LABORATORY SAFETY HANDBOOK

By Earl L. Skinner, Carol A. Watterson, and Joseph C. Chemerys

U.S. GEOLOGICAL SURVEY
Open-file Report 83—131

1983

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

Operations Section
U.S. Geological Survey
405 National Center
Reston, Virginia 22092

Copies of this report can
be purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey
Box 25425, Federal Center
Denver, Colorado 80225
(Telephone: (303) 234-5888)

TABLE OF CONTENTS

LABORATORY SAFETY HANDBOOK

by

Earl L. Skinner,
Carol A. Watterson, and
Joseph C. Chemerys

ABSTRACT

Safety, defined as "freedom from danger, risk, or injury," is difficult to achieve in a laboratory environment. Inherent dangers, associated with water analysis and research laboratories where hazardous samples, materials, and equipment are used, must be minimized to protect workers, buildings, and equipment. Managers, supervisors, analysts, and laboratory support personnel each have specific responsibilities to reduce hazards by maintaining a safe work environment. General rules of conduct and safety practices that involve personal protection, laboratory practices, chemical handling, compressed gases handling, use of equipment, and overall security must be practiced by everyone at all levels.

Routine and extensive inspections of all laboratories must be made regularly by qualified people. Personnel should be trained thoroughly and repetitively. Special hazards that may involve exposure to carcinogens, cryogenics, or radiation must be given special attention, and specific rules and operational procedures must be established to deal with them. Safety data, reference materials, and texts must be kept available if prudent safety is to be practiced and accidents prevented or minimized.

pg 3 follows

INTRODUCTION

Safety is everyone's responsibility. Safety has been defined as "freedom from danger, risk, or injury." Although total "freedom" may not be achievable, danger, risk, and injury can and must be minimized, especially in a laboratory environment. Dangers that involve various degrees of risk are inherent in any laboratory, such as the National Water Quality Laboratories (NWQL) and research laboratories in the Water Resources Division (WRD), that perform work involving the use of hazardous samples, materials, and equipment.

Laboratory managers, supervisors, analysts, and support personnel alike have definite responsibilities that are specific to the work each performs. Managers and supervisors have the responsibility to minimize dangers by providing a safe work environment. First-line and immediate supervisors are responsible for assuring that each employee under their supervision performs in a safe manner and in compliance with prescribed safety standards, practices, and procedures. The supervisor should set a good example by observing all safety rules, wearing protective equipment where recommended, and by being committed to and enthusiastic about safety. Each employee has the basic responsibility to work safely, so as to not endanger himself, others, or property.

This Laboratory Safety Handbook has been prepared to establish safety standards and procedures of safe-working practices in the laboratories in the Water Resources Division as directed in the Geological Survey Safety Handbook, Chapter 3, Section 3.2. The Laboratory Safety Handbook has been approved and will be made available in final copy to each employee who works in one of the WRD laboratories. A record will be kept, with signatures of each employee, to acknowledge having read and understood the contents of the handbook. The responsibility for distributing this handbook to employees and keeping the necessary records lies with the manager of each laboratory.

The mention of "Brand Names" in this handbook and the use of printed materials having a specific company name, registered trademark, patent, or logo constitute neither recommendation nor preference by the U.S. Government or the Geological Survey.

To the best knowledge of the authors, all information and recommendations contained in this publication are believed to be representative of up-to-date and reliable information. The sole intent of the publication is to present a summary of laboratory safety practices that are applicable to laboratories of the U.S. Geological Survey, Water Resources Division.

page 5 follows

CHAPTER I

BASIC SAFETY INFORMATION

It is neither possible nor practical to address every rule of safety. Neither is it reasonable to leave safety rules and practices totally to the discretionary interpretation of each employee. The use of terms such as 'should' and 'recommended' instead of 'must,' 'will,' or 'required' for designation of compliance with a safety rule or practice does not imply that an arbitrary choice is permitted. They are used to allow for those work situtations where a given rule or practice is not germane to the work being done, chemicals being used, or the equipment involved.

It is recommended that a "Job Safety Analysis" be done for every critical operation in each laboratory. A special tab, "Individual Laboratory Information" has been provided to include this and other safety information pertinent to any individual, laboratory, or operation.

Section A. General Rules and Safety Practices

The general rules and safety practices discussed in this section are those that deal with the responsibilities of each employee. They are discussed in six topics labeled "Personal Protection," "Laboratory Practices," "Chemical Handling," "Compressed Gases Handling," "Equipment," and "Security."

Part 1. Personal Protection

Personal protection deals with the basic protection required of every laboratory employee and does not deal with added protection required for activities that deal with more specific hazards.

a. Safety glasses or adequate eye protection is required in every laboratory work area (Exhibit A).

b. Contact lenses should not be worn in the laboratory. Any employee that finds it necessary to wear contact lenses should be aware of the inherent dangers involved with the type they wear and the hazards posed by the work situtation. Your personal physician should be consulted and his/her advice sought. If wearing contacts are deemed to be necessary, then the supervisor and coworkers should be made aware of the situation in case of an accident.

c. Hearing protection must be worn in areas having noise in excess of 85 decibels (Exhibit B).

d. Food and drink are permitted in designated areas only. Hands should always be washed thoroughly before handling food and drink. Laboratory ware should never be used as containers for food or drink. Chemicals should not be permitted in areas designated for eating or drinking.

e. Smoking should be allowed only in properly designated areas. Smoking or open flame must never be permitted in high risk areas such as where organic compounds, flammables, and combustibles are used or stored. Hands should always be washed thoroughly before smoking.

f. Appropriate dress is recommended in the laboratory.

1. Protective footware must be worn at all times. Sandals, open toe, open heel, and porous footware should be avoided.

2. Full length lab coats should be worn in laboratory working areas, and required if shorts, cut offs, or apparel that offers no protection to the legs is worn.

g. Nonporous gloves should be worn when handling hazardous materials or irritants such as acids, bases, organic compounds, toxics, or those materials that are biologically active. Heat resistant gloves or equipment should be used when handling hot objects. Asbestos gloves are not recommended due to health hazards associated with asbestos.

h. Long hair and loose clothing should be confined around known hazards such as open chemicals, moving machinery or parts, hot equipment, or open flames.

i. Immunizations for tetanus and typhoid are recommended for laboratory personnel that handle samples from polluted sources such as raw water, landfill leachates, and other sources of known biologically active contamination. Immunizations should also be considered for other water-borne diseases in case of outbreaks or epidemics.

Part 2. Laboratory Practices

a. Laboratory housekeeping must be performed at regular intervals. A general cleanup in all laboratory areas should be done once per week, especially in high use areas.

-- Spills must be cleaned up immediately.

-- Aisles, passageways, exits, and work areas must be kept clear of clutter.

-- Emergency equipment must be kept free from obstruction, and easily accessible.

-- All heavy items should be stored below head level. Hard hats must be worn if an exception to this practice is granted.

-- All hoods should be free of clutter and extraneous equipment and materials. Hoods should never be used for storage. Designed air-flow patterns and exhaust integrity must be maintained.

b. All samples should be carefully inspected upon receipt for obvious indications of hazards. If the sample appears to be viscous, highly colored, malodorous, or if the container is bulging, precautionary measures should be taken. Consult laboratory management regarding proper policy and protocol. All sample identifications should be checked for sample sources such as landfills, injection wells, sewage, or industrial wastes. Sample bottles with warning labels such as radioactive, biohazard, toxic, poison, or other warnings should be handled with extreme caution. All samples determined or suspected to contain any of the hazards mentioned should be handled as such and disposed of accordingly.

c. All pipetting must be done with bulbs, aspirators, or mechanical suction devices--DO NOT PIPETTE BY MOUTH.

d. All reagents, solutions, and preparations must be clearly and properly labeled. Any container used to store materials different from the originally designated materials must be thoroughly cleaned, the original label removed or obscured, and relabeled to identify its current contents. Containers should never be cross used for incompatible substances (Exhibits C and D).

e. No employee is allowed to work alone in a laboratory (except by approval of the immediate supervisor and with management's knowledge), perform unauthorized experiments or tasks, or leave hazardous operations unattended. If an employee is given permission to work alone at any time, the supervisor must notify some nearby coworker (or security personnel if outside normal duty hours).

f. Responsible behavior in the laboratory is expected of each employee. Horseplay is strictly forbidden. Pushing, shoving, running, throwing objects, and such acts will not be tolerated.

9. Handling Laboratory Glassware (see page 20a)

Part 3. Chemical Handling

a. Chemicals with specific hazards must be stored and handled in accordance with procedures befitting the hazards listed on the container label. Incompatible chemicals should never be stored together (such as alphabetically) but should be grouped according to reactivity (Exhibits C and D). Use of nonporous gloves is recommended when handling chemicals.

b. Strong organic and mineral acids and liquid bases must be transported, used, stored, and disposed of in a safe and proper manner. They must be transported inside a properly designed carrier and used in a hood within a workable reach of an eyewash fountain.

Rubber, plastic, or other nonporous gloves should be worn when handling strong acids and bases.

A face or body shield should be used during any experiment that produces endo- or exo-thermic reactions (either due to mixing or addition of an energy source). Always remember to add acid to water and never in reverse order.

Strong acids and bases must be kept confined to a properly designated temporary storage area when used intermittently or in the stock storage area for long-term storage.

Areas where solid bases and other caustics are weighed and solutions prepared must be kept clean. Table tops and workbench surfaces should always be wiped thoroughly after each use. Wastes that are solid, concentrated, or in quantities greater than 1 liter must be stored in holding receptacles specifically designated and dedicated to specific and compatible wastes. Full receptacles must be transported to the waste storage room and stored with other compatible chemical wastes (Exhibits C and D) for pickup and disposal by a licensed contract waste disposal vendor.

c. Perchloric and hydrofluoric acids require special precautions not necessary for handling other less reactive acids.

1. Perchloric and hydrofluoric acids must be used in hoods that are specifically designated for their use. The perchloric acid hoods must be dedicated solely to use as a perchloric hood, and these hoods must be flushed thoroughly after each use and inspected monthly to assure that chlorate deposits have not formed on walls of the hood. Hydrofluoric acid must be stored in plastic containers and should be used in hoods with doors other than glass to prevent permanent etching. Both of these acids must be used within a workable reach of an eyewash fountain.

2. Perchloric and hydrofluoric acids must be kept confined to a properly designated temporary storage area when used intermittently or confined to the stock storage area when stored long term or permanently.

3. The perchloric acid containers must be inspected regularly (monthly) to assure that chlorates (usually white) do not form around the mouth and other orifices. If such deposits are observed, the packaged material must be treated as if it were explosive. The situation should be reported to management and some arrangements made for proper disposal. Most law enforcement agencies have access to a "bomb squad" unit that will handle the problem. Under no circumstances should the container be opened.

4. All perchloric and hydrofluoric wastes, regardless of quantity, must be isolated in properly designated and dedicated containers and kept in a protected temporary storage area. The containers used to store hydrofluoric acid waste must be plastic. Full containers must be transported to, and stored in, the waste storage area pending pickup and disposal by the designated contract waste disposal vendor. Inspect waste containers monthly for formation of chlorates.

d. Toxic substances are classified in varying degrees. Almost all substances can be toxic in large dosages. There are many substances such as arsenic, cadmium, cyanide, mercury, selenium, and thallium that are toxic in relatively small amounts and must be handled, stored, and disposed of in a safe and proper manner.

Toxic substances enter the body through inhalation, ingestion, absorption, or injection.

Inhaled toxic substances can enter the blood stream quickly through the lungs and the mucous membranes of the mouth. The use of fume hoods helps to prevent fumes, dust, or mists from entering the laboratory atmosphere. Respiratory masks should or glove boxes should be used when using extremely toxic substances.

Ingestion of toxic substances through the mouth, nose, and ears can usually be avoided by practicing proper hygiene. Proper controls that can be taken to reduce the risk of ingesting toxic substances are discussed in Chapter 1, Part 1-d and e.

Absorption through the skin is a common and often insidious method of entry. Toxic substances are absorbed through cuts, abrasons, hair follicles, pores, and sometimes through

fatty tissue. Coats and protective gloves must be worn to minimize absorption through the skin. Do not wear laboratory coats outside of the laboratory. Toxic chemicals can also be taken home through contaminated clothing, exposing other family members.

Injection can be an unexpected method of entry of toxic materials through cuts by glass and other sharp objects contaminated with toxic materials or through accidental injection by a needle. Good laboratory technique and cautious handling of these materials are the best protection against injection of toxics.

Treat all substances, especially metals, as toxic unless they are definitely known to be nontoxic.

1. Toxic and unidentified substances should be handled with nonporous rubber or plastic gloves even when weighing, mixing, or preparing formulae.

2. Particulate filterable, protective, breathing masks should be worn when handling fine metal granules, powders, or dusts.

3. Toxic and unidentified substances should be used in specifically designated areas to prevent undue personal contact and contamination.

4. Hands should be washed thoroughly with soap and water after handling suspect materials, especially before eating or drinking.

5. Wastes containing toxic substances must be placed in specifically designated waste receptacles containing only compatible chemical wastes (Exhibits C and D). Full receptacles must be transported to waste storage areas and stored with other compatible wastes for pick up and disposal by a contract vendor.

e. Organic chemicals must be stored, used, and disposed of in a properly prescribed and safe manner.

1. A carefully monitored inventory should be maintained to prevent overstocking.

2. Only fresh organic stock chemicals should be used. Date received and date opened must be recorded on the container, and general condition must be inspected before the chemical is removed from the stock room. Any organic chemical showing signs of deterioration

should not be used. Any organic chemical that has visable peroxides formed around the mouth or other orifices must be handled with extreme caution and scheduled for disposal as a potential explosive (see Part 3, c.3. for disposal of explosive chlorates).

3. All organic chemicals must be handled using all precautions outlined on the container label.

4. Organic chemicals must be transported in special designated carriers.

5. Containers of organic chemicals should be opened only in an operating hood with an effective face velocity of at least 85 feet/minute or in a bench hood area.

6. Only a working supply (5 gallons maximum) of flammable organics compounds should be kept in the work area outside a safety cabinet. Large quantities (more than 5 gallons) should be kept in the organic chemicals storage area (Exhibit E).

7. Avoid inhalation of or skin contact with organic chemicals. Special care should be taken when handling organics labeled as "toxic," "poison," "carcinogenic," "produces narcotic effects," "absorbs through the skin," or are known to pose other health hazards.

8. Special precautions should be used when handling compounds with specific hazards.

   Flammables must be kept away from open flames, heat, or electrical equipment (Exhibit F). They should be kept in closed and labeled containers (preferably equipped with flame arrestors) when in storage, in use, or set aside for disposal. Flammable liquids that require chilling must be chilled in an explosion-proof refrigerator or freezer. Wastes greater than 5 gallons should be stored in flammable wastes storage areas. Waste receptacles containing flammables should be placed in a protected area at the end of each work day (Exhibit E).

   Carcinogens, mutagens, and teratogens (including pesticides) must be handled only in specially designated and labeled areas and used only by responsible and experienced personnel. These personnel must be totally informed of the hazards, and instructed in proper use and techniques for handling. Adhere to all laboratory standards and published precautions for handling these materials. Carcinogens that are particularly insidious

should be handled only in a glove box (see Chapter II). If acceptable methods for disposal are not available, such carcinogenic waste materials must be kept in a secure container in the waste storage areas. All such wastes must be clearly labeled with the hazard cited.

Poisons must be handled with due caution. Avoid skin contact, especially around the eyes, nose, ears, and mouth. Before using a chemical labeled "POISON," read the precautions listed on the container label and become familiar with antidotes and emergency treatment. The telephone number of the local poison control center should be posted in a conspicuous place, or even memorized.

Irritants must be respected for their unpleasant effects. Avoid skin contact especially around the face. Be alert for symptoms such as swelling, itching, rash, discoloration, and skin eruptions. Know your own allergies, avoid known allergens, and become informed about specific first-aid treatment for them.

Unstable compounds must be handled with respect. They should not be dropped or otherwise unduly jarred, be kept away from flame or heat, and not agitated or mixed vigorously. These compounds must be properly labeled and stored in specially designated areas that are kept cool and dark. The Facility Safety Officer, Safety Committee, or some safety professional must be consulted before any attempts are made to dispose of these compounds.

f. All soxhlet extractions and solvent distillations of flammable compounds should be avoided when possible. Nonflammable solvents should be used whenever possible. When these operations require the use of flammable solvents, then they should be carried out in an operating exhaust hood with the following precautions:

1. Use boiling stones to prevent bumping and surge.
2. Never leave the equipment or operation unattended.
3. Use plastic tubing (preferably Tygon® or an equivalent) and firmly attach the tubing to the condenser.
4. Adjust heating mantle setting and condenser flow to obtain optimum reflux or distillation rate.
5. Do not allow the boiling flask to go dry.

Part 4. Compressed Gases Handling

a. Compressed gases must be handled, stored, and used in accordance with the Compressed Gases Association, Inc. (CGA) pamphlet P-1 (1974). There are several things that should always be considered when dealing with compressed gases, especially flammables (Exhibit G). Know the gases being used and become familiar with specific procedures and precautions for each gas. All lines connected to remote cylinders or tanks must be clearly identified.

b. Compressed gas cylinders must be handled and stored according to the Geological Survey Safety Handbook 4-4.5.1. Each cylinder must be--

1. Carefully inspected when received, stored, transported, and used. Any improper cylinder must be rejected and returned to the vendor immediately.

2. Securely fastened at all times with an approved chain assembly or snugging belt. Floorstands alone are not recommended, especially those with screws that tighten against the cylinders. Floorstands were designed to lend added security and stability to cylinders, not to fully support the cylinders.

3. Capped at all times when not in use (including storing and transporting).

4. Transported or moved with a properly designed vehicle (hand truck). Do not roll, drag, or jar cylinders.

5. Stored so as to separate full and empties (both must be clearly labeled).

6. Stored so that flammables are kept separate from the oxidizers.

c. Hookup of gases should be done according to the following sequences.

1. Select and accept only those cylinders that are capped, properly identified, and in acceptable condition. Use the oldest stock first.

2. Transport to work areas only with approved hand trucks. Do not transport by rolling or dragging the tanks singularly or in pairs. Do not bump tanks against solid obstacles or against each other.

3. Secure the cylinders in the work area with an approved chain assembly or snugging belt.

4. Remove cylinder caps and reinspect the cylinders thoroughly.

5. Use only prescribed CGA fittings and connectors for hookup. Be sure to clean main valve.

6. Check the hookup assembly for suspected gas leaks with leak detection solution prior to release of gas to the instruments.

7. Cut off the main valves at the cylinder first for shutdown. This allows secondary valves to be relieved of the tank pressure.

8. When cylinders are empty, they should be labeled as such, recapped properly, and returned to the designated empty storage area using the same precautions as when handling full cylinders.

Part 5. Equipment

a. Precautionary measures should be taken when using continuous-flow ultracentrifuges.

1. Do not operate with air inlet pressure above 30 psi.

2. Lubricate turbine at the rate of one drop of oil per 10 seconds.

3. Allow turbine to achieve optimum speed before passing water through the centrifuge.

4. Drain oil from exhaust before and after each use.

5. Use the centrifuge only in an operating hood with doors closed as much as the exhaust fan will allow without damage to the fan.

b. Certain procedures should be followed when using an autoclave.

1. DO NOT attempt to operate an autoclave unless familiar with the equipment and method of operation.

2. Follow manufacturer's operating instructions carefully.

3. DO NOT touch cycling units (very hot).

4. DO NOT attempt to open an autoclave when the pressure gauge indicates that pressure is still in the unit.

5. Wear a face shield when cracking the seal at the conclusion of an autoclaving operation. Open the autoclave door slowly to prevent glass breakage due to temperature differentials.

6. Use care in removing hot materials from autoclaves. Heat resistant gloves should be worn or tongs used tc handle hot materials.

c. Electrical and electronic systems must conform to the National Electric Code, National Fire Protection Association Code (NFPA 70-1971) and the American National Standards Institute Code (C1-1971 revised). Compliance must be adjudicated by licensed electricians or duly trained personnel. Any electrical equipment, such as vacuums, that poses a danger when reactivated should be equipped with a manual reset to prevent automatic reactivation after a power outage.

The general conduct to be followed in using electrical equipment is basically as follows:

1. Inspect all electric and electronic systems for obvious hazards before use. Do not activate a manual reset on any electrical equipment, especially vacuums, until a thorough check of operating conditions is made. If a malfunction is suspected, then test the system with a circuit tester to determine if reverse polarity or a faulty ground exists. Circuits must be locked out anytime work is being done on that circuit or any equipment wired into that circuit. All lock outs must be labeled at the main cutoff.

2. Keep informed about the points of regulation for power sources such as connections, switches, circuit boxes and breakers, line cords, grounds, ground fault interruptors, and protective guards. Know where each is located.

3. Post known hazards such as "high voltage," "high temperature," "possible shock," "wear protective equipment," etc.

4. Protect electrical cords and equipment from wet environments to prevent short-circuit grounding.

5. Before servicing electrical or electronic equipment, the power must be shut off and high voltage capacitors must be discharged.

6. All electrical circuits and equipment must be properly grounded. Ground fault interruptors should be installed in any circuit that supplies power to a wet area to prevent electrocution.

   NOTE: The common electrical hazards that are classified as code violations are (Geological Survey Safety Handbook 4-4.1):

   -- Use of extension cords as permanent wiring.
   -- Frayed, cut, or otherwise damaged cords and plugs.
   -- Equipment that causes electrical shock or a simple "tickle."
   -- Use of adaptors to convert grounded (3 pronged) connectors to nongrounded (2 pronged) plugs and cords.
   -- Lack of a third wire at wall receptacles.
   -- Exposed wires and juncture boxes without covers.
   -- Bypassing circuit breakers or otherwise rendering them ineffective.
   -- Lack of ground fault interrupter to circuits supplying power to wet areas.

d. All open flames should be labeled or obvious.

   1. Fuels and oxidants should be adjusted for an optimum burning mix. Pressures should be properly adjusted to prevent flashbacks (always cut off fuel source immediately when flashbacks do occur).

   2. Do not place flames between your body and the cut-off valve.

   3. Do not use open flames around flammable or combustible materials.

   4. Any instrument with a flame attachment should be vented properly. The vent should always be checked to make sure it is open before the flame is ignited. Flame shields that are a part of an instrument should always be used when the instrument is in operation.

   5. Fuels should always be shut off first during shut-down, followed by the oxidizer. Monitor the flame until it is completely extinguished and the gas pressures until no pressure shows on the adjusting valves and gages.

   6. When burners are being used on atomic adsorption spectrophotometers, the drain trap or loop must be filled with the appropriate liquid, and the end of the drain tube must be kept under the surface of the liquid in the waste receptacle.

e. Other energy sources such as heat, ultraviolet lights, machinery with moving parts, and high noise levels must be identified, protected, and clearly labeled.

   1. Identification of the energy and its source must be proper and clear.

   2. All energy sources must be protected to prevent contact with personnel or other incompatible materials.

   3. Dangers associated with all energy sources must be conspicuously labeled for clear understanding.

   4. Heat resistant hand protection should be worn on hands when handling hot items.

   5. Protective glasses or goggles and clothing designed to screen out untraviolet radiation, should be worn anytime open ultraviolet light is being used in the immediate area.

   6. Hearing protection, such as earplugs or headsets, should always be worn when working around excessive noise (Exhibit B).

f. Laboratory exhaust hoods are designed for one specific purpose--to exhaust (remove) hazardous, noxious, or otherwise undesirable gases, vapors, and fumes.

   1. Exhaust hoods should not be used as storage cabinets. Hoods are designed to have minimal obstruction in the air pathways that inhibit free flow of air.

   2. Before an exhaust hood is used for any critical procedure or operation, it should be properly balanced and the air flow should be checked with a flow meter or some means to determine if adequate air is passing through the hood.

   3. Anytime unfamiliar or noxious fumes are detected in the laboratory, all experiments should cease until the source of the fumes has been determined and the exhaust hood has been checked.

   4. Air foils should never be removed from exhaust hoods; they are part of the design for proper air sweep across the floor of the hood.

g. Mercury diffusion pumps pose a hazard. Mercury vapor can be vented into the air in the event the glass pump or the distillation apparatus breaks. Elemental mercury will also spill into the laboratory. To prevent such breakage, the diffusion pump heater should be on controllers that remove power in the event of loss of vacuum or cooling water. If mercury is spilled or if mercury fumes should escape into the air through leakage, the room should be evacuated. Air should be monitored, and personnel should be checked for mercury poisoning.

h. All equipment with moving parts should be secured in place, and belts and exposed moving parts must have appropriate protective guards installed.

Part 6. Security

a. Each employee should be familiar with the Facility Self-Protection Plan and all applicable procedures for personnel evacuation. Emergency numbers for fire, ambulance, police, poison centers, and chemical spills should be posted in a conspicuous and accessible place.

b. All minors entering a laboratory area must do so only with the knowledge and permission of the Facility Safety Officer, Supervisor, or a designated official.

c. All visitors must report to the properly designated person in charge upon arrival, and, if a requirement of a facility, must sign in and out.

d. Narcotics and alcoholic beverages are not permitted in the laboratory for consumption except for those narcotics used for medicinal purposes by order of a physician. In areas required by law or ordinance as part of a drug paraphenalia display restriction, all syringes and injection needles used as part of a laboratory operation must be kept secluded with restricted access.

e. The last employee to leave a laboratory work area at the end of a work day has an overriding responsibility to secure the area.

Part 7. Shipment of Harmful or Dangerous Materials

All materials must be inspected closely before they are shipped. Special rules apply to the shipment of harmful or dangerous materials through the mail. Postal regulations pertaining to such materials must be followed (Exhibit H).

Section B. Inspection Procedures

Part 1. A major safety inspection of all facilities, operations, and equipment shall be made every October to determine the condition and adequacy of safety efforts. This inspection and evaluation will be used to identify conditions requiring corrective actions beyond the scope of the first line supervisor (Geological Survey Safety Handbook 4.1). This inspection will be supervised by the Facility Safety Officer or a duly appointed person with the cooperation of laboratory supervisors who will make necessary personnel available from their groups. The findings of this inspection will be reported to a designated level of management on a Form 9-1836, Rev. 7-74 (Annual October Safety Inspection Report).

Part 2. Industrial hygiene inspections will be conducted as deemed necessary by Laboratory, Region, Division, or Bureau management, according to specifications outlined by the requesting management.

Part 3. Fire hazard inspections should be made on a timely basis. Fire alarm systems must be tested at a regularly designated frequency (at least once annually). The overhead sprinkler system should be tested on a regular basis (once per quarter is recommended) by flushing the trunk lines throughout the entire system. These exercises will be performed by personnel designated in the Facility Self Protection Plan, other duly appointed personnel, or through contract. Each hand-held fire extinguisher should be visually inspected and findings duly noted on a monthly basis by the Safety Officer, a member of a safety committee, or laboratory personnel. These hand-held extinguishers must be thoroughly inspected on an annual (or more frequent) basis by a qualified inspector.

Part 4. Eyewash equipment should be tested several times per year. Frequent testing will also keep the head of the eyewash unit clean and free of debris and deposits. This testing can be done by laboratory personnel.

Part 5. The overhead personnel safety showers should be tested on an annual (or more frequent) basis by personnel assigned by the management at the facility. The testing will include pulling each shower lever and allowing water to flush through the shower head for 10-30 seconds.

Part 6. All laboratory exhaust hoods should be inspected for proper use and adequate face velocity at least semiannually, immediately after maintenance or adjustment and before any hazardous operation is begun. Face velocity measurements should be made with an approved velometer or equivalent equipment.

Section C. Training Requirements

Part 1. New employees must be given a safety orientation, preferably at the time they enter on duty, but before 30 calendar days of service time have elapsed. All newly hired and transferred personnel must be given, without delay, a thorough orientation that covers any hazardous operation specific to the new work area to which they are assigned. They should not be assigned to any hazardous operations without having been thoroughly instructed in all hazards involved. The immediate supervisor has the basic responsibility to make sure the orientation is carried out even if the actual instructions are given by someone else.

Part 2. Each career employee should receive at least 24 hours of structured laboratory safety training during the first year of employement and at least 4-8 hours additional training each successive year.

Part 3. As many employees as possible should be encouraged to receive certified Cardiopulmonary Resusitation (CPR) training (20 percent of the workforce is recommended). Repeat certification should not be mandatory but is advisable and should be encouraged.

Part 4. As many laboratory employees as possible should be encouraged to receive approved emergency first aid training. If an emergency medical facility is not located within 15 minutes travel time of the work facility, all employees should be trained in basic first aid (Geological Survey Safety Handbook 3.14-IIIA).

Part 5. Seminars and films on safety should be conducted at least quarterly. Each employee should attend at least two of these sessions as a credit toward the 4-8 hours annual laboratory safety training (see Section C, Part 2).

Part 6. Management must maintain a safety training and abatement log that documents all training activities and includes a current record of training accomplishments for each employee (Geological Survey Safety Handbook 3.1, IV-A and 4.3).

g. Handling laboratory glassware can be one of the most hazardous activities in a laboratory because of the dangers involved when the glassware is broken. Cuts and punctures caused by broken glassware resulting from improper handling are among the most common injuries reported in a laboratory. A few basic precautions can be taken that will reduce such injuries.

- Use glassware in an uncluttered area generally free from other objects that can cause breakage due to bumping.

- Wear appropriate eye protection (EXHIBIT A).

- All cracked or chipped glassware should be discarded, fire-polished, or repaired by a competent glass-blower.

- Use appropriate gloves or other hand protection devices when handling glassware, especially when washing it. Soap, detergents, and other cleansing agents cause glassware to become very slippery.

- Keep the glassware below the face level at all times, especially if the glassware is stressed from heat or cold or contains loose solid materials.

- Shield all glass apparatus subjected to extremes of temperature or pressure.

- Use caution when opening high-temperature ovens used for drying glassware. The ovens should be opened slowly because rapid temperature changes may cause glassware to break with explosive force. The best course of action is to allow ovens to cool before opening.

- When inserting glass pipettes, glass rods, or glass tubing into rubber stoppers or other tight connections, always wear eye and hand protection, keep the contact surfaces wet or otherwise lubricated, and insert with a slight twisting and pushing motion.

- Dispose of broken glassware and other sharp objects properly. A specially designated and dedicated container should be used for broken glassware and other sharp objects. NEVER mix broken glass or other sharp objects in refuse containers with other materials, especially soft materials such as paper, rags, or packing materials. Anyone handling the broken glass has a need and right to know, espeically the custodian. The container (a 3-20 gallon galvanized garbage can with a snug cover or an equivalent is recommended) should be clearly labeled with warning information (CAUTION: BROKEN GLASS). A red label is best because it draws attention and suggests a danger.

CHAPTER II

SPECIAL HAZARDS, RULES, AND OPERATIONS

There are specific hazards associated with laboratory activities in nonroutine work areas that require special rules and operational practices. Three of these--carcinogens, cryogenics, and radiation--will be discussed in this chapter of the handbook.

Section A. Carcinogens

Carcinogens are substances that cause the development of cancerous growths in living tissue. Many toxic metals, metal compounds, and organic compounds commonly found in many WRD laboratories are known to be or suspected of being carcinogenic. A list of chemicals that are known or anticipated to be carcinogenic to humans is published in the "Second Annual Report on Carcinogens, 1981" published by the Public Health Service (Exhibit J). This report also contains an exhaustive synonym cross reference list. There are other compounds known to be carcinogenic, but the chemicals on this list are the ones to which a significant number of people in the United States are exposed.

Carcinogens (including pesticides) must be used only in special designated and labeled areas and only by responsible and experienced personnel. These personnel must be totally informed of the hazards that involve carcinogens and instructed in proper use and techniques for handling these materials. Adhere to all OSHA standards for handling these materials. Carcinogens that are particularly insidious should be handled only in a glove box. When acceptable methods for disposal are temporarily unavailable, carcinogenic waste materials must be kept in a secure container in the chemical waste storage area. However, proper disposal of these wastes should be done as soon as possible by a competent waste disposal vendor. All such wastes must be clearly labeled with the hazard cited.

Chromium and certain chromic compounds are suspected of being carcinogenic. The use of chromic acid and Chromerge^{R} as glassware cleaning agents is discouraged. These compounds should be used in an operating hood. All glassware should be water soaked and thoroughly rinsed before inserting it into a chromic acid solution. Nonporous gloves should be worn.

Section B. Cryogenic Liquids

Cryogenic liquids used in WRD laboratories are pressurized liquids formed by compressing gases to a point where the temperature reaches -60°C to -270°C. They are particularly hazardous because they can destroy living tissue on contact, build up extreme pressures, explode or cause fires, asphyxiate in a very minimum period of time, and can cause structural materials to become fatigued and brittle.

The low boiling points of cyrogenic liquids (-60°C to -270°C) require that they be kept liquified under pressure. Many are used are at room temperature which means that they are at their boiling point when actually used. Carelessness at this point may result in frostbite and frozen skin tissue through body contact or asphyxiation if inhaled directly from the pressurized cylinder.

Following are some basic safety practices to be considered when using or handling cryogenics.

-- Potholders or protective gloves should be a requirement for using cryogenic liquids or handling cylinders containing them.

-- Never allow cylinder pressure to build up when using cryogenic liquids. Only special pressure containers designed to automatically release excess pressure will prevent pressure buildup and explosions.

-- Keep pressure vents open. Frost formations on a vent orifice is normal, but excessive icing and caking are not. Monitoring cryogenic cylinders for excessive icing and pressure buildup should be done daily.

-- Never breath the fumes from cryogenic liquids directly. The nose, throat, and lungs can be damaged by the cold gases, and immediate asphyxiation or lung damage may result. Asphyxiation from gas gradually displacing the air in a room is also a danger. Cryogenic liquids must be used only with adequate air ventiliation.

-- Cylinder valves, pipes, hoses, and receiving receptacles should be checked periodically for fatigue and embrittlement.

-- The danger of fire or explosion is obviously present when using liquid flammables such as hydrogen, methane, or acetylene. They should not be used around flames or other ignition sources. Liquid hydrogen may condense oxygen out of the air forming an explosive solid. Liquid oxygen saturated combustibles such as wood and asphalt may explode when subjected to shock. A face shield should always be worn when using cryogenic liquids, especially flammables.

-- Venting cryogenic liquids into glass containers such as Dewar or vacuum flasks can result in implosions due to sudden temperature differentials and subsequent formation of vacuums such as occurs during freeze drying. All glass receiving or pass-through equipment should be taped or wrapped with a shatter-proof mesh to prevent flying glass. Face and body shields should also be used.

-- Cryogenic liquids, like most compressed gases, are under extreme pres- sures and, therefore, the cylinder can become a projectile if the cyl- inder head is broken off or the cylinder ruptures. They should be treated as other compressed gases when storing and transporting (see I-A-4).

-- Medical attention is critical if there is tissue damage. Flush with copious amounts of warm water if there is a brief exposure; then get medical attention. Extreme or prolonged exposure requires medical attention IMMEDIATELY.

Carbon dioxide (CO_2), although not considered to be a cryogenic, behaves much like a cryogenic when pressurized and should be handled much the same.

-- CO_2 fire extinguishers can cause skin damage if improperly used. They should never be vented directly on the bare skin. The horn on a CO_2 fire extinguisher, although made of plastic to prevent frostbite damage, will become very cold when in use and should not be touched to the bare skin.

-- Dry ice (solid CO_2) may freeze the skin causing the same problem as cryogenic liquids. Always handle with padded hand protection.

-- Asphyxiation is also a danger from dry ice, especially in deep coolers used to store it. It too should be used with adequate ventilation. A recent example of such a problem with CO_2 fumes was demonstrated quite vividly. An employee, bending over with his face in a large dry ice storage box to reach the last piece of dry ice, suddenly felt a sharp pain in his head. He realized he was breathing too much CO_2 and was able to get to fresh air quickly, heading off serious consequences.

Section C. Radiation

Radiation from radionuclides and instruments can be harmful. Large doses may cause death or permanent damage to the body. Background radiation levels are universally present in nature and are not usually dangerous. Most published exposure and dose limits from artificial radiations are established for adults and may be too liberal for children, young adults, and expectant mothers because a fetus is involved. Radiation discussed in this handbook is limited to radiation in the laboratory setting from radionuclides and from instruments such as lasers, microwaves, and x-rays that emit radiation when the equipment is used in the laboratory.

Part 1. Radiation from Radionuclides

Personnel working in radiochemistry laboratories or laboratory units must perform their day-to-day duties with precautions that are particular to this type of operation. All personnel working in radiochemistry laboratories or units must wear personnel monitoring film badges. Following is a list of pertinent safety rules and practices associated with working in such laboratories or units.

All types of radioactive samples received from or near nuclear test sites or nuclear waste disposal areas must be screened to assess their activity levels. Those samples with activities exceeding the license limits at the receiving laboratory must be processed and analyzed at a facility licensed to handle high level samples.

No employee shall undertake a task involving the use of radioactive materials or radiation sources until authorized by an appropriate authority.

Radioactive materials and radiation sources must be conspicuously labeled at all times with a proper label identifying the radioactive substance, indicating the date it was obtained, and levels of the radioactivity. Current inventories of radioactive materials must be made semiannually to comply with provisions of the Nuclear Regulatory Commission (NRC) regulations. These materials must be monitored as part of a wipe-test program when the extent of radioactivity is unknown or in doubt.

When handling radioactive material sources, proper precautions must be taken.

- -- Do not pipette by mouth. Always use syringes, rubber bulbs, or other mechanical devices.

- -- Work with open sources must be performed inside an exhaust hood or glove box.

- -- Absorbent paper must be used on work surfaces to minimize hazards caused by spillage.

- -- Plastic disposable gloves and other protective apparel such as lead shielded aprons must be worn at all times when handling materials known or thought to be radioactively hot.

- -- High-level open sources must be transported in double containers or trays that will contain the material if spilled.

- -- Liquid and solid wastes must be kept separate because liquids must be solidified in an oil dry compound before shipment or disposal. Contaminated waste papers or plastics must be deposited in suitable receptacles such as white galvanized steel depositories operated with foot levers. Liquid wastes must be stored in designated radioactive waste containers. Labeling is a must.

- -- Hands and arms to above the elbow should be washed thoroughly with soap and water after handling open sources.

All unused radioactive materials must be returned to a proper storage cabinet that is clearly labeled. A shielded cabinet is preferable.

All radioactive waste materials must be packaged, stored, transported, and disposed of according to Nuclear Regulatory Commission (NRC), Department of Transportation (DOT), and Environmental Protection Agency (EPA) regulations governing the licensing of users, transporters, and disposers.

Accidental spills (including contamination of carpets and working areas with radioactively hot sources) must be reported immediately to the responsible radiochemist or Safety Officer, who will contact the facility Health Physicist or proper authority for help in cleanup.

Pregnant women should not receive radiation doses that exceed 0.5 rems because of possible risks to the fetus. (Additional information on the health risks to children of women exposed to radiation during pregnancy is available in the NRC Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure.")

All individuals under age 18 should receive minimal amounts of external or internal radiation, and precautions should be taken to protect these individuals.

Part 2. Radiation Generated by Instruments

Personnel working with instruments that emit radiation must take precautionary measures to assure that minimal exposure to these radiations is maintained. Three such radiations (laser, microwave, and x-ray) are discussed in this part of the handbook.

a. Lasers

A laser is a beam of light which is one-directional, intense, monochromatic radiation in the ultraviolet, infrared, or visible spectrum. Laser lenses emit light in one direction, but beams can be reflected off mirrors or shiny surfaces. This reflected beam may cause as much damage as the direct beam.

The most serious hazard associated with lasers is eye damage to the retina that can result in permanent blindness. The lens of the eye focuses the incident radiation, concentrating the incident visible laser radiation upon the retina. Due to the varying wave lengths, eye protection devices need to be specific for the wave length of the light emitted.

Skin damage can also be a problem. Lasers, like other forms of radiation, can burn the skin and may result in permanent damage. Little is known about long-term skin exposure to stray radiation from lasers.

Lasers having high voltage energy pumps can produce the same types of burns and electrical shocks as with any high voltage system. Therefore, these types of hazards can be minimized by applying the same prudent practices to laser equipment as would be applied to other high voltage systems.

There are other potential hazards associated with the use of lasers. For example, ozone may be produced as a result of air ionization, accidental contact may be made with the cryogenic gases used to cool the crystal, explosions may occur at capacitor banks due to high gas buildup in the flash lamp, and optical pump systems may malfunction and cause directed beams to go astray. Problems, such as igniting combustibles and reflecting the beam, can also occur in a target area.

It is impossible to cover all the safety rules and regulations due to the varying types and classes of lasers. Some basic safety precautions are outlined in the "Geological Survey Safety Handbook, January 1979," Section 3.3.C.1. Any person working with lasers should also be familiar with the reference book entitled, "Safe Use of Lasers," American National Standards Institute, Inc. (2136.1-1973). Copies are available from American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018. Another good reference is "Laser Safety Handbook" by Alex Mallow and Leon Chabot, published by Van Nostrand Rushold Company, 1978.

b. Microwave

Microwave radiation is a serious hazard. It can cause heat damage at fairly low dosages especially to lenses of the eyes, testicles, and other body parts that must maintain temperatures lower than the body. Eye cataracts and male sterility are the most common damages to the body. Birth defects in offspring are also a suspected effect.

The heart and nervous systems are reported to be affected by microwave radiation because of the electrical impulse requirements. Certain types of pacemakers used for heartbeat regulation may fail when exposed to microwave radiation.

Microwave equipment is manufactured under standards requiring the use of inside meshed metal screens to shield against microwave scatter and a throw-out switch that cuts off the power when the door is opened.

The microwave standard lists the maximum acceptable radiation as $10mW/cm^2$ (milliwatts per square centimeter) power or $1mW\text{-hour}/cm^2$ energy for a 0.1 hour period for radiation exposure to any part of the body.

There are four basic safety precautions to take in the use of microwave equipment:

-- Monitor the equipment for acceptable radiation with a field strength meter before installation unless the equipment has been pretested and labeled by the manufacturers. This testing should also be done every year or anytime a malfunction occurs or leaks are suspected.

-- Do not tamper with the throw-out switch; it violates the integrity of the built-in safety features and may result in direct, and possibly extreme, microwave exposure.

-- Do not place metal objects or other materials that deflect micro- waves inside the equipment.

-- Approved warning signs (WARNING - MICROWAVE IN USE HERE) must be installed on doors entering the use area or on hallways within 50 feet of the use area if the door is more than 50 feet away. The microwave unit must also be labeled.

c. X-Ray

X-ray emitting equipment in use by WRD is mostly limited to x-ray diffraction instruments used for performing analyses. The two specific hazards involved in use of x-ray equipment are radiation and high voltage.

Nearly all radiation injuries caused by x-ray diffraction equipment have been to the fingers of operators, causing permanent skin injury. Even momentary exposure to the direct beam near the tube may result in permanent skin injury. X-ray radiation can cause premature aging, loss of hair, sterility, and leukemia. All personnel not familiar with x-ray equipment, especially new employees, should not be around instruments unless properly supervised.

All instruments have instructions for proper shielding which must be followed. The instrument should be periodically checked for radiation leaks at least once every 3 months with a radiation detection meter such as a "Cutie-Pie"® or an equivalent. The film badge technique (whole body and finger badges) and exposure rings are used to continuously monitor the exposure of the staff. Film from badges should be read monthly for accumulated doses. Maximum dosages should not exceed 1.0 rems per month, 3.0 rems per quarter, or 5.0 rems per year.

Emergency actions to be taken for x-ray accidents (Chemical Rubber Company--"Handbook of Radioactive Nuclides").

-- Shut off power to the unit.

-- Have exposed individuals examined by a physician.

-- Obtain and record all details of the incident.

-- Consult appropriate experts to determine the extent of the hazards. Except for obvious first aid, do not treat the patient until the dose received has been determined.

-- There must not be any induced radioactivity in the patient in such an accident.

pg 29 follows

CHAPTER III

SAFETY DATA REFERENCE INFORMATION

Informational safety data reference sheets and materials that are useful aids in determining the basis of criteria that are applicable to established safety practices are included as part of this section of the Laboratory Safety Handbook. They are listed following this page as Exhibits A-J.

pg 31 follows

Exhibit A. Comparison Chart for Eye Protection Devices

Device Type	Splash Protection (Front)	Splash Protection (Side)	Impact Protection Flying Object (Front)	Impact Protection (Side)	Protection Neck and Face	Comfort to Wearer	General Acceptability to wearer	Use Life Time	Relative Cost
Goggles	Excellent	Excellent	Excellent	Excellent	Poor	Fair	Poor	Fair	Moderate to inexpensive
Glasses (without shields)	Good	Poor	Excellent	Poor	Very Poor	Good to Very Good	Very Good	Very Good	Moderate
Glasses (with shields)	Good	Good	Good	Fair	Poor	Good	Good	Very Good	Moderate
Face-Shield (various sizes)	Excellent	Good	Excellent (if adequate thickness)	Good	Depends on type and length	Fair	Good for Short Periods	Fair	Moderate (depending on type)

Adapted From: "Safety in Academic Chemistry Laboratoraies," American Chemical Society, Third Edit. (1979), p.46 - used by permission.

pg 33 follows

Exhibit B. OSHA Standards for
Noise Level vs. Permissible Exposure Time (1981)

Noise level dB(A) [1]	Permissible Time in Hours/Day
Below 80	Not Applicable
80	32 [2]
85	16
90	8
95	4
100	2
105	1
110	1/2
115	1/4
Above 130	None
140	Maximum permissible impact noise

[1] Decibels (dB) measured on the "A" scale of a standard sound level meter at slow response.

[2] Continuous or cumulative for the extended period listed.

Exhibit C. Chemicals and their Incompatible Counterparts [1/]

Chemical	Incompatible Counterpart [2/]
Acetic acid	Chromic acid, nitric acid, hydroxyl-containing compounds, ethylene glycol, perchloric acid, peroxides, and permanganates.
Acetone	Concentrated nitric and sulfuric acid mixtures.
Acetylene	Chlorine, bromine, copper, silver, fluorine, and mercury.
Alkali and alkaline earth metals (such as sodium, potassium, lithium magnesium, calcium; also powdered aluminum)	Carbon dioxide, carbon tetrachloride, and other chlorinated hydrocarbons. (Do not use water, foam, or dry chemical extinguishers on fires involving these metals--dry sand should be available.)
Ammonia (anhydrous)	Mercury, chlorine, calcium hypochlorite, iodine, bromine, and hydrogen fluoride.
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrates, sulfur, fine granules, powders, or dust of solid organics or small combustible particles.
Aniline	Nitric acid or hydrogen peroxide.
Antimony pentasulfide (golden antimony sulfide)	Chlorates, nitrates, other oxidants and acids.
Bromine	Ammonia (especially anhydrous), acetylene, butadiene, butane and other petroleum gases, sodium carbide, turpentine, benzene, and fine metal granules, powders, or dust.
Calcium oxide	Water.
Calcium hypochlorite	Acids or moisture.
Carbon, activated	Calcium hypochlorite and all oxidizing agents.
Chlorates	Ammonium salts, acids, metal powders, sulfur, fine granules, powders, or dust of solid organics or small combustible particles.
Chromic acid and chromium trioxide	Acetic acid, naphthalene, camphor, glycerol, turpentine, alcohol, and other flammable liquids.

Exhibit C. Chemicals and their Incompatible Counterparts (cont'd)

Chemical	Incompatible Counterpart
Chlorine	Ammonia (especially anhydrous), acetylene, butadiene, butane and other petroleum gases, hydrogen, sodium carbide, turpentine, benzene, and fine metal granules, powders, or dusts.
Chlorine dioxide (or peroxide)	Ammonia, methane, phosphine, and hydrogen sulfide.
Chlorosulfonic acid	Water or metals.
Copper	Acetylene or hydrogen peroxide.
Cumeme hydroperoxide	Acids (organic or mineral).
Cyanide	Any acids, nitrates or nitrites, molten potassium, or sodium salts.
Fluorine	Isolate from everything.
Hydrazine	Hydrogen peroxide, nitric acid, and any other oxidant.
Hydrocarbons (benzene butane, propane, gasoline, turpentine, etc.)	Fluorine, chlorine, bromine, chromic acid, and peroxide.
Hydrocyanic acid (prussic acid)	Nitric acid or alkalies.
Hydrofluoric acid, anhydrous (hydrogen fluoride)	Ammonia (aqueous or anhydrous).
Hydrogen peroxide	Copper, chromium, iron, most other metals or their salts, any flammable liquid, combustible materials, aniline, nitromethane.
Hydrogen sulfide	Fuming nitric acid or oxidizing gases.
Hydroxide	Water, acids, flammable liquids, organic halogens, metals (especially aluminum, tin, and zinc), nitromethane, and nitro compounds.
Iodine	Acetylene, ammonia (anhydrous or aqueous).
Mercury	Acetylene, fulminic acid, oxalic acid, and ammonia (especially anhydrous).

Exhibit C. Chemicals and their Incompatible Counterparts (cont'd)

Chemical	Incompatible Counterpart
Nitric acid (concentrated)	Acetic acid, acetone, alcohol, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases.
Nitroparaffins	Inorganic bases or amines.
Oleum (Fuming sulfuric acid; see also sulfuric acid.)	Water.
Oxalic acid	Silver or mercury.
Oxygen	Oils, grease, hydrogen, flammable liquids, solids and gases.
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, and oils.
Peroxides, organic	Acids (organic or mineral); avoid friction, rough handling, and jarring; store cold.
Phosphorus (white)	Air or oxygen.
Picric acid	Metals - also do not agitate or jar.
Potassium chlorate (see chlorates)	Acids, sulfur, phosphorus, sulfite, organics, and combustibles.
Potassium perchlorate	Acids (see also perchloric acid).
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid.
Silver	Acetylene, oxalic acid, tartaric acid, fulminic acid, and ammonium compounds.
Sodium chlorite	Combustible materials, sulfur, acids.
Sodium nitrite (or nitrate)	Ammonium salts, especially ammonium nitrate.
Sodium peroxide	Any oxidizable substance, such as ethanol, methanol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerol, ethylene gylcol, ethyl acetate, methyl acetate, and furfural.

Exhibit C. Chemicals and their Incompatible Counterparts (cont'd)

Chemical	Incompatible Counterpart
Sulfuric acid	Chlorates, perchlorates, and permanganates.
Sulfur	Chlorates, nitrates, and other oxidants.
Titanium	Do not use water, carbon tetrachloride, foam, or dry chemical extinguishers on titanium fires.
Zinc (powder or dust)	Acids, sodium hydroxide, potassium hydroxide, and moisture.
Zirconium	Do not use water, carbon tetrachloride, foam, or dry chemical extinguishers on zirconium fires.

1/ This represents only a partial list but includes many of the commonly used chemicals considered to be incompatible.

2/ Will cause a moderate to severe reaction when mixed; avoid contact with or storing near.

pg 39 follows

Exhibit D. Incompatible Chemicals that React to Produce Common Toxic Gases

Chemical	+ Reactant	⟶ Toxic Gases
Arsenical Materials	Any reducing agent	Arsine
Azides	Acids	Hydrogen azide
Cyanides	Acids	Hydrogen cyanide
Hypochlorites	Acids	Chlorine or hypochlorous acid
Nitrates	Sulfuric acid	Nitrogen dioxide
Nitric acid	Copper, brass, or any heavy metals	Nitrogen dioxide or other nitrous fumes
Nitrites	Acids	Nitrous fumes
Phosphorus	Caustic alkalies or reducing agents	Phosphine
Selenides	Reducing agents	Hydrogen selenide
Sulfides	Acids	Hydrogen sulfide
Tellurides	Reducing agents	Hydrogen telluride

page 41 follows

Exhibit E. Maximum Allowable Container Sizes

Container Type	Flammable Liquids			Combustible Liquids	
	Class IA[1]	Class IB[2]	Class IC[3]	Class II[4]	Class III[5]
Glass	1 pt.[6]	1 qt.[6]	1 gal.	1 gal.	5 gal.
Metal (other than DOT Drums) or approved plastic	1 gal.	5 gal.[7]	5 gal.[7]	5 gal.[7]	5 gal.[7]
Safety Cans	2 gal.	5 gal.[7]	5 gal.[7]	5 gal.[7]	5 gal.[7]
Metal Drums (DOT Spec.)	5 gal.[7]	5 gal.[7]	5 gal.[7]	60 gal.[7]	60 gal.[7]

[1]Class IA liquids are those having flash points below 73°F (22.8°C) and boiling points below 100°F (37.8°C).

[2]Class IB liquids are those having flash points below 73°F (22.8°C) and boiling points at or above 100°F (37.8°C).

[3]Class IC liquids are those having flash points at or above 73°F (22.8°C) and below 100°F (37.8°C).

[4]Class II liquids are those having flash points at or above 100°F (37.8°C) and below 140°F (60°C).

[5]Class IIIA liquids are those having flash points at or above 140°F (60°C) and below 200° (93.4°C).

[6]Sizes as large as 1 gallon may be used if needed and if the required liquid purity would be adversely affected by storage in metal or if the liquid would cause excessive corrosion of the metal container.

[7]In laboratories, no container for Class I or Class II liquids shall exceed a capacity of 1 gallon, except that safety cans may be of 2 gallons capacity.

page 43 follows

Exhibit F. Flash Points and OSHA Class Designations for Some Commonly Used Organic Compounds

Product	Flash Point*		OSHA CLASS
	°C.	°F.	
Acetone, ACS	-18	0	1B
Acetonitrile	5	42	1B
Alcohol, ,Anhydrous	12	54	1B
Benzene, ACS	-11	12	1B
Carbon Tetrachloride, ACS	none	none	-
Chloroform, ACS	none	none	-
Cyclohexane, ACS	-20	- 4	1B
P-Dioxane, ACS	12	54	1B
Ether, Purified, Anhydrous, ACS, and U.S.P.	-45	-49	1A
Ethyl Acetate, ACS	- 4	24	1B
Haxanes, ACS	-22	- 7	1B
Methylene Chloride, ACS	none	none	-
Methyl Ethyl Ketone	- 7	20	1B
Petroleum Ether, 20-40	-46	-50(OC)	1A
Petroleum Ether, 30-60, ACS	-57	-70(OC)	1A
Petroleum Ether, 30-75	-32	-25(OC)	1A
Petroleum Ether, 60-110	-29	-20(OC)	1A
2-Propanol (iso-propyl alcohol), ACS	12	53	1B
iso-Propyl Ether	-28	-18	1B
Tetrahydrofuran	-14	6	1B
Toluene, ACS	4	40	1B
Trichloroethylene, ACS	none	none	-
Xylenes, ACS	27	81	1C

*Laboratory Waste Disposal Manual, Manufacturing Chemists Association, (Sept. 1973). The flash point figures in the chart represent closed cup tests except where the open cup flash point is designated by the initials "OC" following the figure.

OSHA REGULATIONS REQUIRE Class 1A and 1B flammable and combustible liquids in 1-gallon quantities to be used in a metal can wherever possible.

The Code of Federal Regulations states that flammable and combustible liquid containers shall be in accordance with the table in NFPA Publication No. 45 (1975), page 36 (Exhibit "E") except that glass or plastic containers of no more than 1-gallon capacity may be used for a Class 1A or 1B flammable liquid if:

Exhibit F. Flash Points and OSHA Class Designations for Some Commonly Used Organic Compounds (cont'd)

1. Such liquid either would be rendered unfit for its intended use by contact with metals or would excessively corrode a metal container so as to create a leakage hazard.

2. The user's process either would require more than 1 pint of Class 1A liquid of a single assay lot to be used at one time, or would require the maintenance of an analytical standard liquid of a quality which is not met by the specified standards of liquids available. The required quantity of the analytical standards liquid to be used in any one control process would have to exceed 1/16 the capacity of the container allowed for the class of liquids (Exhibit "E").

Adapted From: J. T. Baker Chemical Co. Printed Data Sheet C-466 (11/75) - used by permission.

Exhibit G. Handling and Storing Gases

1. Refer to all State and local regulations regarding the storage of cylinders.

2. Know and understand the properties of each gas before it is used. The ignition temperature, flammability range, and vapor density of the gas should also be known.

3. Do not remove or deface labels, decals, etc. provided by the supplier for the identification of the cylinder's content.

4. Never alter safety devices in valves or cylinders.

5. Store only the amount of flammable gas required for a specific application.

6. Never transfer gases from one cylinder to another.

7. Leave the valve protection cap in place until the cylinder has been either secured against a wall or bench or placed in a cylinder stand and is ready for use.

8. Always employ a hand truck or other suitable device for transporting cylinders, even for a short distance.

9. Protect cylinders against damage.

10. Never drop cylinders or permit them to strike each other violently.

11. Do not use cylinders for other than their intended purpose.

12. Assign a definite storage area for cylinders and post it with the names of the gases stored.

13. Provide a dry, well-ventilated, and preferably fire-resistant storage area.

14. Store empty and charged cylinders separately and arrange charged cylinders so that old stock is used first.

15. Protect cylinders stored in the open against rusting and extremes of weather.

16. Store cylinders away from sources of heat and ignition and never expose them to temperatures above 125°F.

17. Store cylinders containing flammable gases away from other combustible materials.

Exhibit G. Handling and Storing Gases (cont'd)

18. Separate cylinders containing oxygen and other oxidents from flammable gas cylinders by a minimum of 20 feet or by a fire-resistant partition.

19. Never place cylinders where they could become part of an electrical circuit.

20. Use soapy water or approved explosimeters to detect flammable gas leaks.

21. Before returning empty cylinders to the supplier, close the cylinder valve (leaving a positive pressure remaining in the cylinder), replace all original valve outlet caps, and mark the cylinder "EMPTY."

22. When doubt exists as to the correct handling procedures for a particular gas, contact the supplier.

Adapted From: Speciality Gas Department, Air Products and Chemicals, Inc. Publication 10 M 6/76 HP - used by permission.