low expansion (less than 20-1), medium expansion (20-200-1), and high expansion (200-1000-1) foams. Foaming agents include aqueous film-forming foam, fluoroprotein foam, alcohol-type foam and high expansion foam. Application can be effected via fixed systems or through the use of special portable extinguishers.

6.4.3-5 Inspection and Maintenance of Sprinkler Systems Inspection and maintenance are critical to the reliability of sprinkler system operation. Items to be inspected include the sprinkler control valves, the water pressure or extinguishing pressure agent and (in the case of dry pipe systems) the air pressure. Fire pumps and suction tanks should also be checked if they are system components. Sprinkler system maintenance should address head condition, corrosion and freezing. In water systems, periodic flushing of yard mains and branch lines will help ensure reliable water flow.

6.4.3-6 Handling and Storage of Flammable and Combustible Liquids Most laboratory operations involve the use of flammable and/or combustible liquids. General safe handling procedures for these materials are summarized below (DiBerardinis 1987, 291):

- All non - working quantities of flammable liquids should be stored in a storage cabinet approved by Underwriters Laboratory or Factory Mutual, or in a designated flammable liquids storage room with suitable fire protection, ventilation, spill-containment trays and electrical equipment meeting the requirements of OSHA.

- The flammable liquids should be segregated from other hazardous materials such as acids or bases.
- Whenever flammable liquids are stored or handled, ignition sources must be eliminated. Therefore, smoking must be prohibited.
- If flammable liquids must be kept at low temperatures, they should be stored in explosion-proof refrigerators.
- Flammable liquids transfer should be done in the designated storage room or over a tray within an effective fume hood. In a storage room, all transfer drums should be grounded and bonded and should be equipped with pressure-relief devices and dead-man valves.
- Safety cans should be used when handling small quantities of flammable liquids.

The classification system for flammable and combustible liquids given is widely accepted throughout the world. It was prepared by the National Fire Protection Association Technical Committee on Classification and Properties of Flammable liquids, and is found in the NFPA Standard 321, "Basic Classification of Flammable and Combustible Liquids." The guidelines provided by the NFPA are summarized below:

1. Flammable Liquids: Flammable liquids have flash points below 100°F (38°C) and vapor pressures not exceeding 40 psia at 100°F (275kPa at 38°C). They are classified as Class I liquids and may be subdivided as follows:
   - Class IA liquids have flash points below 73°F (23°C) and boiling points below 100°F (38°C).
   - Class IB liquids have flash points below 73°F (23°C) and boiling points at or above 100°F (38°C).
   - Class IC liquids have flash points at or above 73°F (23°C) and below 100F (38°C).
2. Combustible liquids: Liquids with flash points at or above 100°F (38°C) are referred to as combustible liquids and may be subdivided as follows:

- Class II liquids have flash points at or above $100^{O}F$ ($38^{O}C$) and below 140F ($60^{O}C$).
- Class IIA liquids have flash points at or above $140^{O}F$ ($60^{O}C$) and below 200F ($93^{O}C$).
- Class IIIB liquids have flash points at or above $200^{O}F$ ($93^{O}C$).

The appropriate measures for the handling and/or storage of flammable and combustible liquids are specific to both site and chemical(s). However, there is an ever-present need to minimize uncontrolled vapors and spills. In addition, ignition sources in the area of use should be controlled. Equipment and procedures for control includes the employment of explosion-proof electrical equipment, flame arresters, grounding and bonding and the prohibition of smoking. Additional details on flammable and combustible liquids handling and storage can be found in NFPA Standard 30, "Flammable and Combustible Liquids Code."

6.5 Safety in the Classroom

There are several general rules an instructor assigned to a laboratory must follow (Van Houten 1990, 48):

- Students will be instructed regarding specific safety hazards in a given area as well as safety procedures. Including exits and fire alarm locations each semester;
- Students will be instructed in the proper and safe way to carry chairs an other items including, but not limited to, lab equipment and chemicals ;
- Each student will have a seat or sufficient space to allow for the normal process of instruction to take place;
- Classroom aisles will be kept clear and wide enough for passing;
- Classroom doorways will never be obstructed;
- Students will not lean back on chairs;
- Floors will be kept dry and clean from debris to avoid slipping;

- Equipment and supplies used in the classrooms will be properly stored to avoid creating hazardous conditions;
- Stepladders or step stools will be used in a proper and safe manner supervised by the instructor;
- All physical hazards (e.g., broken windows, chairs, etc.) in need of repair will be reported immediately to the appropriate person;
- Safety goggles and other safety equipment will be used for appropriate activities;
- Proper ventilation will always be assured when using chemicals that will give off vapors;
- Fume hoods will be periodically checked;
- When working in the classroom, close supervision will be maintained at all times;
- Electrical equipment will be used with caution and under close supervision;
- All correction that must be done (e.g., maintenance) will be noted in writing on a work order or by telephone in case of an emergency; and
- All important telephone numbers (police, fire department, etc.) will be posted in the event of an emergency.

CHAPTER 7

SPECIFIC HAZARDS

7.1 Introduction

A laboratory safety program must account not only for anticipated or common hazards, but also for more specific, inherent hazards which may occur. Such hazards warrant consideration not only because of the danger they pose, but also because of their associated regulations which must be adhered to. One such example of such a potential hazard is waste management.

7.2 Waste Management

All universities and schools are responsible for the development of a waste management program that will ensure the safe handling and disposal of all laboratory wastes. This program should reflect the specific activities of the individual laboratories and should incorporate all federal, state and local regulations.

An effective program for managing laboratory wastes has two basic goals: (1) to operate the laboratory in compliance with all applicable regulations; and (2) to manage the wastes generated in a manner that protects employees, students, maintenance workers, visitors, citizens and the environment (Ferrante 1989, 19). A laboratory should communicate these goals through policy statements and detailed standard operating procedures (SOPs), which form the basis of personnel training. Section 5.8 of the previous chapter entitled, "Procedures for Disposing Chemicals in Laboratories" should be used as a cross reference for several basic disposal procedures for chemical wastes.

Universities must update their waste management program periodically, so that it reflects changes in laboratory activities and governmental requirements. It may be helpful if certain laboratory operators periodically take refresher courses to keep themselves current with the latest waste management policies and procedures. The university should review its policies and procedures from time to time with its employees. The object of such reviews would be to gather feedback from all laboratory operators and to ensure a consistent understanding of the laboratory's waste management program.

7.2.1 Implementation of a Waste Management Program

The waste management program should reflect the specific activities of the laboratory. Generally, the program objectives should include (Sitig 1985, 36):

- protection of the health and safety of workers;
- protection of the environment;
- protection of the health and safety of the public;
- compliance with federal, state and local regulations; and
- adherence to management practices.

7.2.2 Regulatory Compliance

Regulations that govern the handling of waste streams are derived from federal, state and local authorities. They control chemical release to the air, water and land. The impacts on the environment from the failure to control hazardous wastes are covered by federal legislation and includes the following federal regulations.

7.2.2-1 Clean Air Act The Clean Air Act requires states to develop their own plans for complying with federal air guidelines. Each state must develop a permit system for air pollution sources. Operations at laboratories that may require air pollution permits include incineration of animal carcasses and other wastes, vents from hoods and possibly industrial boilers (Dux and Stalzer 1988, 127). Requirements vary from state to state. Therefore, a laboratory should contact the appropriate environmental agency to determine what operations require air permits.

7.2.2-2 Clean Water Act The Clean Water Act is a federal program that gives the state the power to issue water discharge permits. If a laboratory discharges to a surface water body, such as a river, lake, pond or stream, it may require a National Pollutant Discharge Elimination System (NPDES) permit. This permit, which is usually administered by the state, may set limits for certain pollutants. It may also specify monitoring and reporting requirements and water pollution control equipment maintenance. A facility that uses a septic system may also discharge wastes that could impact water quality. Some stated require a permit for all systems that may impact groundwater quality, including septic systems. Such facilities may be required to obtain what is often called a discharge-to-groundwater permit.

The regulatory concern centers on any inorganic (especially heavy metal) or organic wastes that may enter the wastewater stream. Other criteria, such as suspended solids, pH, fecal coliform and oil/grease content of the aqueous wastes may also apply. A facility unsure of the quality of its discharge should contact the state environmental agency to determine its need for a water permit. Any requirements stated in the water discharge should contact the state environmental agency to determine its need for a water permit. As with air permits, any requirements stated in the water discharge permits should be incorporated into the laboratory standard operating procedures.

7.2.2-3 Toxic Substances Control Act (TSCA) The Toxic Substances Control Act has only limited applicability for most laboratories. One set of requirements that may apply concerns the on site use of polychlorinated biphenyl's (PCB's). Before the late 1970's, manufacturers often used PCB's as a dielectric material in electrical equipment. PCB's in this form may also be present in older transformers, capacitors or switching gear located on site (DiBerardinis 1987, 233). Even if the laboratory does not own or operate such equipment, the laboratory may be responsible for determining whether the owner or operator is operating any PCB equipment. This obligation may mean that the laboratory has to establish a special monitoring and maintenance program. A laboratory should be able to document what electrical equipment it uses, regardless of whether it is being properly managed by the operator/owner.

7.2.2-4 Resource Conservation and Recovery Act (RCRA) RCRA covers the management of regulated hazardous wastes and specifies several basic responsibilities for generators of wastes. According to the act, a waste generator must determine whether the wastes are regulated as hazardous, determine its generator status by calculating the amount of hazardous waste generated and comply with the management regulations according to the appropriate generator status. RCRA gives the generator "cradle to grave" responsibility for the wastes it produces. The act even makes the generator liable for its waste materials even after they have reached their final disposition.

A waste may be defined as any solid, liquid or gaseous material that is no longer used and will either be recycled, disposed of to stores in anticipation of treatment or disposal. Part 261 of Title 40 of the Code of Federal Regulations defines hazardous wastes in two basic parts: a waste is regulated as hazardous (1) if it is specifically listed by name or by category, or (2) if it meets one of four characteristics, specifically - corrosivity, ignitability, reactivity and extraction procedure (EP) toxicity. Typical laboratory wastes that are regulated as hazardous include acids and bases, heavy metals and inorganic materials, ignitable wastes, reactives (oxidants) and solvents.

The first responsibility of a laboratory is to determine whether it generates hazardous wastes. This determination can be made by identifying all waste streams and applying the criteria for hazardous waste against each waste stream. If a university determines that it is generating hazardous waste, it must quantify the amount to ascertain the regulatory status that applies to the location. If the location generates more than 1000 kg of hazardous waste (or 1 kg of acutely hazardous waste) per month, the location must meet all the requirements of a generator as specified in 40 CFR 262 and as modified by each state. If the location generates less than 1000 kg but more than 100 kg of hazardous waste (and less than 1 kg of acutely hazardous waste), only some of the generator requirements may apply. If the location generates less than 100 kg of waste in any calendar month, it is exempt from the formal management program requirements, as long as it accumulates no more than 1000 kg of waste on site. However, it is important to check state regulations, since some states have reduced the quantity criteria.

All generator categories are required to manage their wastes safely and must send them to approved handling facilities. Generators of more than 100 kg of waste per month must obtain an identification number through the state environmental agency or from the regional office of the federal Environmental Protection Agency (EPA). When sending wastes off site, generators must pack them according to Department of Transportation (DOT) specifications as noted in 40 CFR 262 and
40 CFR 172.

Laboratories may choose to package their own wastes, or they may have a hazardous waste contractor do this, as part of the removal service. The other requirements for regulated generators are concerned with the accumulation and storage of the wastes, the tracking and reporting of these wastes and the actions to be taken in the event of an emergency.

7.2.2-5 Superfund, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Another set of environmental regulations that apply to facilities that manage hazardous waste was established by the comprehensive act called CERCLA, or Superfund. Although the majority of these regulations deal with waste disposal sites, a portion of them apply to the release of regulated hazardous wastes by a laboratory to the environment. The EPA regulation 40 CFR 302 explains the required reporting steps and defines the minimum reportable release (reportable quantities or RQs) in the event that a regulated hazardous waste is released. This notification system should be included in the laboratory SOPs and may even apply to non waste materials the laboratory handles.

The laboratory is responsible to determine whether any state or local regulations apply to its waste activities. The state environmental agency should be able to identify state and local requirements, to provide a local agency contact that can define applicable requirements. A listing of state environmental agencies can be found in Appendix F.

If a facility generates wastes, it can minimize the volume and cost of these wastes by following a few basic housekeeping principles (Castegnaro and Sansone 1989, 244):

- Do not mix non hazardous and hazardous wastes. Such a mixture will have to be regulated as a hazardous waste, thus increasing the cost and responsibility associated with the waste.
- Segregate hazardous wastes. This may be required to prevent the mixing of incompatible wastes, but it also makes sense to preserve the waste properties, therefore making recycling or treatment easier and less expensive.
- Avoid spills or leaks. Through a preventive maintenance program and inspections, a facility can minimize spills and leaks, thus reducing the amount of wastes generated. Keep in mind that clean up materials for hazardous wastes are regulated as hazardous wastes.

In a laboratory environment, these principles can be implemented by providing separate, clearly identified containers for non hazardous solids, hazardous solids, non hazardous liquids, hazardous halonated liquids and non hazardous halonated liquids. Only compatible materials should be placed in the same container. This practice can help avoid creating orphan wastes (wastes that are of unknown origin and characteristics and are therefore difficult to handle). The facility should handle orphan material as a hazardous waste and should characterize it to the degree possible. The facility should also examine the storage of chemicals and experimental apparatus to identify potential spills and leaks and to plan how to avoid them.

The best way to manage wastes is not to generate any in the first place. This approach is based on the concept of waste minimization. A laboratory can minimize wastes by substituting non hazardous chemicals for hazardous ones, carefully controlling chemical inventories and using chemicals to recover systems efficiently. Each laboratory should strive to minimize its wastes to the extent practical and should review its waste minimization approaches periodically to incorporate new laboratory operations and new waste minimization techniques (NACUBO 1987, 53).

Laboratories can manage their inventories to minimize the generation of wastes from the disposal of expired or degraded materials by adopting a "first in/first out" policy (i.e., using older chemicals before newer ones). A part of this policy is to clearly mark the expiration dates on the containers, along with the date the material was received and to conduct periodic inventories on materials. This information can help to serve the procurement process by documenting the usage rate. Additionally, costs can be reduced by eliminating unnecessary chemical purchases. Not only are expired chemicals unusable and a waste of resources, but some chemicals form dangerous degradation products as well. Therefore, each laboratory should have an inventory policy and a system to implement it.

Using chemicals efficiently is a goal every laboratory should have to reduce reagent costs as well as waste disposal costs. Such a policy must be implemented on a case-by-case basis, relying on the judgment of the investigators and the needs of the study. Some possible methods are to reduce the amount of solvent during glassware cleaning and to implement higher efficiency extraction procedures.

Recovering materials is another approach that can minimize wastes. A laboratory can regenerate solvents through distillation (i.e., removing contaminants). Also, it can use such techniques as ion exchange, ultra filtration, reverse osmosis, centrifuging and distillation to reduce both raw material usage and waste disposal costs. Each laboratory should also review the materials it uses to identify opportunities to replace chemicals with substitutes that are more readily recoverable. Such approaches may result in a net savings to the laboratory.

A final option for waste management may be on-site treatment, such as pH adjustment or precipitation. These options might allow a laboratory to include all or part of a given waste stream in its wastewater flow. This would reduce the volume of wastes regulated as hazardous. In some cases, however, on site-treatment is regulated under RCRA, or it may be unacceptable to the local water or sewer authority. Even if treatment is allowed, such approaches may not be considered to be best management practiced if they increase the quantity of pollutants in the environment. The laboratory should contact the state environmental agency to ascertain whether any on-site treatment is acceptable.

Several references are available to help laboratory employees handle waste materials safely. The first source of information is the MSDS. The MSDS specifies the properties and hazards of the chemical and also prescribes the manner in which a laboratory should handle the resultant waste. Additional reference materials can be obtained from organizations like the NFPA (e.g., Hazardous Chemical Data and Manual of Hazardous Chemical Reactions) and from trade and professional organizations.

7.2.3 Radioactive Waste

The actual handling of radioactive waste is an issue separate from hazardous waste. Radioactive waste results when a laboratory uses radioisotopes, usually as tracers. A radioactive material is one that contains at least 0.005 micro curie per gram of material, or per milliliter of a liquid (Martin and Habison 1989, 18). Below this limit, a laboratory may disregard materials without regard to their radioactive component; above this limit disposal becomes a strictly regulated issue.

Regulations regarding waste packaging and disposal of radioactive material can be found in 10 CFR 20 State Disposal Site Regulations and 49 CFR 173, Nuclear Regulatory Commission (NRC) Regulations (10 CFR 20) which include the disposal of radioactive materials down a drain and alternative methods. Before disposing any radioactive waste, a laboratory should contact a waste broker. Waste brokers accept packaged waste drums and transport them to a final disposal site. A waste broker will tell the laboratory how to properly segregate, package and label the disposal containers. These requirements may differ for various states, depending on the waste site to which the broker delivers.

As with hazardous waste, the generator is ultimately responsible for the waste, even if it is handled by contractor (Sheiein 1987, 24). Therefore, it is very important that the laboratory make sure that its contractor handles its waste responsibly and legally.

The Nuclear Regulatory Commission requires laboratories to keep detailed records of all materials they dispose of (whether down the drain or in a drum). The U.S. Department of Transportation requires that the manifest accompanying the waste give a detailed description of the type of waste and the amount of radioactive material in each drum shipped to a disposal site.

7.2.3-1 Radioactive Waste Packaging When preparing a radioactive waste for disposal, a laboratory should pack the waste into DOT-approved 55-gallon steel drums by one of five categories: dry solid waste, adsorbed liquids, animal carcasses, aqueous vials and liquid scintillation vials. A laboratory should place all such wastes into a thick plastic bag before putting it into the drum. Adsorbent material is used to line the bottom between the drum and the plastic bag. Typical adsorbent include SpeediDry® and diatomaceous earth. Regulations do not allow the mixing of waste types within a single drum. The five waste types should be packaged as described below:

- Dry solid waste is placed inside a thick plastic bag, along with a layer of absorbent in the bottom of the drum.
- Adsorbed liquids require placement of a layer of adsorbent in the bottom of the drum before the bag is installed. With the plastic bag lining in the drum, the liquids are

poured into alternating layers of 12-inch thick adsorbent. The drum must contain enough adsorbent to adsorb at least twice the volume of radioactive liquid contents.

- Animal carcasses are placed inside 30-gallon, plastic lined drums with lime and adsorbent in a 1 10 ratio. The 30-gallon drum is then placed in a 55-gallon drum with enough adsorbent to fill all the space between drums. Both drums are sealed.
- Aqueous vials are placed unopened in either 30- or 55-gallon plastic lined drums with 3 inches of adsorbent placed in the bottom of the drum before the liner is installed. The vials (not to exceed 50 cc/vial) and adsorbent are placed in alternating layer not exceeding 6 inches in depth. The top layer must consist of at least 3 inches if adsorbent material.

7.2.4 Biohazards Waste Management

Similar to chemical and radioactive wastes, laboratories must handle biohazards wastes independently. However, unlike other wastes, biohazardous wastes must be decontaminated before disposal, which is the laboratory's responsibility. The point at which biohazardous agents are to be decontaminated depends partly on the actual agent and partly on personal preference. Any decontamination procedure should include the following general procedures (NIH 1984, 76):

- Biohazardous materials should be sterilized before regular washing or disposal.
- A strong oxidizing material should never be autoclaved with paper, cloth or other organic materials, because an explosion may result.
- Floors and laboratory surfaces should be disinfected regularly.
- Floors should not be swept.
- Decontamination procedures should be assessed for compatibility with materials that come in contact with disinfectant (e.g., gloves, bench tops, plastics and floor tiles). Specific decontamination methods are described below:

1. Wet Heat: Steam sterilization in an autoclave at a pressure of approximately 15 psi and a temperature of 121°C (205°F) for at least 15 minutes. Autoclaves should be calibrated for temperature and pressure, and monitored with a biological indicator. It is important that the steam and the heat be made to contact the biological agent. Therefore, bottles containing a liquid material should have loosened caps, or cotton plug caps, to allow for steam and heat exchange within the bottle.
2. Dry Heat: This form of sterilization generally requires temperatures of 160-170°C (320-338°F) for 2-4 hours. Again, it is important that the items be arranged in the autoclave with regard to heat transfer.
3. Liquid Disinfectants:

- Alcohol: Ethanol or isopropanol (70-85%) can effectively denature proteins, but not lipids. Therefore, when using alcohol, it is important to know whether the agent is composed mostly of lipid.
- Chlorine: A 1:100 dilution of bleach is very effective disinfectant against all microorganisms. This disinfective may be effective against several life-threatening viruses, including the AIDS virus. It is important to remember , that this compound will lose its effectiveness over time and that even at a 1:100 dilution, it is corrosive to metal and even stainless steel.
- Iodine: Wescodyne is an iodine based disinfectant often encountered in a laboratory. Dilution's of 3 oz. in 5 gallons of water are recommended for general laboratory cleanup, and a 1:10 dilution in 50% ethanol is recommended for washing.
- Formaldehyde: Formaldehyde is an effective disinfectant at 5% active ingredient concentration. Vapors of formaldehyde solutions may be irritating and should not be inhaled. Formaldehyde solutions should be made fresh to ensure effectiveness.
- Phenolic compounds: These disinfectants are not generally effective against bacteria, but they are usually used as disinfectants against rickettsia, fungi, and some vegetable bacteria. Phenol alone is not a good disinfectant because of its physical properties.

4. Gases/Vapors:

- Formaldehyde: One method of decontaminating a biological safety cabinet involves heating paraformaldahyde inside a sealed cabinet. This creates a vapor that can travel throughout the cabinet. Users should consult the cabinet manufacturer or manual for details of decontamination. A similar method may be employed in the decontamination of carbon dioxide incubators and even laboratories. Such procedures require considerable caution (use of gloves, masks and coats is recommended).

7.3 Chemical Incompatibilities [*CHP*]

The risks associated with chemical incompatibilities must be managed in any laboratory activity in which chemicals are handled or used. The mixing of incompatible chemicals can result in sudden, violent and unforeseen hazards and may cause significant personal injury and property damage.

7.3.1 Dangers of Incompatible Chemicals

In general, chemicals react to form compounds or other chemicals, with an attendant consumption or generation of energy. The dangers that are inherent in chemical incompatibility occur when the end products or by-products themselves are toxic or hazardous, or when the generation of energy is at a magnitude to be destructive.

Dangerous by-products or reaction products include solids, liquids and gases (gases are of the greatest concern). Chemical reactions can produce gases and vapors that are harmful by virtue of their toxicity or their flammability or both (Pepitone 1989, 137). Even the reactions that generate a substantial amount of an innocuous gas or vapor warrant concern, since they can displace the available oxygen in an enclosed area and create an oxygen-deficient environment.

The formation of liquid or solid hazardous reaction products can also present risks. Reagents that are thought to be pure can be used for applications that might be inappropriate for the liquid or solid reaction product. The generation of energy is often accompanied by the generation of toxic reaction products. A fire will produce not only light and heat, but also the toxic products of combustion. Whenever the generation of light, heat or pressure occurs in excessive magnitude. or with excessive speed, an explosion or fire can result, and the result can be catastrophic.

7.3.2 Avoiding Incompatible Reactions

The contact and reaction of incompatible reactions can occur in one of two ways. The mix can result from an accident, or an intentional combination. Avoiding the accidental mixture of chemicals is accomplished in the same manner as the avoidance of spills and leaks. The segregation of incompatible materials in storage areas is particularly important.

Intentional mixing of chemicals must always be preceded by careful analysis of the materials being used, and the possibility of unwanted or an unforeseen reaction. Reference must be made to the MSDS. Additionally, reference sources are an excellent source of incompatibility information (EPA Document 600/2-8-076 and CHRIS Hazardous Chemical Data). Appendix G lists chemical incompatibilities and hazardous waste compatibility's.

7.4 Biohazards [*CHP*]

Laboratory associated infections, usually having a delayed onset, are less readily recognized than acute health effects associated with chemical exposure. Where laboratory animals, particularly rodents and primates, are used in research and testing laboratories, their presence may introduce a source of exposure to zoonotic diseases (AIHA, Biohazards Committee 1985, 112). Employees in vitro testing laboratories may also be concerned with exposure to biohazards.

7.4.1 Animal Diseases

Infection from animals can occur by numerous routes, including bites; scratches; through feces, urine or other excretions; coat shedding and aerosols created by animal respiratory patterns. However, the most frequently encountered exposures involve skin accidentally punctured with infected needles, necropsy exposures from lacerations and splashes and manual conhunctivial exposures.

7.4.2 Classification of Etiologic Agents on the Basis of Hazard

Biological agents are typically classified in their order of risk to humans. Each classification relates to a laboratory biosafety level, with safety equipment, procedures and facility design combined to determine the minimum amount of protection required before exposure. The following classification is taken from the manual entitled Biosafety in Microbiological and Biomedical Laboratories, prepared by the Center for Disease Control (CDC) with the National Institute of Health (NIH).

1. Class 1. Agents of no or minimal hazard under ordinary conditions of handling.
2. Class 2. Agents of ordinary potential hazard. This classification includes agents that may produce diseases of varying degrees of severity from accidental inoculation or injection or other means of cutaneous penetration but are contained by ordinary laboratory techniques.
3. Class 3. Agents involving special hazards or agents derived from outside the United States, that require a federal permit for importation, unless they are specified for higher classification. This class includes pathogens that require special conditions for containment.
4. Class 4. Agents that require the most stringent conditions for their containment because they are extremely hazardous to laboratory personnel, or may cause serious epidemic diseases. This class includes Class 3 agents from outside the United States

when they are employed in entomological experiments or when other entomological experiments are conducted in the same laboratory area.

5. Class 5. Foreign animal pathogens.

The above classifications and safety levels should be used as recommendations to reduce the exposure and escape of pathogen microbes. However, before a hazard can be controlled, or the necessary precautions taken in handling the agent, those at risk must know what pathogen they may encounter. The international biohazard sign (Figure 7.1) should be posted with care in any area where a known pathogen is in use.

Figure 7.1 International Biohazard Sign
(after AIHA Biohazards Committee, 1985)

The principle investigator should review each program and identify all areas that should be posted. The sign should be removed after the experiment has been completed and the room has been decontaminated.

7.4.3 Facility Design

A poorly designed facility can contribute to the spread of microorganisms throughout a laboratory. The following is a general summary of the protection recommended for each of the biosafety hazard levels (CDC and NIH 1987, 76).

1. Biosafety Level 1: For agents of no known or minimal potential hazard, generally Class 1 agents.

- Discretionary limited access to the laboratory when experiments are in progress.
- Surfaces are designed to be easily cleaned. Bench tops are impervious to water and resistant to acid, alkali, organic solvents and moderate heat.
- Work surfaces are decontaminated daily and after spills.
- Contaminated liquid or solid wastes are decontaminated before disposal.
- Mechanical pipettes are used.
- Eating, drinking or smoking is prohibited.
- Hands must be washed after handling viable materials and animals and before leaving the laboratory.
- Procedures are performed in a manner most likely not to produce aerosols.
- Laboratory coats, gowns or uniforms are worn.
- Insect control and rodent control programs are in effect.

2. Biosafety Level 2: For work involving agents of moderate potential hazard, generally Class 2 agents. Follow the same guidelines as Biosafety Level 1, but also:

- Access to the laboratory is limited when work is being conducted.
- Personnel are trained in handling pathogenic agents and are directed by competent scientists.
- Biological safety cabinets or other physical containment equipment is used when aerosols are generated.
- A universal hazard warning sign is placed on the door of the laboratory, identifying the infectious agent, giving precautions that are to be taken before entry, and listing the name and telephone number of the person to be contacted in the event of an emergency.
- Gloves are to be worn to avoid skin contamination with infectious materials.

- Needle-locking syringes or disposable syringe-needle units are used. Needles are not broken, and needles and syringes are autoclaved before disposal, in an impervious container.
- Spills and exposures are reported. Medical treatment is provided when necessary and written records are maintained.
- A biosafety manual is prepared.

3. Biosafety Level 3: Work with indigenous or exotic agents that may cause a serious or potentially lethal disease as a result of exposure from inhalation, generally Class 3 agents. Same guidelines as Biosafety Level 2, but also:

- Laboratory doors are enclosed when experiments are in progress.
- Decontamination occurs at another site, away from the laboratory.
- Access is highly restrictive, including a double set of doors separating the laboratory from other areas.
- Each laboratory is equipped with a sink.
- The universal biohazard symbol is posted on laboratory doors.
- Infectious work is done in a biological safety cabinet.
- Disposable plastic-backed matting is used on non perforated work surfaces within biological safety cabinets.
- Respirators or surgical masks are worn in infected animal rooms.
- Vacuum lines are adapted with high efficiency particulate air (HEPA) filters and liquid disinfectant traps.
- Exhaust from biological safety cabinets is HEPA-filtered and discharged directly to the outside.
- Ducted exhaust air ventilation systems are used. Exhaust airflow is not recirculated.
- Baseline serum samples are collected for all at-risk personnel.

4. Biosafety Level 4: This level is for maximum containment. It involves work that is dangerous and exotic agents that present a risk of life-threatening disease, generally Class 4 agents. Follow the same guidelines as Biosafety Level 3, but also:

- Work is conducted in a Class 3 biological safety cabinet or in a Class 1 or 2 unit with one-piece, positive pressure suits.
- Access is under strict control.
- Showering is required on entry and exit.
- Transfer of materials requires non breakable secondary containment.
- Delivery and shipment of supplies and materials is effected through a double-door autoclave, fumigation chamber, or ventilated airlock.
- Facility design is such that interior walls, floors and ceiling form a tight seal and bench tops have a minimal number of seams.
- Exhaust and effluents are decontaminated before being released from the facility.

7.4.3-1 Safe Practices Additionally, general safety practices for handling agents include:

- Never put a pipette in the mouth.
- Do not eat, drink, smoke or chew gum in the laboratory.
- Label all rooms or equipment with the universal biohazard symbol when biohazards are used. Be sure to remove all labels upon decontamination.
- Use needle-locking syringes or disposable syringe-needle units.
- Place used syringes and needles in an impervious container. Do not clip or shear needles after use.
- Equip centrifuges with trunnioncups with germicidal solution to prevent the spread of contamination from broken vials.
- Wash hands thoroughly after completing experiments and before leaving the laboratory.
- Place contaminated pipettes in disinfectant solution after use and then autoclave them.

- Use only cotton-plugged pipettes.
- Place wastes that have been contaminated by an infectious agent in a sealed, labeled plastic bag, to be autoclaved later at the appropriate temperature and pressure.
- Monitor autoclaves for effectiveness with biological indicators.
- Work with infectious material in a biological safety cabinet that will adequately contain the hazard.
- Wear appropriate personal protective equipment for the biohazard (i.e., gloves, coat, suit, mask and/or respirator).

7.4.3-2 Control of Microorganisms Furthermore, the following features of a laboratory will enhance the control of microorganisms:

- Any laboratory that holds an infectious agent or animal experimentally inoculated with an infectious agent, or an animal room, should be under negative pressure with respect to the outer areas.
- Air coming into or out of a biohazard area should be made to pass through a HEPA filter.
- A biohazard laboratory is a restricted-access area.
- Animal rooms or biohazard areas should be located away from the stream of general traffic movement.
- Where possible, ultraviolet lights should be used to control the spread of microorganisms as an overnight decontamination process.

Biological wastes, like chemical and radioactive wastes, require an effective waste management program and a review of the specific regulations pertaining to the individual laboratory.

7.5 Radiation [*CHP*]

The applications of laser, microwave and ultrasound technologies are necessary in many laboratories. In the use of radioactive materials, one must take proper precautions to prevent the contamination of equipment, working area, and people. Poor laboratory safety skills can result in severe problems, as well as repercussions for the school in the form of fines, lawsuits or a loss of licenses. This section presents a means for developing a safe working environment by discussing laboratory safety precautions and what a laboratory needs to implement in a radiation safety protection program. Non ionizing radiation will also be discussed.

7.5.1 Implementation of a Radiation Safety Program

Before a facility can begin receiving a radiochemical, a radiation safety officer (RSO) must be appointed and notified. The RSO needs to know:

- from who the radiochemical are to be obtained,
- where they are to be used,
- which ones are to be used, and
- how much will be needed.

This information gives the RSO the basis for determining which federal regulations apply to the situation and whether licenses presently held will allow the operation. The federal government controls any laboratory involvement with radioactive materials and elements. The executive departments and agencies of the federal government have established general and permanent rules for the handling and controlling of radioactive materials. These have been published in the Code of Federal Regulations (CFR) and the Federal Register (FR). Title 10 of the CFR, which the Nuclear Regulatory Commission (NRC) oversees, contains all necessary information on the use of radiation.

Any individual who becomes involved with radioactive materials should also become familiar with Title 10, especially Part 20 (10 CFR 20). Each laboratory that uses radioactive materials should post 10 CFR 20 in a conspicuous area. The concept of urging employees to be exposed to an amount of radiation "as low as reasonably achievable" (ALARA) is usually the policy of most laboratories. To check the radiation level to which a worker may have been exposed, there are several monitoring methods available. The radiation safety officer should advise laboratory users on the benefits of each method.

- Designation of a control area where the workers can dress in the appropriate manner and remove protective clothing upon completion of their work.
- Use of a dosimeter to check the radiation exposure of each worker. Film badges or a pocket ionizing chambers are common forms of a dosimeter. These devices allow the RSO to quantitatively determine the amount of radiation to which the worker has been exposed.
- A wipe test program to check for area contamination. The RSO takes periodic wipes of the laboratory and counter area using special paper or any 2-inch filter paper. The RSO then checks the wipes for contamination with a radiation detector.

7.5.1-1 Components of a Radiation Safety Program A radiation safety program should be implemented and consist of the following procedures:

- administration of a personnel monitoring service with records that are kept up to date;
- performance of routine radiation contamination surveys in the laboratory and counter areas, with complete records to be analyzed for trends;
- frequent maintenance and calibration instrumentation, with results recorded;
- recording of all radioactive materials and the date received;
- provision of protective clothing labels, absorbent paper and other equipment needed to maintain a healthful working atmosphere; and
- control of radioactive waste, with efforts made to minimize the amount of waste produced without compromising safety.

7.5.1-2 Radioactive Waste Disposal The disposal of radioactive waste is very costly. Therefore, a laboratory should keep accurate records of the amount of waste generated. To ensure that an atmosphere is conducive to the safe handling and use of a radiochemical, a laboratory should establish certain good housekeeping and general safety regulations (e.g., no eating, smoking or chewing gum in laboratory; wash hands before leaving the laboratory, etc.)

The laboratory operators should place equipment that becomes contaminated through normal use in a designated area, or container, with tissue or absorbent paper. They should dispose of solid wastes and pour liquid wastes into containers marked "radioactive," with the type and amount of radioactive chemical noted.

All laboratory operators should always wear rubber gloves or gloves recommended for lab use in handling a particular chemical when working with radio - chemicals. This includes handling any contaminants, stock solution containers and waste containers and the disposal of absorbent paper or tissues. At the conclusion of their work, the laboratory operators should wash their hands with their gloves still on, making sure not to contaminate the faucet appliances. Also, they should check their gloves for contamination while still on; if free of contamination, they may take them off, and then wash their hands. If their gloves are still contaminated, they should wash them again, check for contamination and then remove them, turning them inside out to prevent the ungloved hand from touching the outside contaminated surface. Laboratory users should dispose of the gloves in the waste can marked "radioactive." At the conclusion of the laboratory experiment or working period, the work area should be surveyed to identify spills that were not observed during the laboratory experiment.

7.5.2 Non - ionizing Radiation

Non - ionizing radiation does not possess sufficient energy to displace electrons that are bound to atoms. However, non - ionizing radiation can damage atoms. In a laboratory environment, the most common forms of non - ionizing radiation encountered are lasers, light, microwaves and ultrasound.

7.5.2-1 Laser Recognition: The acronym LASER stands for "light amplification by the stimulated emission of radiation." Lasers are devices that produce light at very specific frequencies of the electromagnetic spectrum. The properties of lasers are similar to those of the other members of the electromagnetic spectrum. However, lasers can achieve great power densities which, along with operating at a single wavelength, has made them indispensable in today's marketplace (Martin, Lippit and Prothero 1987, 212).

The U.S. Food and Drug Administration (FDA) has stipulated that all manufacturers of lasers must meet the agency's performance standards. The standards created by the FDA divide laser products into four separate classes, based on the biological effect produced by the laser and the intensity of the radiation in the laser beam.

1. Class I lasers produce radiation that causes no biological damage. The continuos output of Class I lasers is not more than 0.39 μW.
2. Class II lasers produce radiation that can cause eye damage if exposures are direct and prolonged. The continuous output of a Class II laser is not more than 1mW. These lasers operate in:
   - visible (400-700 nm) and continuous wave (CW) bands, and can emit a power exceeding P_{exempt} at point 10 cm from the exit port of the laser system. Such laser devices can emit a power that exceeds the appropriate P_{exempt} for the classification duration, but not exceeding P_{exempt} for a 0.25 second exposure.
3. Class III lasers emit radiation that is powerful enough to damage skin tissue from direct or indirect exposures off of shiny surfaces for a short duration. The continuous output of Class III lasers is not more then 500 mW. These medium power laser devices produce radiation in:

- the infrared (1.4μm-1mm) and the ultraviolet (200-400nm) bands and can emit power in excess of P_{exempt} for the classification duration, but they cannot emit:
  (a) an average radiant power in excess of 0.5 W, for T_{max} greater than 0.25 second, or
  (b) a radiant exposure of 10 J cm^{-2} within an exposure duration of 0.25 second or less.
- visible (400-700 nm) band, CW, or repetitive pulses, modes that produce a radiant power in excess of P_{exempt} for a 0.25 second exposure (1 mW for a CW laser), but they cannot emit an average radiant power of 0.5 W for T_{max} greater than 0.25 seconds,
- visible or near-infrared (400-1400 nm) bands, and emit a radiant exposure in excess of Q_{exempt} but they cannot emit a radiant exposure that exceeds either 10 J cm^{-2} or that required to produce a hazardous diffuse reflection; and
- near-infrared (700-1400 nm) CW band or they and repetitively pulsed models emit tiny amounts of power in excess of P_{exempt} for the classification duration, but they cannot emit an average power of 0.5 W or greater for periods in excess of 0.25 seconds.

4. Class IV lasers emit extremely powerful radiation, which can cause damage to tissue when exposures are short and the beam is direct, reflected or diffused. The continuous output of a Class IV laser, is more than 500 mW. These high powered laser devices operate in:

- ultraviolet (200-400 nm) and infrared bands, and emit an average power in excess of 0.5 W for periods greater than 0.25 seconds or a radiant exposure of 10 J cm^{-2} within an exposure duration of 0.25 second or less; and
- visible (400-700nm) and near-infrared (700-1400 nm) bands, and emit an average power of 0.5W or greater, for periods greater than 0.25 second or a radiant exposure in excess of either

Instrument name: ______________________________
Manufacturer: ______________________________
Laser Class I II III IV V Laser type: ______________
Yes No Is instrument designed to be portable?

Manufacturer's suggestions for facility safeguards:
____

Additional facility safeguards deemed necessary:
____

Manufacturer's suggestions for safety procedures & PPE:

Protective eyewear
____

Additional safety procedures and Personal Protective Equipment (PPE) deemed necessary:
Training session for all employees
Occupational vision program
____

The safety needs to protect employees from the potential hazards involved when using lasers have been evaluated, all parties agree on control measures indicated, training is complete, and work can proceed.

M.D.
Responsible Physician Safety Officer Industrial Hygienist

Figure 7.2 Sample Facilities Preparedness and Procedures Statement (after Dux and Stalzer 1988)

10 J cm^{-2}, or that required to produce a hazardous diffuse reflection.

The only Class IV lasers that may be used in medicine are completely enclosed, so that accidental exposure to personnel cannot occur. Therefore, safety policies and procedures are not applicable. Prior to the purchase of a laser, some type of prepurchasing form (refer to Figure 7.2) should be completed and sent to the Health and Safety Officer.

Typically, lasers require very little monitoring. The manufacturer designates both the power level and the wavelength. With this information, the facility can classify the laser into one of the four classes (I-IV). The facility can then apply the controls based on the designated classification. The ACGIH lists the TLV's for lasers based on their exposure duration, radiation exposure, irradiance and wavelength. A laser safety form is often helpful in the gathering of information and when applying the proper controls (Figure 7.3).

7.5.2-2 Laser Control Most control measures depend on a laser's classification (I-V). Class V lasers are either Class II, Class III, or Class IV lasers that have been contained in a protective housing and are operated so that they are incapable of emitting hazardous radiation from the enclosure. A facility must install and maintain a stringent control system before any laser system can qualify for this level of classification. In general, Class I lasers are considered to be exempt of producing damaging radiation levels and therefore are exempt from any control measures or other forms of surveillance. A more detailed description of control methods are given below (Bretherick 1987, 249).

1. Class II - Low Power Visible Lasers: Precautions are required only to prevent continuos staring into the direct beam. Momentary exposure (quarter-second) is not considered to be hazardous.

- The laser beam should not be purposefully directed toward the eye of any person for exposure duration's that would be hazardous.

LASER SURVEY			
BUILDING NUMBER	ROOM NUMBER	ORGANIZATION	PHONE

OPERATORS		
NAME	SS	DATE OF PHYSICAL

HAZARD CONTROL EVALUATION	YES	NO
1. Are laser warning signs displayed?		
2. Is area secured or have limited access?		
3. Is beam termination adequate?		
4. Are laser safety glasses available?		
5. Are laser safety glasses identified?		
6. Is an SOP available?		
7. Are personnel aware of the laser health hazards?		
8. Is viewing of the beam with optical instruments performed?		
9. Are precautions for toxic gases, fumes, or projectiles adequate?		
10. Others?		
11. Training		
12.		
13.		
14.		

Figure 7.3 Example of a Laser Survey Form
(after Dux and Stalzer 1988)

- A warning label reading: "CAUTION. DO NOT STARE INTO LASER BEAM" should be placed in a conspicuous location on the exterior housing of the laser.
- Scanning lasers should be designed to prevent laser emission when the scanning ceases.

2. Class III - Medium Power, CW or Pulsed Laser Systems: These lasers are potentially hazardous if the direct beam is viewed by the unprotected eye. Care is required to prevent direct beam viewing and to control specular reflections.

- General safety precautions should be observed (e.g., not allowing the laser beam to be aimed at specular surfaces).
- The laser should be operated only in a well-controlled area.
- The laser beam should be terminated, where feasible, at the end of its useful beam path by interposing a material that is diffuse and of such color, or reflectivity as to make positioning possible by minimizing the reflection.
- Specularly reflective material should be eliminated from the beam area and good housekeeping should be maintained.
- Eye protection is required if direct beam (or specularly reflected beam) intraviewing is possible.

3. Class IV - High Power Laser Installation: Pulsed Class IV visible and near-infrared lasers are hazardous to the eye from direct beam viewing and from specular and diffuse reflections.

- A facility must deny access to unauthorized or transient personnel while the laser is capable of operating through the use of safety interlocks, or similar devices, at the entrance of the laser facility.
- Manufacturers should design laser electronic firing systems for pulsed lasers to preclude the accidental pulsing of a stored charge. For this purpose, the firing circuit design should incorporate a "fail safe" system.
- The safety procedure for pulsed lasers should include the use of an alarm

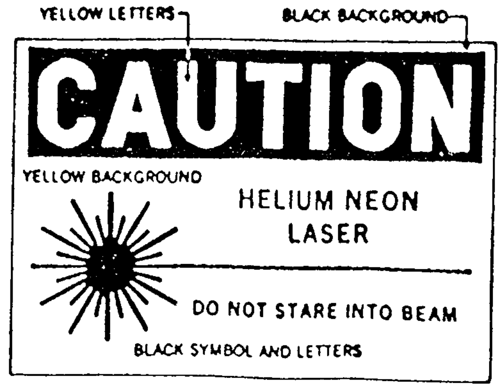


Figure 7.4 Label for Low Power Lasers
(after Dux and Stalzer 1988)

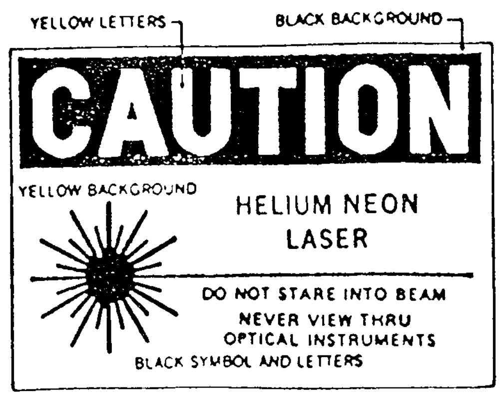


Figure 7.5 Label for Medium Power Visible Laser
(after Dux and Stalzer 1988)

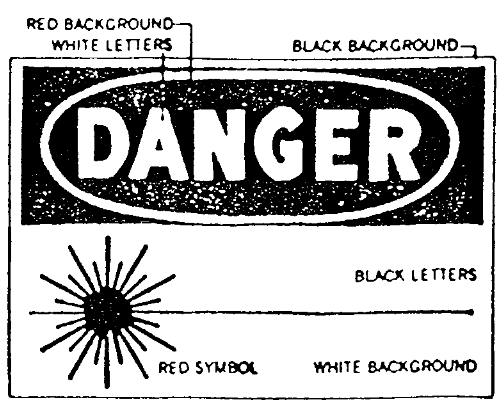


Figure 7.6 Label for Medium and High Power Lasers
(after Dux and Stalzer 1988)

system, including a muted sound and/or flashing lights and a countdown routine. This procedure should be initiated once the laser begins to charge.

- Good room illumination is important in areas where laser eye protection is required. Light colored, diffuse surfaces in the room help achieve this condition.
- Class IV pulsed ultraviolet, infrared and all CW lasers are a potential fire and skin hazard.

Signs should be posted in all potentially hazardous areas. Examples of signs are shown in Figure 7.4 - Figure 7.6.

7.5.3 Microwave Equipment

Microwave equipment has become commonplace in homes (ovens) and in the work environment (test equipment). In addition, microwave equipment is used in a laboratory technique known as diathermy. Operators who perform this technique are exposed to microwave radiation. Additionally, microwave ovens are also heavily used in laboratories. Facilities that use microwave equipment should follow the standards for exposure to microwave radiation developed by the Physical Agents Committee of ACGIH.

Microwave radiation affects molecular rotation and increases the kinetic energy of molecules in materials. The increase in kinetic energy has a thermal effect on the material which is a primary concern in body systems. Moderate heating of body tissue may cause the following: birth defects, testicular degeneration and partial or total sterility, cataracts, changes in immunological and endocrinal functions and behavioral anomalies (Martin and Habison 1989, 137). In the medical application, microwave diathermy, the typical frequency used falls between 30 and 3000 MHz, and the primary body organ of concern is the lens of the eye; the critical wavelength region for eye cataracts.

All microwave installations should be maintained at a periodic frequency that is based on frequency of use and the manufacturer's recommendation. All sampling of microwaves should be documented. Microwave exposures are measured in the same units as ultraviolet radiation, milliWatts per square centimeter (mW/cm^2). The TLV's for microwave exposure are as follows:

- A power density of 10 mW/cm^2 limit is allowed for an exposure period of not more than 8 hours in one day.
- A laboratory operator may not be exposed to microwave energy that has a power density between 10 and 25 mW/cm^2 for more than 10 minutes in any one hour period.
- Laboratory operators are not to be exposed to microwave energy that has a power density greater than 25 mW/cm^2.

A very important control measure for a microwave oven is a good periodic maintenance program in which the gaskets and general condition of the installation are both evaluated on a continual basis.

7.5.4 Ultrasound

Ultrasound can be used in laboratories as an imaging technique. The ultrasound TLV's presented by the ACGIH are centered around the third octave-band at 20 kHz. Below 20 kHz the subjective effects of this noise are not present, and on the third octave above 20 kHz hearing loss is possible because of the sub harmonics that exist at these frequencies. Table 7.1 presents the ultrasound TLV's.

7.6 Allergens and Embryotoxins [*CHP*]

7.6.1 Allergens

A wide variety of substances can produce skin and lung hypersensitivity. Examples include such common substances as diazomethane, chromium, nickel, bichromates, formaldehyde, isocyanates and certain phenols (Castegnaro and Sansone 1989, 123). Because of this variety and because of the varying response of individuals, suitable gloves should be used whenever hand contact with products of unknown activity is possible. The following guidelines should be adhered to:

- Gloves should be selected on the basis of the material being handled, the particular hazard involved and their suitability for the operation being conducted.
- Before each use, gloves should be inspected for discoloration, punctures and tears.
- Before removal, gloves should be washed appropriately. However, it is important to remember that some gloves, e.g., leather and polyvinyl alcohol are water permeable.
- Glove materials are eventually permeated by chemicals. However, they can be used safely for limited time periods if specific use and glove characteristics (thickness and permeation rate and time) are known. Some of this information can be obtained from glove manufacturers or the gloves can be tested for breakthrough rates and times.
- Gloves should be replaced periodically, depending on frequency of use and permeability to the substance handled. Gloves overtly contaminated should be rinsed (if impermeable to water) and then carefully removed.

There are various compositions and thicknesses of rubber gloves. Common glove materials include neoprene, polyvinyl chloride, nitrile, butyl and natural rubbers. These materials differ in their resistance to various substances. More specific information is available from glove manufacturers' catalogs.

7.6.2 Embryotoxins

Embryotoxins are substances that act during pregnancy to cause adverse effects on the fetus. These effects include embryolethality (death of the fertilized egg, the embryo, or the fetus), malformations (teratologic effects), retarded growth and postnatal functional deficits (Castegnaro and Sansone 1989, 129).

A few substances have been demonstrated to be embryotoxic in humans. These include organomercurials, lead compounds and the formerly used sedative, thalidomide. Many substances, some common (e.g., sodium chloride) have been shown to be embryotoxic to animals at some exposure level, but usually this is at a considerably higher level than in the course of the normal laboratory work. However, some substances do require special controls because of embryotoxic properties. One example is formamide. Women of child-bearing potential should handle this substance only in a hood and should take precautions to avoid skin contact with the liquid because of the ease with which it passes through the skin.

Since the period of greatest susceptibility to embryotoxins is the first 8-12 weeks of pregnancy, which includes a period when a woman may not know she is pregnant, women of child-bearing potential should take care to avoid skin contact with all chemicals. The following procedures are recommended to be followed routinely by women of child-bearing potential in working with chemicals requiring special control because of embryotoxic properties (Sitig 1985, 132):

1. Each use should be reviewed for particular hazards by the research supervisor, who will decide whether special procedures are warranted or whether warning signs should be posted. Consultation with appropriate safety personnel may be desirable. In cases of continued use of a known embryotoxin, the operation should be reviewed annually or whenever a change in procedures is made.
2. Embryotoxins requiring special control should be stored in an adequately ventilated area. The container should be labeled in a clear manner such as the following: EMBRYOTOXIN - READ SPECIFIC PROCEDURES FOR USE. If the storage container is breakable, it should be kept in an impermeable, unbreakable secondary container having sufficient capacity to retain the material should the primary container accidentally break.
3. Women of child-bearing age should be especially cautious in guarding against spills and splashes. Operations should be carried out using impermeable containers and in adequately ventilated areas. Appropriate safety apparel, especially gloves, should be

worn. All hoods, glove boxes or other essential engineering controls should be known to be operating at required efficiency before work is started.

4. Supervisors should be notified of all incidents of exposure or spills of embryotoxins requiring special control. A qualified physician should be consulted about any exposures of women (skin contact or any inhalation) of child-bearing age above the acceptable level.

7.7 Chemicals of Moderate Chronic or High Acute Toxicity [*CHP*]

7.7.1 Introduction

The procedures and precautions described below should be followed if any of the substances to be used in significant quantities is known to be moderately or highly toxic. If any of the substances being used is known to be highly toxic, it is desirable that there be two people present in the area at all times. These procedures should also be followed if the toxicological properties of any of the substances being used or prepared are unknown. If any of the substances to be used or prepared are known to have high chronic toxicity (e.g., compounds of heavy metals and strong carcinogens), then the precautions and procedures described below should be implemented with additional precautions to aid in containing and ultimately destroying substances that have high chronic toxicity.

7.7.2 Precautionary Measures

The overall objective is to minimize exposure of the laboratory worker to toxic substances, by any route of exposure and by taking all reasonable precautions. The following three precautions should always be followed (Martin, Lippit and Prothero 1987, 59):

1. Protect the hands and forearms by wearing either gloves and a laboratory coat or suitable long gloves to avoid contact of toxic material with the skin.

1. Protect the hands and forearms by wearing either gloves and a laboratory coat or suitable long gloves to avoid contact of toxic material with the skin.
2. Procedures involving volatile toxic substances and those involving solid or liquid toxic substances that may result in the generation of aerosols should be conducted in a hood or other suitable containment device. The hood should have been previously evaluated to establish that it is providing adequate ventilation and has an average face velocity of not less than 60 linear ft/min.
3. After working with toxic materials, wash the hands and arms immediately. Never eat, drink, smoke, chew gum, apply cosmetics, take medicine or store food in areas where toxic substances are being used.

These standard precautions will provide laboratory operators with good protection from most toxic substances. In addition, records that include amounts of material used and names of workers involved should be kept as part of the laboratory notebook record of the experiment. To minimize hazards from accidental breakage of apparatus or spills of toxic substances in the hood, containers of such substances should be stored in pans or trays made of polyethylene or other chemically resistant material. Apparatus should be mounted above trays of the same type of material. Alternatively, the working surface of the hood can be fitted with a removable liner of adsorbent plastic-backed paper. Such procedures will contain spilled toxic substances in a pan, tray or adsorbent liner and greatly simplify subsequent cleanup and disposal. Vapors that are discharged from the apparatus should be trapped or condensed to avoid adding substantial amounts of toxic vapor to the hood exhaust air. Areas where toxic substances are being used and stored should have restricted access and special warning signs posted if a special toxicity hazard exists

7.7.3 Waste Disposal

Proper waste disposal procedures are important to follow. Volatile toxic substances should never be disposed of by evaporation in the hood (Pepitone 1989, 79). If practical, waste materials and waste solvents containing toxic substances should be decontaminated chemically by some procedure that can reasonably be expected to convert essentially all of the toxic substance to non toxic substances. If chemical decontamination is not feasible, the waste materials and solvents containing toxic substances should be stored in closed, impervious containers so that personnel handling the containers will not be exposed to their contents. In general, liquid residues should be contained in glass or polyethylene bottles half filled with vermiculite. All containers of toxic wastes should be suitably labeled to indicate the contents (chemicals and approximate amounts) and the type of toxicity hazard that the contact may pose. For example, containers of wasted from experiments involving appreciable amounts of weak or moderate carcinogens should carry the warning: CANCER SUSPECT AGENT. All wastes and residues that have not been chemically decontaminated in the exhaust hood where the experiment was carried out should be disposed of in a safe manner that ensures that personnel are not exposed to the material.

The laboratory worker should be prepared for possible accidents or spills involving toxic substances. If a toxic substance contacts the skin, the area should be washed well with water or a safety shower should be used. If there is a major spill outside the hood, the room or appropriate area should be evacuated and necessary measures to prevent exposure of other workers should be taken. Spills should be cleaned up by personnel wearing suitable personal protective apparel. If a spill of a toxicollogiacally significant quantity of a toxic material occurs outside the hood, a supplied air, full face respirator should be worn. Contaminated clothing and shoes should be thoroughly decontaminated or incinerated.

7.8 Chemicals of High Chronic Toxicity [*CHP*]

7.8.1 Introduction

All the precautions and procedures described in the previous section (7.7) should be followed when working with substances known to have high chronic toxicity. In addition, when such substances are to be used in quantities in excess of a few milligrams to a few grams (depending on the hazard posed by the particular substance), the additional precautions described below should be followed. Each laboratory worker's plans for experimental work and for disposing of waste materials should be approved by the laboratory supervisor. Consultation with the department safety coordinator may be appropriate to ensure that the toxic material is effectively contained during the experiment and that waste materials are disposed of in a safe manner. Substances in this high chronic toxicity category include certain heavy metal compounds and compounds normally classified as strong carcinogens. Examples of compounds frequently considered to be strong carcinogens include the following: benzopyrene, 3-methylcholanthrene, 12-dimethylbenz anthracene, dimethylcarbamoyl chloride, hexamethylphosphoramide, 2-nitronaphthalene, propane sultone and many N-nitrosamides.

7.8.2 Recordkeeping and Labeling Requirements

An accurate record of the amounts of such substances being stored and the amounts used, dates of use, and names of users should be maintained. It may be appropriate to keep such records as part of the record of experimental work in the laboratory workers' research notebooks, but it must be understood that the research supervisor is responsible for ensuring that accurate records are kept. Any volatile substances having high chronic toxicity should be stored in a ventilated storage area in a secondary tray or container having sufficient capacity to contain the material should the primary container accidentally break. All containers of substance in this category should have labels that identify the contents and include a warning such as the following: WARNING: HIGH CHRONIC

TOXICIY or CANCER-SUSPECT AGENT. Storage areas for substances in this category should have limited access and special signs should be posted if a special toxicity hazard exists. Any area used for substances of high chronic toxicity should be maintained under negative pressure with respect to surrounding areas (DiBerardinis 1987, 112).

7.8.3 General Guidelines

All experiments with and transfers of such substances or mixtures containing these substances should be performed in a controlled area A controlled area is a portion of a laboratory or a facility such as an exhaust hood or a glove box that is designated for the use of highly toxic substances. Its use need not be restricted to the handling of toxic substances if all personnel who have access to the controlled area are aware of the nature of the substances being used and the precautions that are necessary. If a negative pressure glove box is used in which work is done thorough attached gloves, the ventilation rate in the glove box should be at least two volume changes per hour. The pressure should be at least 0.5 in. of water lower than that of the external environment and the exit gases should be passed through a trap or a high efficiency particular air (HEPA) filter (DiBerardinis 1987, 119). Positive pressure glove boxes are normally used to provide an inert anhydrous atmosphere. If these glove boxes are used with highly toxic compounds, then the box should be thoroughly checked for leaks before each use and the exit gases should be passed through a suitable trap or filter. Laboratory vacuum pumps used with substances having high chronic toxicity should be protected by high efficiency scrubbers or HEPA filters and vented into an exhaust hood. Motor driven vacuum pumps are recommended because they are easy to decontaminate. Decontamination of a vacuum pump should be carried out in an exhaust hood. Controlled areas should be clearly marked with a conspicuous sign such as the following: WARNING: TOXIC SUBSTANCE IN USE or CANCER SUSPECT AGENT: AUTHORIZED PERSONNEL

ONLY. Only authorized and instructed personnel should be allowed to work in or have access to controlled areas.

7.8.4 Precautionary Measures

Proper gloves should be worn when transferring or otherwise handling substances or solutions of substances having high chronic toxicity. In some cases, the laboratory operator or research supervisor may deem it advisable to use other protective apparel, such as an apron of reduced permeability covered by a disposable coat. Extreme precautions such as these might be taken, for example, when handling large amounts of certain heavy metals and their derivatives or compounds known to be potent carcinogens. Surfaces on which high chronic toxicity substances are handled should be protected from contamination by using chemically resistant trays or pans that can be decontaminated after the experiment or by using dry, adsorbent, plastic-backed paper that can be disposed of after use.

On leaving a controlled area, laboratory workers should remove any protective apparel that has been used and thoroughly wash hands, forearms, face and neck. If disposable apparel or adsorbent paper liners have been used, these items should be placed in a closed and impervious container that should then be labeled in some manner such as the following: CAUTION: CONTENTS CONTAMINATED WITH SUBSTANCES OF HIGH CHRONIC TOXICITY. Non disposable protective apparel should be thoroughly washed and containers of disposable apparel and paper liners should be incinerated (Bretherick 1987, 76).

7.8.5 Waste Disposal

Wastes and other contaminated materials from an experiment involving substances of high chronic toxicity should be collected together with the washings from flasks and either decontaminated chemically or placed in closed, suitably labeled containers for incineration away from the controlled area. If chemical decontamination is to be used, a method should be chosen that can reasonably be expected to convert essentially all of the toxic materials into non toxic materials.

In the event that chemical decontamination is not feasible, wastes and residues should be placed in an impervious container that should be closed and labeled in some manner such as the following: CAUTION: COMPOUNDS OF HIGH CHRONIC TOXICITY or CAUTION: CANCER-SUSPECT AGENT. Transfer of contaminated wastes from the controlled area to the incinerator should be done under the supervision of authorized personnel and in such a manner as to prevent a spill or loss. In general, liquid wastes containing such compounds should be placed in glass or polyethylene bottles half filled with vermiculite and these should be transported in plastic or metal pails of sufficient capacity to contain the material in case of accidental breakage of the primary container (Bretherick 1987, 82).

7.8.6 Decontamination

Normal laboratory work should not be resumed in a space that has been used as a controlled area until it has been adequately decontaminated. Work surfaces should be thoroughly washed and rinsed. If experiments have involved the use of finely divided solid materials, dry sweeping should not be done. In such cases, surfaces should be cleaned by wet mopping or by use of a vacuum cleaner equipped with a HEPA filter. All equipment (e.g., glassware, vacuum traps and containers) that is known or suspected to have been in contact with substances of high chronic toxicity should be washed and rinsed before they are removed from the controlled area (Sitig 1985, 211).

In the event of continued experimentation with a substance of high chronic toxicity (i.e., if a laboratory user regularly uses toxicologically significant quantities of such a substance three times a week), a qualified physician should be consulted to determine whether it is advisable to establish a regular schedule of medical surveillance or biological monitoring.

Additionally, certain state and federal regulatory agencies have listed substances whose use and disposal is regulated. These lists of regulated substances are usually accompanied by specific requirements for use and disposal. The list of substances and the requirements for use and disposal are changing frequently. Since compliance of these requirements is required by law, every department safety coordinator and all research supervisors should know the current lists of regulated substances and the requirements for their use and disposal.

7.9 Animal Work with Chemicals of High Chronic Toxicity [*CHP*]

The use of substances of high chronic toxicity in experimental animals can present a special exposure hazard, in particular because of the possibility of the formation of aerosols or dusts that contain the toxic substance. Such dusts and aerosols can become dispersed throughout the laboratory or animal quarters through the animal food, urine or feces. Accordingly, procedures should be devised that reduce the formation of such aerosols and dusts to the lowest possible level. All procedures should be designed to minimize the possible exposure of personnel.

Administration of the substances by injection or gavage is preferable (Martin, Lippit and Prothero 1987, 239). However, if it is to be administered in the diet, a relatively closed caging system, either one in which the cages are under negative pressure or one in which there is a horizontal laminar airflow directed toward HEPA filters, should be used. Procedures such as the use of a vacuum cleaner equipped with a HEPA filter or wetting the bedding to reduce dusts should be used for the removal of contaminated bedding or cage matting. All toxic substance-containing diets should be mixed within closed containers and within a hood.

Workers carrying out such operations should wear plastic or rubber gloves and a fully buttoned laboratory coat or equivalent clothing at all times. If exposure to aerosols cannot be controlled in other ways, a respirator should be used. When large scale studies are being carried out with highly toxic substances, special facilities or rooms having restricted access are preferable (Martin, Lippit and Prothero 1987, 240). If the caging system for any test animals does not adequately protect the personnel, the use of a jumpsuit or similar clothing with shoe and head coverings should be considered.

CHAPTER 8

SUMMARY AND CONCLUSIONS

8.1 Analysis of the Guide

The Occupational Safety and Health Administration recently enacted the standard 29 CFR 1910.1450 entitled, "Occupational Exposures to Hazardous Chemicals in the Laboratory." This standard requires that a Chemical Hygiene Plan be formulated to protect all persons from health hazards associated with toxic substances used in laboratories. Typically, industrial laboratories employ knowledgeable professionals to work with consistent, well defined laboratory operations. In such an environment, compliance guidelines may be readily established and implemented. However, academic laboratories warrant special consideration. Several distinct characteristics confronting an academic laboratory include: a broad range of research and experimentation, curriculum revisions and the continual admittance of new laboratory personnel (students). The above factors present colleges and universities with the unique challenge of ensuring laboratory health and safety.

The objective of the "Laboratory Health and Safety Compliance Guide for Private Colleges and Universities" is to assist private colleges and universities to establish and implement a laboratory health and safety plan consistent with applicable OSHA and EPA regulations. The guide is written in a manner to cover a wide range of topics and applications which account for the varying health and safety concerns faced by academic laboratories. Such a broad presentation of subject matter allows each college and university to select the appropriate material tailored to its continual, yet varying, needs.

8.1.1 Advantages

There are numerous advantages to a laboratory health and safety guide. A comprehensive guide will serve not only as a legal document to ensure government compliance, but will also provide a solid basis upon which to ensure the health and safety of all involved persons. If properly adhered to, this guide should assure an intrinsically safe environment, thus decreasing the quantity and severity of accidents and injuries associated with laboratory operations.

An effective laboratory health and safety guide should define the proper procedures, actions and steps necessary to minimize injuries and accidents. Such a written policy of health and safety will provide consistent guidelines to follow. A comprehensive laboratory health and safety guide will also serve as an important resource for specific information, and provide crucial facts in the event of an emergency. The formulation and implementation of such a guide is a proactive approach in the prevention and minimization of all associated laboratory hazards.

8.1.2 Recommendations

A laboratory health and safety guide constitutes one part of an overall health and safety program. The entire academic community should be aware of the establishment and existence of the guide. The document should be written consistent with previously established academic manuals. Additionally, the guide should be distributed to the appropriate persons and be readily accessible during all laboratory operations.

The manual should be written by someone who understands the specific needs of the particular school and the scope of all laboratory operations. The guide must be expressed in a concise, comprehensible manner which is readily understood by all potential laboratory operators (including maintenance personnel). A comprehensive table of contents should be included for easy reference. Also, an index should be created listing specific topics, in addition to names and telephone numbers of people to contact in the event of an emergency.

The guide should incorporate all potential hazards and be thoroughly reviewed by both administrators and students. Such a review will ensure that all relevant material is incorporated in a manner which can be readily interpreted and implemented. The document must be continually reviewed. This review process will ensure that all new laboratory operations are accounted for, in addition to adhering to all relevant government regulations.

8.2 Considerations for Laboratory Health and Safety

All individuals exposed to laboratory operations are subjected to many kinds of hazards. Although this can be said of most workplaces and environments, laboratories characteristically contain a greater variety of possible hazards, thus requiring precautions not ordinarily encountered. In particular, academic laboratories have the unique responsibility of introducing relatively inexperienced students to laboratory procedures and safety precautions necessary to properly conduct all laboratory operations.

It is crucial to identify and regulate potential hazards to help minimize the associated risks of laboratory activities. The formulation of a comprehensive laboratory health and safety program will permit each college and university to assess its specific laboratory health and safety needs. Additionally, a guide will help ensure compliance with the new OSHA laboratory regulation (29 CFR 1910.1450), and to provide all laboratory personnel with a document upon which to model their behavior. However, the actual writing of a laboratory health and safety guide is just one step in ensuring overall laboratory safety.

Important academic administrators (college or university President, Provost, Vice Presidents, etc.) should be informed of the hazards involved and asked to support a comprehensive laboratory health and safety program. Such influential support will enhance the overall program, making it an important part of the university's commitment to its administrators, faculty, staff and students. The documented plan must be implemented and enforced. Using proper procedures must be continually stressed, and in many instances taught. Safe procedures and actions should not be taken for granted, but rather, continually reinforced. In conclusion, the formulation and implementation of a laboratory health and safety guide is a difficult task requiring much time and effort. However, once established, the laboratory health and safety guide will serve as more than a commitment to satisfy government regulations; it will fulfill the school's moral responsibility to teach and ensure perhaps the most fundamental lesson of all - health and safety.

Appendix A

Glossary of Acronyms Used

Glossary of Acronyms Used

ACGIH:	American Conference of Governmental Industrial Hygenists
AIHA:	American Industrial Hygiene Association
ALARA:	as low as reasonably achievable
ANSI:	American National Standards Institute
BNA:	Bureau of nAtional Affairs
CDC:	Centers for Disease Control
CERCLA:	Comprehensive Environmental Response, Compensation and Liability Act
CFR:	Code of Federal Regualtions
CPR:	Cardio Pulminary Resuscitation
CW:	Continous Wave
DHR:	Design HAzard Review
DOT:	Department of Transportation
EPA:	U.S. Environmental Protection Agency
FR:	Federal Register
HEPA:	High Efficiency Particualte Air (filter)
HSO:	Health and Safety Officer
IARC:	International Agency for Research on Cancer
LASER:	Light Amplification by the Stimulated Emission of Radiation
LC50:	Concentration of material in air that causes death of 50% of test animals
LD50:	Single dose quantity of material that will cause death of 50% of test animals
LEV:	Local Exhaust Ventillation
MSDS:	Material Safety Data Sheet
MSHA:	Mine Safety and Health Act
NFPA:	National FIre Protection Agency
NIH:	National Institutes of Health
NIOSH:	National Institute for Occupational Safety and Health
NRC:	Nuclear Reglatory Commission
OSH Act:	Occuppational Safety and Health Act
OSHA:	Occupational Safety and Health Administration
PCB:	Polychlorinated biphenyl
PEL:	Permissible Exposure Limit
PPE:	Personal Protective Equipment
RCRA:	Resource Conservation and Recovery Act
RCRA:	Resource Conservation and Recovery Act of 1976
RSO:	radiation safety officer
SOP	Standard Operating Procedure
TLV:	Threshold Limit Value
TLV:	Threshold Limit Value (established by ACGIH)
TSCA:	Toxic Substance Control Act
TWA:	Time Weighted Average
VDT:	Video Display Terminal

Appendix B

Example of a Material Safety Data Sheet

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements.

U.S. Department of Labor
Occupational Safety and Health Administration
(Non-Mandatory Form)
Form Approved
OMB No. 1218-0072

IDENTITY (As Used on Label and List)
STREETEX

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: R. R. Street & Co., Inc.	Emergency Telephone Number: 1-800-228-5635
Address (Number, Street, City, State, and ZIP Code): 625 Enterprise Drive	Telephone Number for Information: 312-571-4242
OakBrook, IL 60521	Date Prepared: January, 1988

Section II — Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	CAS #	% (optional)
Trade Secret	Not Established	C 25 p.p.m.	Trade Secret	
Trade Secret	Not Established	Not Established	Trade Secret	
Trade Secret	Not Established	Not Established	Trade Secret	

Section III — Physical/Chemical Characteristics

Boiling Point °F	210	Specific Gravity (H_2O = 1)	1.018
Vapor Pressure (mm Hg.) @ 20°C, Estimated	17	Melting Point: Not Applicable.	—
Vapor Density (AIR = 1) Solvents, average	2.3	Evaporation Rate (Butyl Acetate = 1) Estimated, initial	0.3
Solubility in Water: Complete.		pH	7

Appearance and Odor
Clear, water white, mild odor.

Section IV — Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
None at boiling point, (C.O.C.)	Not Applicable.	—	—

Extinguishing Media
Not Applicable.

Special Fire Fighting Procedures
Not Applicable.

Unusual Fire and Explosion Hazards
Not Applicable.

Section V — Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable	X	None.

Incompatibility (*Materials to Avoid*)
Strong oxidizing agents, strong acids, and alkalies.

Hazardous Decomposition or Byproducts
Carbon dioxide, carbon monoxide, and oxides of sulfur.

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur	X	None.

Section VI — Health Hazard Data

Route(s) of Entry	Inhalation?	Skin?	Ingestion?
	Primary	Secondary	Unlikely

Health Hazards (*Acute and Chronic*)
Inhalation: May cause headache. Skin: Prolonged or widespread exposure may result in the absorption of potentially harmful amounts. Eyes: Liquid may cause corneal damage. Ingestion: May be absorbed and produce central nervous system depression; in extreme cases, unconsciousness and death.

Carcinogenicity:	NTP?	IARC Monographs?	OSHA Regulated?
	No	No	No

Signs and Symptoms of Exposure
Inhalation: Dizziness, drowsiness, nasal, and respiratory irritation. Skin: Irritation. Eyes: (Liquid) - Severe irritation; (Vapor) - Irritation. Ingestion: Headache, dizziness nausea, vomiting, diarrhea, and irritation of the gastrointestinal tract. Vomit can be aspirated into lungs, causing chemical pneumonia.

Medical Conditions Generally Aggravated by Exposure Not Available.

*Emergency and First Aid Procedures
Inhalation: Remove to fresh air. If breathing stops, give artificial respiration. Call a physician. Skin: Remove contaminated clothing. Wash with water. Eyes: Flush eyes with water for at least 15 minutes. Call a physician. Ingestion: Call a physician immediately. Do not induce vomiting unless instructed to do so by poison center or physician.

Section VII — Precautions for Safe Handling and Use

Steps to Be Taken in Case Material Is Released or Spilled
Wear protective equipment (Sec. VIII). Clean up with absorbent and place in closed containers for disposal. Avoid discharge to natural waters. Do not flush to sewer.

Waste Disposal Method
Dispose of in accordance with Federal, state, and local regulations.

Precautions to Be Taken in Handling and Storing
Store in sealed, labelled containers.

Other Precautions
Do not wear contact lenses. Do not breath spray or vapor. Avoid contact with skin and eyes.

Section VIII — Control Measures

Respiratory Protection (*Specify Type*) Organic vapor-type respirator with mist pre-filter if T.L.V. is exceeded. Self-contained breathing apparatus in high concentrations.

Ventilation	Local Exhaust: If necessary.	Special: Not Applicable.
	Mechanical (General): If adequate to keep concentration below 25 p.p.m. ceiling.	Other: Open doors and/or windows.

Protective Gloves: P.V.C.

Eye Protection: Chemical goggles or face shield.

Other Protective Clothing or Equipment
Eye wash station.

Work/Hygienic Practices
Wash thoroughly after handling. Do not eat or drink in work area.

* U.S.G.P.O. 1986-491-529/45775

*After emergency actions: Call the emergency medical information number on this sheet or a physician immediately for further instructions.

Appendix C

Vendors of Monitoring Equipment

Calibration Gases and Equipment

Air Engineers, Inc., Safety & Health Division
American Bristol Industries, Inc.
Ashland Chemical Company
Bacharach, Inc.
Briggs Weaver, Inc.
Calibrated Instruments, Inc.
Carey Machinery & Supply Company, Inc.
CEA Instruments, Inc.
Chapin Ashuelot Medical & Safety Supply
Continental Safety Equipment, Inc.
CSE Corporation
Day Star Corporation
Detcon, Inc.
Digicolor
Direct Safety Company
Dynamation, Inc.
Eastco Industrial Safety Corporation
ECI United Safety, Inc.
Environmental Compliance Corporation
Gas Tech, Inc.
GC Industries, Inc.
GT Safety Equipment, Inc.
IMR Corporation
Industrial Products Company
Industrial Protective Equipment Supply Company
International Ecology Systems Corporation
Interstate Safety & Supply, Inc.
Jones Safety Supply, Inc.
Kurz Instruments, Inc.
Lifecom Safety Service & Supply Company
Lumidor Safety Products
Mast Development Company
Matheson Gas Products, Inc.
MSA
National Draeger, Inc.
National Mine Service Corporation
Newark Glove & Safety Equipment Company, Inc.
Pendergast Safety Equipment
Precision Flow Devices
Pro Am Safety
ProTech Safety Equipment, Inc.
Protective Equipment, Inc.
Raeco, Inc.
Reis Equipment Company
Safety Services, Inc.
Safety Supply Canada
Scott Specialty Gases
Sensidyne, Inc.
Sierra Monitor Corporation
SKC West, Inc.
Standard Safety Equipment Company
Tackaberry Company

Texas Analytical Controls, Inc.
Thermo Environmental Instruments
Tierney Safety Products
Tracor Atlas, Inc.
Vallen Safety Supply Company
VICI Metronics
Wolsk Alarms, Ltd.

Carbon Monoxide Monitors and Detectors

Acme Engineering Products, Inc.
Advanced Chemical Sensors Company
M. Clifford Agress, PE
Air Engineers, Inc., Safety & Health Division
American Bristol Industries, Inc.
Andersen Samplers, Inc.
Arbill, Inc.
Bacharach, Inc.
Baseline Industries
Biotrak, Inc.
Briggs Weaver, Inc.
Butler National Corporation
Calibrated Instruments, Inc.
Carey Machinery & Supply Company, Inc.
CEA Instruments, Inc.
Chapin Ashuelot Medical & Safety Supply
Chestec, Inc.
Conney Safety Products Company
Continental Safety Equipment, Inc.
Control Instruments Corporation
Critical Services
CSE Corporation
Day Star Corporation
Delaware Valley Safeguard
Devco Engineering, Inc.
Direct Safety Company
Dynamation, Inc.
Dynatron, Inc.
Eagle Air Systems
Eastco Industrial Safety Corporation
ECI United Safety, Inc.
Engwald Corporation
Emmet Corporation
Enterra Instrumentation Technologies, Inc.
Foxboro Company
Gas Tech, Inc.
GfG Gas Electronics, Inc.
GT Safety Equipment, Inc.
Halprin Supply Company
Hazco, Inc.
Health Consultants, Inc.
High Pressure Equipment, Inc.
Horiba Instruments, Inc.
Hub Safety Equipment
Industrial Analytical Laboratory, Inc.
Industrial Products Company
Industrial Protective Equipment Supply Company
Industrial Safety Products, Inc.
Industrial Scientific Corporation
International Sensor Technology

Interscan Corporation
Interstate Industrial Supply
Interstate Safety & Supply, Inc.
Jones Safety Supply, Inc.
Kanton Air Products Corporation
Laboratory Safety Supply Company
Lifecom Safety Service & Supply Company
Lumidor Safety Products
Macurco, Inc.
Mateson Chemical Corporation
Matheson Gas Products, Inc.
MC Products
MDA Scientific, Inc.
Metrosonics, Inc.
Mine Safety Appliance Company
MSA
National Draeger, Inc.
National Mine Service Company
Neotronics
Neutronics, Inc.
Newark Glove & Safety Equipment Company, Inc.
Frank Niemi Products, Inc.
Pedly & Knowles & Company
Pendergast Safety Equipment
Pro Am Safety
ProTech Safety Equipment, Inc.
Racal Airstream, Inc.
Raeco, Inc.
Reis Equipment, Inc.
Rockford Medical & Safety Company
Roxan, Inc.
Rubin Brothers
Safety Services, Inc.
Scott Aviation
Sensidyne, Inc.
Sheridan Safety Supply, Inc.
Sieger Gasalarm
Sierra Monitor Corporation
SKC West, Inc.
Standard Marketing International, Inc.
Standard Safety Equipment Company
Sunshine Instruments
Syracuse Safety Services, Inc.
Tackaberry Company
Thermo Environmental Instruments
Trace Analytical
Tracor Atlas, Inc.
Trusafe, Inc.
US Industrial Products Company, Inc.
US Safety, Ceeso Service Company
Vallen Safety Supply Company
Ward International
Wise El Santo Company
Wolsk Alarms Ltd.

Detector Tubes

Advanced Chemical Sensors Company
Air Engineers, Inc., Safety & Health Division
American Bristol Industries, Inc.
Arbill, Inc.
Automation Products, Inc.
Bacharach, Inc.
BGI, Inc.
Carey Machinery & Supply Company, Inc.
Chapin Ashuelot Medical & Safety Supply
Chemrox, Inc.
Continental Safety Equipment, Inc.
Day Star Corporation
Delaware Valley Safeguard
Detector Electronics Corporation
ECI United Safety, Inc.
Edcor Safety
Emmet Corporation
Environmental Compliance Corporation
Fire House
Foxboro Company
GT Safety Equipment, Inc.
Hazco, Inc.
Health Consultants, Inc.
Industrial Analytical Laboratory, Inc.
Industrial Products Company
Interstate Safety & Supply, Inc.
Jones Safety Supply, Inc.
Lifecom Safety Service & Supply Company
Matheson Gas Products, Inc.
Mine Safety Appliance Company
MSA
National Draeger, Inc.
National Mine Service Company
PCP, Inc.
Pedly & Knowles & Company
Pendergast Safety Equipment
ProTech Safety Equipment, Inc.
Protective Equipment, Inc.
Raeco, Inc.
Reis Equipment Company
Roxan, Inc.
Safety Services, Inc.
Safety Supply Canada
Scott Specialty Gases
Sensidyne, Inc.
Sheridan Safety Supply, Inc.
AJ Sipin Company, Inc.
SKC, Inc.
SKC West, Inc.
Standard Safety Equipment Company
Syracuse Safety Services, Inc.
Tackaberry Company
Tierney Safety Products
Vallen Safety Supply Company

Formaldehyde Monitors and Detectors

Advanced Chemical Sensors Company

Aetna Technical Services, Inc.
Air Engineers, Inc., Safety & Health Division
Air Quality Research
American Medical Laboratories Inc., Industrial Hygiene Division
Anacon
Andersen Samplers, Inc.
Arbill, Inc.
Assay Technology, Inc.
Bacharach, Inc.
Baseline Industries
Butler National Corporation
Carey Machinery & Supply Company, Inc.
CEA Instruments, Inc.
Continental Safety Equipment, Inc.
Day Star Corporation
Delaware Valley Safeguard
Devco Engineering, Inc.
Direct Safety Company
Eastco Industrial Safety Corporation
ECI United Safety, Inc.
Edcor Safety
Emmet Corporation
Environmental Compliances Corporation
Foxboro Corporation
GT Safety Equipment, Inc.
Hager Laboratory, Inc.
Hazco, Inc.
HNU Systems, Inc.
Holland Safety Supply
Industrial Analytical Laboratory, Inc.
Industrial Products Company
Industrial Protective Equipment Supply Company
International Ecology Systems Corporation
International Sensor Technology
Interstate Safety & Supply, Inc.
Laboratory Safety Supply Company
LaMotte Chemical
Macurco, Inc.
Mateson Chemical Corporation
Matheson Gas Products, Inc.
MDA Scientific, Inc.
National Draeger, Inc.
National Mine Service Company
PCP, Inc.
Delta Thermographics, Inc.
Dyn Optics
Epic, Inc.
Fox Valley Systems, Inc.
Foxboro Company
Gas Tech, Inc.
Horiba Instruments, Inc.
Ikegami Electronics USA, Inc.
International Light, Inc.
Interstate Safety & Supply, Inc.

MC Products
MSA
Neotronics
Pacer Industries, Inc.
Racco, Inc.
Teledyne Analytical Instruments

Personal Monitors

Advanced Chemical Sensors Company
Air Engineers, Inc., Safety & Health Division
Air Quality Research
American Gas & Chemical Company Ltd.
American Medical Laboratories, Inc., Industrial Hygiene Division
Anacon
Andersen Samplers, Inc.
Arbill, Inc.
Asbestos Control Technology, Inc.
Assay Technology, Inc.
Audio Medical, Inc.
Bacharach, Inc.
Baird Corporation
BGI, Inc.
Briggs Weaver, Inc.
Butler National Corporation
Carey Machinery & Supply Company, Inc.
Chapin Ashuelot Medical & Safety Supply
Chemrox, Inc.
Continent Safety Equipment, Inc.
Critical Services
Day Star Corporation
Delaware Valley Safeguard
Devco Engineering, Inc.
Direct Safety Company
Dosimeter Corporation of America
Du Pont de Nemours & Company, Inc.
Dynamation, Inc.
Eastco Industrial Safety Corporation
ECI United Safety, Inc.
Emmet Corporation
Environmental Compliance Corporation
Environmental Safety Products, Inc.
ESA Laboratories, Inc.
Gabriel Environmental Energy
GasTech, Inc.
GC Industries, Inc.
GfG Gas Electronics, Inc.
GMD Systems, Inc.
Grace Industries, Inc.
GT-Safety Equipment, Inc.
Hager Laboratory, Inc.
Halprin Supply Company
Hazco, Inc.
Health Consultants, Inc.
Honba Instruments, Inc.
ICN Dosimetry Services
Ikegami Electronics USA, Inc.
Impact Hearing Conservation, Inc.

Industrial Hygiene Specialties Company
Industrial Products Company
Industrial Protective Equipment Supply Company
Industrial Safety Products, Inc.
Industrial Scientific Corporation
International Sensor Technology
Interscan Corporation
Interstate Safety & Supply, Inc.
Pendergast Safety Equipment
Photovac, Inc.
ProTech Safety Equipment, Inc.
Racco, Inc.
Reis Equipment Company
Roxan, Inc.
Safety Services, Inc.
Safety Supply Canada
Sensidyne, Inc.
Sentex Sensing Technology, Inc.
Sheridan Safety Supply, Inc.
Sierra Monitor Corporation
SKC, Inc.
SKC West, Inc.
Standard Safety Equipment Company
Syracuse Safety Services, Inc.
Tackaberry Company
Thomas Scientific
3M Company Occupational Health & Safety Products
Tierney Safety Products
US Industrial Products Company, Inc.
Vallen Safety Supply Company
Wise El Santo Company

Hydrocarbon Detectors and Analyzers

Andersen Samplers, Inc.
Bacharach, Inc.
CEA Instruments, Inc.
Control Instruments Corporation
CSE Corporation
Day Star Corporation
Devco Engineering, Inc.
Digicolor
ERDCO Engineering Corporation
Foxboro Company
General Monitors, Inc.
Gow Mac Instrument Company
International Sensor Technology
Lumidor Safety Products
Macurco, Inc.
Matheson Gas Products, Inc.
Photovac, Inc.
Safety Supply Canada
Sensidyne, Inc.
Sentex Sensing Technology, Inc.
Sentrol Industrial, Inc.
Sierra Monitor Corporation
Thermo Environmental Instruments

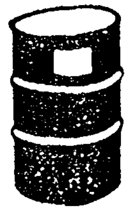
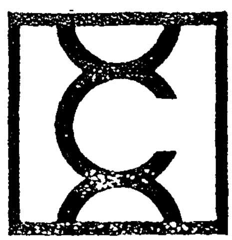
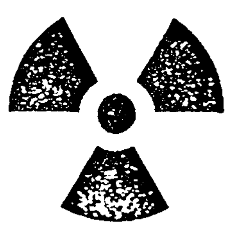
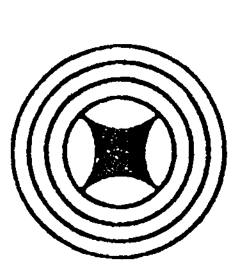
Tracor Instruments

Infrared Analyzers and Accessories

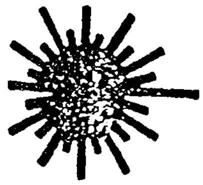
Anacon
Astro Resources International Corporation
Jerome Instrument Corporation
Jones Safety Supply, Inc.
Laboratory Safety Supply Company
RS Landauer Jr. & Company
Lifecom Safety Service & Supply Company
Lumidor Safety Products
Mateson Chemical Corporation
Matheson Gas Products, Inc.
MC Products
MDA Scientific Inc.
Metrosonics, Inc.
Mine Safety Appliance Company
MSA
National Draeger Inc.
National Mines Service Company
Neotronics
Nuclear Associates
Nuclepore Corporation
Pendergast Safety Equipment
ProTech Safety Equipment, Inc.
Protective Equipment, Inc.
Raeco, Inc.
React Environmental Crisis Engineers
Safety Services, Inc.
Safety Supply Canada
Scott Specialty Gases
Sensidyne, Inc.
Sentrol Industrial, Inc.
Sierra Monitor Corporation
SKC, Inc.
SKC West, Inc.
Somatronix Research Corporation
Spectrex Corporation
Sperry Vision Corporation
Standard Marketing International, Inc.
Standard Safety Equipment Company
Supelco, Inc.
Syncor International Corporation
Syracuse Safety Services, Inc.
Tackaberry Company
Technical Associates
Teledyne Analytical Instruments
Texas Analytical Controls, Inc.
Thermo Analytical, Inc.
Thermonetics Corporation
3M Company, Occupational Health & Safety
Tierney Safety Products
Tornado Enterprises, Inc.
Vallen Safety Supply Company
Ward International
Wise El Santo Company
Xetex, Inc.

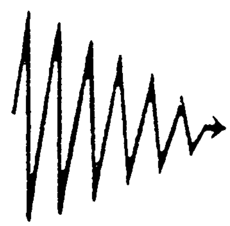
Appendix D

Examples of Caution Signs

Sticker:	*Description:*
 CHEMICAL STORAGE	New Jersey Regulated Hazardous Substance: Room may contain one or more of the Right-To-Know listed materials in quantity.
 CANCER HAZARD	Potential Cancer Hazard: Room may contain one or more of the Regulated Carcinogens and/or Class I Suspect Carcinogens in any quantity.
 RADIATION HAZARD	Caution Radioactive Material: Room is designated for radioisotope use and may contain one or more radioisotopes.
 MICROWAVE RADIATION	Microwave Radiation: Room may contain an instrument which emits microwaves.

Sticker:	*Description:*
 FLAMMABLE SOLVENTS	Flammable: This symbol will indicate the presence of highly flammable substances (ones with low flash points). No smoking or heat sources or any other types of ignition sources should be in the area.
 HIGH VOLTAGE	High Voltage: This symbol will indicate an area with high voltage current, extreme caution should be used when in the area. Severe electrical shock could occur.
 NO SMOKING	No Smoking: This symbol will indicate that there is to be no smoking in the area. Danger from an ignition source or toxicological problems could occur.
 NO EATING OR DRINKING	No Eating: This symbol will indicate that no eating or drinking should take place. Danger from chemical ingestion may occur.

Sticker:	*Description:*
 LASER LIGHT	Laser Light: Room contains a laser and entrance should not be gained during its use.
 BIOHAZARD	Bio Hazard: Area contains Biological Specimens which could cause health hazards.
 TOXIC CHEMICALS	Toxic Chemical: Room contains chemicals that are dangerous if improperly handled.
 ELECTRICAL HAZARD	Electrical Hazard: This sign will indicate if there is any equipment which will pose an electrical danger to anyone who is near the equipment.

Sticker:	Description:
	Corrosive Material: This sign will indicate the presence of any chemicals which will cause chemical burns to the skin or be a health hazard if breathed in.
	Ultraviolet Light: Area may have source of Ultra Violet Light Emissions.

Appendix E

Summary of Human Factors Issues

Chemical	Is Incompatible with
Acetic Acid	Chromic Acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Acetone	Concentrated nitric and sulfuric acid mixtures
Alkali and alkaline earth metals (e.g., powdered aluminum or magnesium, calcium, lithium, sodium, potassium)	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, halogens)
Ammonia (anhydrous)	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid (anhydrous)
Ammonium Nitrate	Acids, powdered metals, flammable liquids, chlorates, nitrates, sulfur, finely divided organic or combustible materials
Aniline	Nitric Acid, hydrogen peroxide
Arsenal materials	Any reducing agent
Acids	Acids
Bromine	See Chlorine
Calcium Oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents
Carbon Tetrachloride	Sodium
Chlorates	Ammonium salts, acids, powdered metals, sulfur, finely divided organic or combustible materials
Chromic acid and chromium trioxide	Acetic acid, naphthalene, camphor, glycerol, alcohol, flammable liquids in general
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, benzene, finely divided metals turpentine
Chlorine dioxide	Ammonia, methane, posphane, hydrogen sulfide
Copper	Acetylene, hydrogen peroxide
Cumene hydroperoxide	Acids (organic and inorganic)
Cyanides	Acids
Flammable liquids	Ammonium nitrate, chromatic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
Fluorine	Everything
Hydrocarbons (e.g., butane, propane, benzene)	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrocyanic acid	Nitric acid, alkali
Hydrofluoric acid (anhydrous)	Ammonia (aqueous or anhydrous)
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, alcohol's, acetone, organic materials, aniline, nitromethane, combustible materials)
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon

Hydrogen Sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Nitrates	Sulfuric Acid
Nitric Acid (concentrated)	Acetic acid, aniline, chromic acid, Hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases, copper, gas, any heavy metals
Nitrates	Acids
Nitraparafinns	Inorganic bases, amines
Oxalic Acid	Silver, mercury
Oxygen	Oils, grease, hydrogen, flammable liquids, solids or gases
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, oils
Peroxides, organic	Acids (organic or mineral), avoid friction, store cold
Phosphorous (white)	Air, oxygen, alkalis, reducing agents
Phosphorous pentoxide	Water
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium chlorate	Sulfuric and other acids
Potassium perchlorate (see also chlorates)	Sulfuric and other acids
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing Agents
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds, fulminic acid
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium Nitrate	Ammonium nitrate and other ammonium salts
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulfides	Acids
Sulfuric acid	Potassium chlorate, potassium perchlorate, potassium permanganate (similar compounds of light metals, such as sodium, lithium)
Tellurides	Reducing agents

Appendix F

State Environmental Agencies

ALABAMA

Alabama Department of Environmental Management
Land Division
1751 Federal Drive
Montgomery, Alabama 36130
(205) 271-7730

ALASKA

Department of Environmental Conservation
P.O. Box 0
Juneau, Alaska 99811
Program Manager: (907) 465-2666
Northern Regional Office (Fairbanks): (907) 452-1714
South-Central Regional Office (Anchorage): (907) 274-2533
Southeast Regional Office (Juneau): (907) 789-3151

AMERICAN SAMOA

Environmental Quality Commission
Government of American Samoa
Pago Pago, American Samoa 96799
Overseas Operator
(Commercial Call (684) 663-4116)

ARIZONA

Arizona Department of Health Services
Office of Waste and Water Quality
2005 North Central Avenue
Room 304
Phoenix, Arizona 85004
Hazardous Waste Management: (602) 255-2211

ARKANSAS

Department of Pollution Control and Ecology
Hazardous Waste Division
P.O. Box 9583
8001 National Drive
Little Rock, Arkansas 72219
(501) 562-7444

CALIFORNIA

Department of Health Services
Toxic Subtances Control Division
714 P Street, Room 1253
Sacramento, California 95814
(916) 324-1826
State Water Resources Control Board
Division of Water Quality
P.O. Box 100
Sacramento, California 95801
(916) 322-2867

COLORADO

Colorado Department of Health
Waste Management Division
4210 East 11th Avenue
Denver, Colorado 80220
(303) 320-8333 Ext. 4364

CONNECTICUT

Department of Environmental Protection
Hazardous Waste Management Section
State Office Building
165 Capitol Avenue
Hartford, Connecticut 06106
(203) 566-8843, 8844
Connecticut Resource Recovery Authority
179 Allyn Street, Suite 603
Professional Building
Hartford, Connecticut 06103
(203) 549-6390

DELAWARE

Department of Natural Resources and Environmental Control
Waste Management Section
P.O. Box 1401
Dover, Delaware 19903
(302) 736-4781

DISTRICT OF COLUMBIA

Department of Consumer and Regulatory Affairs
Pesticides and Hazardous Waste Materials Division
Room 114
5010 Overlook Avenue, S.W.
Washington, D.C. 20032
(202) 767-8414

FLORIDA

Department of Environmental Regulation
Solid and Hazardous Waste Section
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32301
RE: SQG's
(904) 488-0300

GEORGIA

Georgia Environmental Protection Division
Hazardous Waste Management Program
Land Protection Branch

Floyd Towers East, Suite 1154
205 Butler Street, S. E.
Atlanta, Georgia 30334
(404) 656-2833
Toll Free: (800) 334-2373

GUAM

Guam Environmental Protection Agency
P.O. Box 2999
Agana, Guam 96910
Overseas Operator
(Commercial Call (671) 646-7579)

HAWAII

Department of Health
Environmental Health Division
P.O. Box 3378
Honolulu, Hawaii 96801
(808) 548-4383

IDAHO

Department of Health and Welfare
Bureau of Hazardous Materials
450 West State Street
Boise, Idaho 83720
(208) 334-5879

ILLINOIS

Environmental Protection Agency
Division of Land Pollution Control
2200 Churchill Road, #24
Springfield, Illinois 62706
(217) 782-6761

INDIANA

Department of Environmental Management
Office of Solid and Hazardous Waste
105 South Meridian
Indianapolis, Indiana 46225
(317) 232-4535

IOWA

U.S. EPA Region VII
Hazardous Materials Branch
726 Minnesota Avenue
Kansas City, Kansas 66101
(913) 236-2888
Iowa RCRA Toll Free:
(800) 223-0425

KANSAS

Department of Health and Environment
Bureau of Waste Management
Forbes Field, Building 321
Topeka, Kansas 66620
(913) 862-9360 Ext. 292

KENTUCKY

Natural Resources and Environmental Protection Cabinet
Division of Waste Management
18 Reilly Road
Frankfort, Kentucky 40601
(502) 564-6716

LOUISIANA

Department of Environmental Quality
Hazardous Waste Division
P.O. Box 44307
Baton Rouge, Louisiana 70804
(504) 342-1227

MAINE

Department of Environmental Protection
Bureau of Oil and Hazardous Materials Control
State House Station #17
Augusta, Maine 04333
(207) 289-2651

MARYLAND

Department of Health and Mental Hygiene
Maryland Waste Management Administration
Office of Environmental Programs
201 West Preston Street, Room A3
Baltimore, Maryland 21201
(301) 225-5709

MASSACHUSETTS

Department of Environmental Protection
Division of Solid and Hazardous Waste
One Winter Street, 5th Floor
Boston, Massachusetts 02108
(617) 292-5589
(617) 292-5851

MICHIGAN

Michigan Department of Natural Resources
Hazardous Waste Division
Waste Evaluation Unit
Box 30028
Lansing, Michigan 48909
(517) 373-2730

MINNESOTA

Pollution Control Agency
Solid And Hazardous Waste Division
1935 West County Road, B-2
Roseville, Minnesota 55113
(612) 296-7282

MISSISSIPPI

Department of Natural Resources
Division of Solid and Hazardous Waste Management
P.O. Box 10385
Jackson, Mississippi 39209
(601) 961-5062

MISSOURI

Department of Natural Resources
Waste Management Program
P.O. Box 176
Jefferson City, Missouri 65102
(314) 751-3176
Missouri Hotline:
(800) 334-6946

MONTANA

Department of Health and Environmental Sciences
Solid and Hazardous Waste Bureau
Cogswell Building, Room B-201
Helena, Montana 59620
(406) 444-2821

NEBRASKA

Department of Environmental Control
Hazardous Waste Management Section
P.O. Box 94877
State House Station
Lincoln, Nebraska 68509
(402) 471-2186

NEVADA

Division of Environmental Protection
Waste Management Program
Capitol Complex
Carson City, Nevada 89710
(702) 885-4670

NEW HAMPSHIRE

Department of Health and Human Services
Division of Public Health Services
Office of Waste Management
Health and Welfare Building
Hazen Drive
Concord, New Hampshire 03301-6527
(603) 271-4608

NEW JERSEY

Department of Environmental Protection
Division of Waste Management
32 East Hanover Street, CN-028
Trenton, New Jersey 08625
Hazardous Waste Advisement Program: (609) 292-8341

NEW MEXICO

Environmental Improvement Division
Ground Water and Hazardous Waste Bureau
Hazardous Waste Section
P.O. Box 968
Santa Fe, New Mexico 87504-0968
(505) 827-2922

NEW YORK

Department of Environmental Conservation
Bureau of Hazardous Waste Operations
50 Wolf Road, Room 209
Albany, New York 12233
(518) 457-0530
SQG Hotline: (800) 631-0666

NORTH CAROLINA

Department of Human Resources
Solid and Hazardous Waste Management Branch
P.O. Box 2091
Raleigh, North Carolina 27602
(919) 733-2178

NORTH DAKOTA

Department of Health
Division of Hazardous Waste Management and Special Studies
1200 Missouri Avenue
Bismarck, North Dakota 58502-5520
(701) 224-2366

NORTHERN MARIANA ISLANDS, COMMONWEALTH OF

Department of Environmental and Health Services
Division of Environmental Quality
P.O. Box 1304
Saipan, Commonwealth of Mariana Islands 96950
Overseas call (670) 234-6984

OHIO

Ohio EPA
Division of Solid and Hazardous Waste Management
361 East Broad Street
Columbus, Ohio 43266-0558
(614) 466-7220

OKLAHOMA

Waste Management Service
Oklahoma State Department of Health
P.O. Box 53551
Oklahoma City, Oklahoma 73152
(405) 271-5338

OREGON

Hazardous and Solid Waste Division
P.O. Box 1760
Portland, Oregon 97207
(503) 229-6534
Toll Free: (800) 452-4011

PENNSYLVANIA

Bureau of Waste Management
Division of Compliance Monitoring
P.O. Box 2063
Harrisburg, Pennsylvania 17120
(717) 787-6239

PUERTO RICO

Environmental Quality Board
P.O. Box 11488
Santurce, Puerto Rico 00910-1488
(809) 723-8184
or
EPA Region II
Air and Waste Management Division
26 Federal Plaza
New York, New York 10278
(212) 264-5175

RHODE ISLAND

Department of Environmental Management
Division of Air and Hazardous Materials
Room 204, Cannon Building
75 Davis Street
Providence, Rhode Island 02908
(401) 277-2797

SOUTH CAROLINA

Department of Health and Environmental Control
Bureau of Solid and Hazardous Waste Management
2600 Bull Street
Columbia, South Carolina 29201
(803) 734-5200

SOUTH DAKOTA

Department of Water and Natural Resources
Office of Air Quality and Solid Waste
Foss Building, Room 217
Pierre, South Dakota 57501
(605) 773-3153

TENNESSEE

Division of Solid Waste Management
Tennessee Department of Public Health
701 Broadway
Nashville, Tennessee 37219-5403
(615) 741-3424

TEXAS

Texas Water Commission
Hazardous and Solid Waste Division
Attn: Program Support Section
1700 North Congress
Austin, Texas 78711
(512) 463-7761

UTAH

Department of Health
Bureau of Solid and Hazardous Waste Management
P.O. Box 16700
Salt Lake City, Utah 84116-0700
(801) 538-6170

VERMONT

Agency of Environmental Conservation
103 South Main Street
Waterbury, Vermont 05676
(802) 244-8702

VIRGIN ISLANDS

Department of Conservation and Cultural Affairs
P.O. Box 4399
Charlotte Amalie, St. Thomas
Virgin Islands 00801
(809) 774-3320
or
EPA Region II
Air and Waste Management Division
26 Federal Plaza
New York, New York 10278
(212) 264-5175

VIRGINIA

Department of Health
Division of Solid and Hazardous Waste Management
Monroe Building, 11th Floor
101 North 14th Street
Richmond, Virginia 23219
(804) 225-2667
Hazardous Waste Hotline:
(800) 552-2075

WASHINGTON

Department of Ecology
Solid and Hazardous Waste Program
Mail Stop PV-11
Olympia, Washington 98504-8711
(206) 459-6322
In-State: 1-800-633-7585

WEST VIRGINIA

Division of Water Resources
Solid and Hazardous Waste/Ground Water Branch
1201 Greenbrier Street
Charleston, West Virginia 25311

WISCONSIN

Department of Natural Resources
Bureau of Solid Waste Management
P.O. Box 7921
Madison, Wisconsin 53707
(608) 266-1327

WYOMING

Department of Environmental Quality
Solid Waste Management Program
122 West 25th Street
Cheyenne, Wyoming 82002
(307) 777-7752
or
EPA Region VIII
Waste Management Division (8HWM-ON)
One Denver Place
999 18th Street
Suite 1300
Denver, Colorado 80202-2413
(303) 293-1502

Appendix G

Chemical Compatibility Chart

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	*Inorganic Acids*	1																							
2	Organic Acids	X	2																						
3	Caustics	X	X	3																					
4	Amines & Alkanolamines	X	X		4																				
5	Halogenated Compounds	X		X	X	5																			
6	Alcohols, Glycols & Glycol Ethers	X					6																		
7	Aldehydes	X	X	X	X		X	7																	
8	Ketones	X		X	X			X	8																
9	Saturated Hydrocarbons									9															
10	Aromatic Hydrocarbons	X									10														
11	Olefins	X				X						11													
12	Petroleum Oils												12												
13	Esters	X		X	X									13											
14	Monomers & Polymerizable Esters	X	X	X	X	X	X								14										
15	Phenols			X	X			X							X	15									
16	Alkylene Oxides	X	X	X	X		X	X							X	X	16								
17	Cyanohydrins	X	X	X	X	X		X									X	17							
18	Nitriles	X	X	X	X												X		18						
19	Ammonia	X	X					X	X					X	X	X	X	X		19					
20	Halogens			X			X	X	X	X	X	X	X	X	X	X				X	20				
21	Ethers	X													X						X	21			
22	Phosphorus, Elemental	X	X	X																	X		22		
23	Sulfur, Molten									X	X	X	X				X						X	23	
24	Acid Anhydrides	X		X	X		X	X							X		X	X	X	X					24

X *Represents unsafe combinations*

The following pages list the chemicals by chemical name and by reactivity groups. Obtain the group for the chemical and then read chart, first from left to right, then down.

Chemicals Not On Chart

Carbon Bisulfide forms an unsafe combination with reactivity groups 1, 4, 19, 20, and epichlorohydrin.

Epichlorohydrin forms an unsafe combination with reactivity groups 1, 2, 3, 4, 14, 15, 19, 20, 22, 23, 24, and carbon bisulfide.

Motor Fuel antiknock compounds form unsafe combinations with reactivity groups 1, 4, 5, 6, 7, 15, 19, and 20

Reactivity Groups.

Group 1: Inorganic Acids

Chlorosulfonic acid
Hydrochloric acid (aqueous)
Hydrofluoric acid (aqueous)
Hydrogen chloride (anhydrous)
Hydrogen fluoride (anhydrous)
Nitric acid
Oleum
Phosphoric acid
Sulfuric acid

Group 2: Organic Acids

Acetic acid
Butyric acid (*n*-)
Formic acid
Propionic acid
Rosin oil
Tall oil

Group 3: Caustics

Caustic potash solution
Caustic soda solution

Group 4: Amines and Alkanolamines

Aminoethylethanolamine
Aniline
Diethanolamine
Diethylamine
Diethylenetriamine
Diisopropanolamine
Dimethylamine
Ethylenediamine
Hexamethylenediamine
Hexamethylenetetramine
2-Methyl-5-ethylpyridine
Monoethanolamine
Monoisopropanolamine
Morpholine
Pyridine
Triethanolamine
Trietylamine
Triethylenetetramine
Trimethylamine

Group 5: Halogenated Compounds

Allyl chloride
Carbon tetrachloride
Chlorobenzene
Chloroform
Chlorohydrins, crude
Dichlorobenzene (*o*-)
Dichlorobenzene (*p*-)
Dichlorodifluoromethane
Dichloroethyl ether
Dichloropropane
Dichloropropene
Ethyl chloride
Ethylene dibromide
Ethylene dichloride
Methyl bromide
Methyl chloride
Methylene chloride
Monochlorodifluoromethane
Perchloroethylene
Propylene dichloride
1,2,4-Trichlorobenzene
1,1,1-Trichloroethane
Trichloroethylene
Trichlorofluoromethane

Group 6: Alcohols, Glycols and Glycol Ethers

Allyl alcohol
Amyl alcohol

1,4-Butanediol
Butyl alcohols (iso, *n*, sec, tert)
Butylene glycol
Corn syrup
Cyclohexyl alcohol
Decyl alcohols (*n*, iso)
Dextrose solution
Diacetone alcohol
Diethylene glycol
Diethylene glycol dimethyl ether
Diethylene glycol monobutyl ether
Diethylene glycol monoethyl ether
Diethylene glycol monomethyl ether
Diisobutyl carbinol
Dipropylene glycol
Dodecanol
Ethoxylated dodecanol
Ethoxylated pentadecanol
Ethoxylated tetradecanol
Ethoxylated tridecanol
Ethoxytriglycol
Ethyl alcohol
Ethyl butanol
2-Ethylbutyl alcohol
2-Ethylhexyl alcohol
Ethylene glycol
Ethylene glycol monobutyl ether
Ethylene glycol monoethyl ether
Ethylene glycol monomethyl ether
Furfuryl alcohol
Glycerine
Heptanol
Hexanol
Hexylene glycol
Isoamyl alcohol
Isooctyl alcohol
Methoxytriglycol
Methyl alcohol
Methylamyl alcohol
Molasses, all
Nonanol
Octanol
Pentadecanol
Polypropylene glycol methyl ether
Propyl alcohols (*n*, iso)
Propylene glycol
Sorbitol
Tetradecanol
Tetraethylene glycol
Tridecyl alcohol
Triethylene glycol
Undecanol

Group 7: Aldehydes

Acetaldehyde
Acrolein (inhibited)
Butyraldehyde (*n*, iso)
Crotonaldehyde
Decaldehyde (*n*, iso)
2-Ethyl-3-propylacrolein
Formaldehyde solution
Furfural
Hexamethylenetetramine
Isooctyl aldehyde
Methyl butyraldehyde
Methyl formal
Paraformaldehyde
Propionaldehyde
Valeraldehyde

Group 8: Ketones

Acetone
Acetophenone
Camphor oil
Cyclohexanone
Diisobutyl ketone
Isophorone
Mesityl oxide

Methyl ethyl ketone
Methyl isobutyl ketone

Group 9: Saturated Hydrocarbons

Butane
Cyclohexane
Ethane
Heptane (*n*-)
Hexane (*n*, iso)
Isobutane
Liquefied natural gas
Liquefied petroleum gas
Methane
Nonane
n-Paraffins
Paraffin wax
Pentane (*n*, iso)
Petrolatum
Petroleum ether
Petroleum naphtha
Polybutene
Propane
Propylene butylene polymer

Group 10: Aromatic Hydrocarbons

Benzene
Cumene
p-Cymene
Coal tar oil
Diethylbenzene
Dodecyl benzene
Dowtherm
Ethyl benzene
Naphtha, coal tar
Naphthalene (includes molten)
Tetrahydronaphthalene
Toluene
Triethyl benzene
Xylene (*m*-, *o*-, *p*-)

Group 11: Olefins

Butylene
1-Decene
Dicyclopentadiene
Diisobutylene
Dipentene
dodecene
1-Dodecene
Ethylene
Liquefied petroleum gas
1-Heptene
1-Hexene
Isobutylene
Nonene
1-Octene
1-Pentene
Polybutene
Propylene
Propylene butylene polymer
Propylene tetramer (dodecene)
1-Tetradecene
1-Tridecene
Turpentine
1-Undecene

Group 12: Petroleum Oils

Asphalt
Gasolines
  Casingead
  Automotive
  Aviation
Jet fuels

JP-1 (kerosene)
JP-3
JP-4
JP-5 (kerosene, heavy)
Kerosene
Mineral spirits
Naphtha (non aromatic)
Naphtha
solvent
Stoddard solvent
VM & P
Oils
Absorption oil
Clarified oil
Crude oil
Diesel oil
Fuel oils
No. 1 (kerosene)
No. 1-D
No. 2
No. 2-D
No. 4
No. 5
No. 6
Lubricating oil
Mineral oil
Mineral seal oil
Motor oil
Penetrating oil
Range oil
Road oil
Spindle oil
Spray oil
Transformer oil
Turbine oil

Group 13: Esters

Amyl acetate
Amyl tallate
Butyl acetates (*n*, iso, sec)
Butyl benzyl phthalate
Castor oil
Cottonseed oil
Croton oil
Dibutyl phthalate
Diethyl carbonate
Dimethyl sulfate
Dioctyl adipate
Dioctyl phthalate
Epoxidized vegetable oils
Ethyl acetate
Ethyl diacetate
Ethylene glycol monoethyl ether acetate
ethylhexyl tallate
fish oil
Glycol diacetate
Methyl acetate
Methyl amyl acetate
Neatsfoot oil
Olive oil
Peanut oil
Propyl acetates (*n*, iso)
Resin oil
Soya bean oil
Sperm oil
Tallow
Tanner's oil
Vegetable oil
Wax, carnauba

Group 14: Monomers and Polymerizable Esters

Acrylic acid (inhibited)
Acrylonitrile
Butadiene (inhibited)
Butyl acrylate (*n*, iso)
Ethyl acrylate (inhibited)
2-Ethylhexyl acrylate (inhibited)
Isodecyl acrylate (inhibited)

Isoprene (inhibited)
Methyl acrylate (inhibited)
Methyl methacrylate (inhibited)
σ – Propiolactone
Styrene (inhibited)
Vinyl acetate (inhibited)
Vinyl chloride (inhibited)
Vinylidene chloride (inhibited)
Vinyl toluene

Group 15: Phenols

Carbolic oil
Creosote, coal tar
Cresols
Nonylphenol
Phenol

Group 16: Alkylene Oxides

Ethylene oxide
Propylene oxide

Group 17: Cyanohydrins

Acetone cyanohydrin
Ethylene cyanohydrin

Group 18: Nitriles

Acetonitrile
Adiponitrile

Group 19: Ammonia

Ammonium hydroxide

Group 20: Halogens

Bromine
Chlorine

Group 21: Ethers

Diethyl ether (ethyl ether)
1,4-Dioxane
Isoprophyl ether
Tetrahydrofuran

Group 22: Phosphorus, Elemental

Group 23: Sulfur, Molten

Group 24: Acid Anhydride

Acetic anhydride
Propionic anhydride

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