U of MN Nanofabrication Center

Laboratory Safety Plan

Updated July 2007

Chapter 1 - Introduction

1. Purpose

This Laboratory Safety Plan (LSP) describes policies, procedures, equipment, personal protective equipment and work practices that are capable of protecting employees from the health hazards in laboratories. This Plan is intended to meet the requirements of the federal Laboratory Safety Standard, formally known as "Occupational Exposure to Hazardous Chemicals in Laboratories", a copy of which is found in Appendix A. , This LSP also addresses the concerns of the Minnesota Employee Right To Know Act (MERTKA) and the federal Toxic Substance Control Act (TSCA).

This LSP is intended to safely limit laboratory workers' exposure to OSHA- and MERTKA-regulated substances. Laboratory workers must not be exposed to substances in excess of the permissible exposure limits (PEL) specified in OSHA rule 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances. PELs for regulated substances are provided in Appendix B. PELs refer to airborne concentrations of substances and are averaged over an eight-hour day. A few substances (listed under Individual Chemical Standard in the Federal column in Appendix C) also have "action levels". Action levels are air concentrations below the PEL which nevertheless require that certain actions such as medical surveillance and workplace monitoring take place. An employee's workplace exposure to any regulated substance must be monitored if there is reason to believe that the exposure will exceed an action level or a PEL. If exposures to any regulated substance routinely exceed an action level or permissible exposure level there must also be employee medical exposure surveillance.

MERTKA requires employers to evaluate their workplaces for the presence of hazardous substances, harmful physical agents, and infectious agents and to provide training to employees concerning those substances or agents to which employees may be exposed. Written information on agents must be readily accessible to employees or their representatives. Employees have a conditional right to refuse to work if assigned to work in an unsafe or unhealthful manner with a hazardous substance, harmful physical agent or infectious agent. Labeling requirements for containers of hazardous substances and equipment or work areas that generate harmful physical agents are also included in MERTKA.

Toxic Substances Control Act (TSCA) requires that prudent laboratory practices be developed and documented for research involving new chemicals that have not had their health and environmental hazards fully characterized. Laboratories engaged in research must consider the applicability of the Toxic Substances Control Act (TSCA) on their operation. TSCA, administered by the U.S. Environmental Protection Agency (EPA) under the New Chemicals Program [http://www.epa.gov/oppt/newchems/], is intended to ensure that the human health and environmental effects of chemical substances are identified and adequately addressed prior to commercial use or transport of those substances. A new chemical is a chemical substance that is produced or imported and not yet listed on the TSCA Chemical Substance Inventory. Each laboratory or research group that synthesizes or imports new chemicals must determine if and how TSCA applies to their laboratory activities – see Appendix O.

2. Scope and Application

The Laboratory Safety Standard applies where 'laboratory use' of hazardous chemicals occurs. Laboratory use of hazardous chemicals means handling or use of such chemicals in which all of the following conditions are met:

i. the handling or use of chemicals occurs on a 'laboratory scale', that is, the work involves containers which can easily and safely be manipulated by one person,
ii. multiple chemical procedures or chemical substances are used, and
iii. protective laboratory practices and equipment are available and in common use to minimize the potential for employee exposures to hazardous chemicals.

At a minimum, this definition covers employees (including student employees, technicians, supervisors, lead researchers and physicians) who use chemicals in teaching, research and clinical laboratories at the University of Minnesota. Certain non-traditional laboratory settings may be included under this standard at the option of individual departments within the University. Also, it is the policy of the University that laboratory students, while not legally covered under this standard, will be given training commensurate with the level of hazard associated with their laboratory work.

This standard does not apply to laboratories whose function is to produce commercial quantities of material. Also, where the use of hazardous chemicals provides no potential for employee exposure, such as in procedures using chemically impregnated test media and commercially prepared test kits, this standard will not apply. This standard applies to all Nanofabrication Center employees (students, civil service, academic and professional, and faculty) as well as all users with a valid access card to NFC facilities in rooms 1-146, 1-148, 1-132, and 1-138 of the Electrical Engineering and Computer Science building.

3. Coordination With Other Standards and Guidelines

The Laboratory Safety Standard and MERTKA address occupational safety issues. Other federal, state and local standards that address use of hazardous chemicals and other materials are listed in Appendix C. Note particularly the listed chemicals with individual standards in the ‘Federal’ column, since these compounds generally have *action limits* (usually set at half the TLV), *air monitoring requirements*, and *medical monitoring requirements.* If a researcher is using one of these chemicals, or in the unlikely event that there is a conflict between provisions of various standards, the Department of Environmental Health and Safety should be contacted.

4. Responsibilities

Implementation of the Laboratory Safety Standard at the University is a shared responsibility. Employees, supervisors, Research Safety Officers, department heads, deans, upper administrative staff, and DEHS staff all have roles to play. These roles are outlined below.

A. **President, Vice Presidents, Provosts and Chancellors (Central Administration)**
Upper level administrators are responsible for:

- promoting the importance of safety in all activities;
- promoting the same attitude among all levels of employment at the University;
- supporting a broad-based laboratory safety/chemical hygiene program that will protect U of MN laboratory employees from health effects associated with hazardous chemical, physical or biological agents; and
- ensuring that deans, directors and department heads provide adequate time and recognition for employees who are given laboratory safety responsibilities.

Performance will be measured by:

- DEHS's documentation and annual reporting of the level of compliance within each of the reporting units.

B. **Deans, Directors and Department Heads**

DDDs are responsible for:

- identifying at least one technically-qualified research safety officer for the unit. (Colleges or institutes that are made up of a number of large laboratory-based departments are urged to assign research safety officers within each department. Large departments may assign one research safety officer for each division);
- transmitting the name of the designated research safety officer to the U of MN's Chemical Hygiene Officer;
- ensuring that the designated research safety officer is adequately trained regarding the roles and responsibilities of the position;
- ensuring that the designated research safety officer modifies this generic Laboratory Safety Plan to incorporate location-specific information;
- carries out his/her assigned responsibilities
- evaluating the performance of the research safety officer(s) as part of overall job performance; and
- taking appropriate measures to assure that college/department/division activities comply with University and OSHA laboratory safety policies;

Performance will be measured by:

- DEHS's record of a trained, research safety officer for the unit.
- DEHS's record of a current, tailored Laboratory Safety Plan for the unit.

C. **Department of Environmental Health and Safety (DEHS)**

The Chemical Hygiene Officer for the University is Dawn Errede, and the entire DEHS staff will participate in providing resources for departments in the development of their individual health and safety programs. The Department of Environmental Health and Safety is responsible for:

- preparing and updating the University's generic Laboratory Safety Plan;
- distributing the LSP to departments or other units who will tailor and implement the plan;
- training designated departmental research safety officers regarding their responsibilities for safety and compliance with regulations and University standards that apply to research; and
- monitoring the progress of departments toward achieving compliance.

Performance will be measured by

- DEHS's documentation that review and evaluation of the generic LSP occurs at least annually, updates as necessary;
- annual feedback to DDDs regarding DEHS's records of lab safety officer training and current LSP s within the units;

D. **Research Safety Officer**

The NFC Research Safety Officer is Greg Cibuzar.

The RSO's roles and responsibilities are described in greater detail in the RSO Toolkit Briefly, the RSO will:

- serve as liaison between employing department and the Department of Environmental Health and Safety;
- know the rules, to help researchers comply with applicable state, federal and university requirements;
- develop and implement a Laboratory Safety Plan for the department;
- coordinate training to ensure all researchers understand their responsibilities and the policies that apply to their research.
- coordinate inspections of laboratories and ensure laboratory supervisors address any noted deficiencies;
- keep records to document compliance with state, federal and university requirements.

Performance will be measured by DEHS's documentation that:

- review and evaluation of the tailored LSP occurs at least annually;
- the research safety officer's personal training records are current.

E. **Supervisors/Principal Investigators**

The supervisor of NFC staff is Greg Cibuzar.

The immediate supervisor of a laboratory employee is responsible for:

- assuring that potential hazards of specific projects have been identified and addressed before work is started;
- ensuring there are written, laboratory-specific standard operating procedures for the protocols carried out in the laboratory that incorporate directions about how to mitigate the hazards of the procedures.
- informing and training employees regarding the specific hazards in their area and in the work they will be doing;
- scheduling time for the employee to attend designated training sessions;
- enforcing U of MN safety policies and safe work practices;
- conducting periodic audits of the research space under the supervisors control;
- reporting hazardous conditions to the college or departmental research safety officer;
- investigate laboratory accidents and send an Accident Investigation Worksheet (Appendix N) with recommendations to the departmental research safety officer for review.

Performance will be measured by:

- home department's documentation of current, pertinent safety training for the supervisor and each employee in the supervisor's group;
- home department's documentation of regular audits for laboratory space under the control of the supervisor.

F. **Employee**

Employees who have significant responsibility for directing their own laboratory work are responsible for assuring that potential hazards of specific projects have been identified and addressed before work is started. All laboratory employees however, are responsible for:

- attending safety training sessions;
- following safety guidelines applicable to the procedures being carried out;
- assuring that required safety precautions are in place before work is started; and
- reporting hazardous conditions as they are discovered.

Performance will be measured by:

- supervisor's assessment of employee's adherence to topics covered in safety training.

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Chapter 2 - Standard Operating Procedures

As noted in Chapter 1, Principal Investigators are responsible for ensuring there are written standard operating procedures (SOPs) for the research protocols conducted in their area. The SOPs must identify the hazards of the protocol, as well as measures to be taken to mitigate those hazards. The references listed below may provide enough detail to serve as the SOPs for some research protocols. Other protocols may require more tailoring, as described in Section 5 of this chapter.

1. Chemical Procedures

A. **Prudent Practices in the Laboratory (Appendix D)**

Laboratory standard operating procedures found in Prudent Practices in the Laboratory: Handling and Disposal of Chemicals (National Research Council, 1995) are adopted for general use at the University of Minnesota. Departmental Research Safety Officers have hard copies of this text, and the entire contents are accessible on the web. Note especially the following topics which are covered in Chapters 5 and 6 of Prudent Practices:

Chapter 5 Working with Chemicals

- Introduction
- Prudent Planning
- General Procedures for Working with Hazardous Chemicals
- Working with Substances of High Toxicity
- Working with Biohazardous and Radioactive Materials
- Working with Flammable Chemicals
- Working with Highly Reactive or Explosive Chemicals
- Working with Compressed Gases

Chapter 6 Working with Laboratory Equipment

- Introduction
- Working with Water-Cooled Equipment
- Working with Electrically Powered Laboratory Equipment
- Working with Compressed Gases
- Working with High/Low Pressures and Temperatures
- Using Personal Protective, Safety, and Emergency Equipment
- Emergency Procedures

B. **Controlled Substances**

In conducting research with controlled substances, University authorized employees must comply with federal and state laws and regulations regarding their uses, including registration with the Drug Enforcement Administration (DEA), storage requirements, inventory maintenance and substance disposal. A condensed guide to federal regulations as well as policies and forms pertaining to controlled substances are available on the Controlled Substances webpage.

C. **The American Chemical Society's "Safety in Academic Chemistry Laboratories"**

ACS's "Safety in Academic Chemistry Laboratories" is another useful text. This manual presents information similar to that found in Prudent Practices, but in a considerably condensed format.

D. **Hazardous Waste Management**

Extensive and detailed policies regarding hazardous waste management are specified in the University's guidebook "Hazardous Chemical Waste Management, 5th edition". Please refer to this text for approved waste handling procedures (http://www.dehs.umn.edu/hazwaste_chemwaste_umn_cwmgbk.htm).

E. **Emergency Procedures for Chemical Spills**

The procedures listed below are intended as a resource for your department in preparing for emergencies before they happen. If you are currently experiencing an emergency such as a chemical or blood spill, please contact the Department of Environmental Health and Safety at 612-626-6002.

Complete spill response procedures are described in the Hazardous Chemical Waste Management guidebook (http://www.dehs.umn.edu/hazwaste_chemwaste_umn_cwmgbk_sec3.htm#qrcsep). However, the quick reference guide is included for convenience in this Laboratory Safety Plan.

Quick Reference Guide

Evacuate

- Leave the spill area; alert others in the area and direct/assist them in leaving.
- Without endangering yourself: remove victims to fresh air, remove contaminated clothing and flush contaminated skin and eyes with water for 15 minutes. If anyone has been injured or exposed to toxic chemicals or chemical vapors, call 911 and seek medical attention immediately.

Confine

- Close doors and isolate the area. Prevent people from entering spill area.

Report

- From a safe place, call the Department of Environmental Health and Safety (EHS) (612) 626-6002 during working hours, 911 after hours (Twin Cities Campus 911 operators will contact on-call EHS personnel).
- Report that this is an emergency and give your name, phone and location; location of the spill; the name and amount of material spilled; extent of injuries; safest route to the spill.
- Stay by that phone, EHS will advise you as soon as possible.
- EHS or the Fire Department will clean up or stabilize spills, which are considered high hazard (fire, health or reactivity hazard). In the case of a small spill and low hazard situation, EHS will advise you on what precautions and protective equipment to use.

Secure

- Until emergency response personnel arrive: block off the areas leading to the spill, lock doors, post signs and warning tape, and alert others of the spill.
- Post staff by commonly used entrances to the area to direct people to use other routes.

After an accident, supervisor(s) must complete and fax in reporting forms within 24 hours. Workers' Compensation policy and reporting forms are available on the web (Appendix J).

2. Biohazardous Procedures

All researchers working with human blood or body fluids, or other pathogens must follow the university's Exposure Control Plan, and complete Boodborne Pathogens Training, available on the web. All researchers working with infectious material including attenuated lab & vaccine strains (bacteria, viruses, parasites, fungi, prions), biologically-derived toxins, rDNA, and artificial gene transfer must follow requirements of the University's Biosafety Program detailed in the Biosafety Manual and on the Institutional Biosafety Committee's website.

Biosafety Manual

The University's Biosafety Manual is made up of three components; researchers must implement all three components in their lab safety manual.

- Biosafety Principles and Practices;
- CDC/NIH's text Biosafety in Microbiological and Biomedical Laboratories (BMBL).
- Individual lab-specific Standard Operating Procedures (SOPs) that:
  - specify the biohazards being used
  - identify the material handling steps that may pose a risk of exposure (sharps, injecting animals, centrifugation, aerosol production, transport, etc.)
  - describe equipment and techniques used to reduce the above risk of exposure
  - give instructions for what to do in case of an accidental exposure/spill
  - list wastes that will be generated and how to properly dispose of wastes

Institutional Biosafety Committee (IBC)

The IBC is charged under Federal Regulations (NIH) and University of Minnesota Regents' Policy with the oversight of all teaching and research activities involving:

- Recombinant DNA
- Artificial gene transfer
- Infectious agents including attenuated lab & vaccine strains
- Biologically derived toxins

See the IBC web site for procedures to apply for approval for the above work.

Select Agents

All research with organisms or toxins that are federally designated as select agents requires the lab to be registered with the Centers For Disease Control. See the Biosafety Section of the DEHS web site for a list of select agents and procedures for their use.

Additional Biosafety References

World Health Organization (WHO) *Laboratory Safety Manual*, available on the web at, http://www.who.int/csr/resources/publications/biosafety/WHO_CDS_CSR_LYO_2004_11/en/

National Research Council's text *Biosafety in the Laboratory: Prudent Practices for Handling and Disposal of Infectious Materials* (1989), available on the web at http://books.nap.edu/books/0309039754/html/R1.html#pagetop.

Biological Material Safety Data Sheets (MSDS) available at http://www.phac-aspc.gc.ca/msds-ftss/index.html.

3. Radioactive Procedures

All researchers using radioactive materials at the University of Minnesota must:

- obtain a permit for the possession and use of radioactive materials (contact the Radiation Protection Division);
- complete required training modules; and
- comply with the radiation policies and procedures of the university (contained in the Radiation Protection manual).

The Radiation Protection manual contains information on a number of topics including license committees, the permitting process, purchasing procedures, transfer procedures, general safety, personnel dosimetry, waste management, emergency management (spill control), record keeping, and regulatory guides on occupational exposure and prenatal exposure.

Training is required for all personnel who require access to areas where radioactive materials are used or stored. This training can be completed on line (http://www.dehs.umn.edu/rad_radmat_training.htm).

4. General Safety Procedures

Other University of Minnesota Policies for Safe Practices in Laboratories are accessible in Appendix E of this laboratory safety plan.

Lab Safety

- Emergency Eyewash and Safety Shower Installation
- Eye Protection/Personal Protective Equipment
- Flammable and Combustible Liquid Quantities in U of M Laboratories
- Controlled Substances
- Greenhouse Policy-Fumigation/Smoke Generation Procedure
- Labeling Chemicals
- Lock Out/Tag Out
- Respiratory Protection Program
- Termination of Laboratory Use of Hazardous Materials

Fire Safety

- Flammable and Combustible Liquid Quantities in U of M Laboratories
- Fire Safety at the University
- Portable Fire Extinguishers-Type and Placement

General Safety

- Emergency Procedures
- Eye Protection/Personal Protective Equipment
- Extension Cords in University Buildings
- Foot Protection/Safety-Toe Shoes
- Holiday Decorations
- Portable Fire Extinguishers-Type and Placement
- Public Corridors
- Respiratory Protection Program
- Step Ladders-Care and Use
- Temperature Standard
- University of Minnesota Twin Cities Campus Smoke-Free Indoor Air Policy
- Supervisors Injury/Illness Investigation Form
- Working with PCBs

5. Laboratory-Specific Standard Operating Procedures

The Nanofabrication Center Safety Manual, reprinted in Appendix R, contains additional operating procedures. Specifically, section I contains procedures relating to general safety, alarms and evacuation, chemical safety, compressed gases, cryogenic hazards, fire hazards, electrical safety, and lab ettiquette. These procedures were written specifically for the hazards associated with working in a cleanroom facility with semiconductor fabrication equipment, and must be strictly adhered to. Appendix S lists the standard operating procedures (SOPs) currently available for NFC process equipment. Please consult NFC staff or the NFC www site at www.nfc.umn.edu for complete details regarding the SOPs for NFC equipment.

6. General Emergency Procedures

The procedures listed below are intended as a resource for your department in preparing for emergencies before they happen. If you are currently experiencing an emergency such as a chemical or blood spill, please contact the Department of Environmental Health and Safety at 612-626-6002.

For University employees who have been exposed to bloodborne or other infectious pathogens, please follow the procedures below under "Needle Stick." For all other emergencies call 911.

Campus Safety Information Guidebook
(http://www.dem.umn.edu/Emergency%20Response%20Guide/index.htm)

- bomb threats
- medical emergencies
- fire
- severe weather
- utility outages
- warning systems/sirens

Chemical Spills (http://www.dehs.umn.edu/hazwaste_chemwaste_umn_cwmgbk_sec3.htm)

Fire Safety (http://www.dehs.umn.edu/policies_bcfs_firesafety.htm)

Needle Sticks (http://www.dehs.umn.edu/bio_pracprin_blood_needle.htm)

http://www.dehs.umn.edu/rad_radmat_incidents.htm
(http://www.dehs.umn.edu/rad_radmat_incidents.htm)

Workplace Violence (contact Human Resources (OHR@hr-mail.ohr.umn.edu) for a hard-copy)

7. Planning for Shutdowns

Researchers should develop written procedures to deal with events such as loss of electrical power (affecting fume hoods, coolers etc.) or other utilities (water), or temporary loss of personnel due to illnesses such as pandemic flu. Guidance on factors to consider when developing shut-down plans is included in the Lab Hibernation Checklist in Appendix Q.

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Chapter 3 - Criteria for Implementation of Chemical Control Measures

Engineering controls, personal protective equipment, hygiene practices, and administrative controls each play a role in a comprehensive laboratory safety program. Implementation of specific measures must be carried out on a case-by-case basis, using the following criteria for guidance in making decisions. Assistance is available from the Department of Environmental Health and Safety.

1. Engineering controls

a) Fume Hoods

The laboratory fume hood is the major protective device available to laboratory workers. It is designed to capture chemicals that escape from their containers or apparatus and to remove them from the laboratory environment before they can be inhaled. Characteristics to be considered in requiring fume hood use are physical state, volatility, toxicity, flammability, eye and skin irritation, odor, and the potential for producing aerosols. A fume hood should be used if a proposed chemical procedure exhibits any one of these characteristics to a degree that (1) airborne concentrations might approach the action level (or permissible exposure limit), (2) flammable vapors might approach one tenth of the lower explosion limit, (3) materials of unknown toxicity are used or generated, or (4) the odor produced is annoying to laboratory occupants or adjacent units.

Procedures that can generally be carried out safely outside the fume hood include those involving (1) water-based solutions of salts, dilute acids, bases, or other reagents, (2) very low volatility liquids or solids, (3) closed systems that do not allow significant escape to the laboratory environment, and (4) extremely small quantities of otherwise problematic chemicals. The procedure itself must be evaluated for its potential to increase volatility or produce aerosols.

In specialized cases, fume hoods will contain exhaust treatment devices, such as water wash-down for perchloric acid use, or charcoal or HEPA filters for removal of particularly toxic or radioactive materials.

b) Safety Shields

Safety shields, such as the sliding sash of a fume hood, are appropriate when working with highly concentrated acids, bases, oxidizers or reducing agents, all of which have the potential for causing sudden spattering or even explosive release of material. Reactions carried out at non-ambient pressures (vacuum or high pressure) also require safety shields, as do reactions that are carried out for the first time or are significantly scaled up from normal operating conditions.

c) Biological Safety Cabinets

Biological Safety Cabinets (BSC), also known as tissue culture hoods or laminar flow hoods, are the primary means of containment for working safely with infectious microorganisms. Cabinets are available that either exhaust to the outside or that recirculate HEPA filtered air to the laboratory. They are not to be used for working with volatile or hazardous chemicals unless they are specifically designed for that purpose and are properly vented. Generally, the only chemical work that should be done in a BSC is that which could be done safely on a bench top involving chemicals that will not damage the BSC or the HEPA filter. For proper cabinet selection and use see, the CDC publication Primary Containment for Biohazards.

d) Other Containment Devices

Other containment devices, such as glove boxes or vented gas cabinets, may be required when it is necessary to provide an inert atmosphere for the chemical procedure taking place, when capture of any chemical emission is desirable, or when the standard laboratory fume hood does not provide adequate assurance that overexposure to a hazardous chemical will not occur. The presence of biological or radioactive materials may also mandate certain special containment devices. High strength barriers coupled with remote handling devices may be necessary for safe use of extremely shock sensitive or reactive chemicals.

Highly localized exhaust ventilation, such as is usually installed over atomic absorption units, may be required for instrumentation that exhausts toxic or irritating materials to the laboratory environment. Ventilated chemical storage cabinets or rooms should be used when the chemicals in storage may generate toxic, flammable or irritating levels of airborne contamination.

2. Personal Protective Equipment

a) Skin Protection

In addition to the information in the NFC Safety Manual section 3.2 (Appendix R in this plan), the following procedures should be followed.

As skin must be protected from hazardous liquids, gases and vapors, proper basic attire is essential in the laboratory. Long hair should be pulled back and secured and loose clothing (sleeves, bulky pants or skirts) avoided to prevent accidental contact with chemicals or open flames. However, bare feet, sandals and open-toed or perforated shoes are not permitted in any laboratory. Short pants and short skirts are not permitted. Long pants should be worn to cover skin that could be exposed during a spill.

Lab coats are strongly encouraged as routine equipment for all laboratory workers. It is the responsibility of the employer to purchase and wash lab coats for employees who request them or are required to wear them. Lab coats are required when working with radioactive materials, biologically-derived toxins, Biosafety Level II organisms, carcinogens, reproductive toxins, substances which have a high degree of acute toxicity, and any substance on the OSHA PEL list carrying a "skin" notation. See Appendix B for chemical listings. Lab coats cannot be assumed to provide complete protection against all agents, but will provide an extra layer that can be removed if accidentally contaminated, buying time for the researcher to get to the emergency shower and minimize direct skin contact. For strong acids and bases, a lab apron impervious to liquids would be a more appropriate choice.

Gloves made of appropriate material are required to protect the hands and arms from thermal burns, cuts, or chemical exposure that may result in absorption through the skin or reaction on the surface of the skin. Gloves are also required when working with particularly hazardous substances where possible transfer from hand to mouth must be avoided. Thus gloves are required for work involving pure or concentrated solutions of select carcinogens, reproductive toxins, substances which have a high degree of acute toxicity, strong acids and bases, and any substance on the OSHA PEL list carrying a "skin" notation.

Since no single glove material is impermeable to all chemicals, gloves should be carefully selected using guides from the manufacturers. General selection criteria are outlined in Prudent Practices, p. 132, and glove selection guides are available on the web . However, glove-resistance to various chemicals materials will vary with the manufacturer, model and thickness. Therefore, review a glove-resistance chart from the manufacturer you intend to buy from before purchasing gloves. When guidance on glove selection for a particular chemical is lacking, double glove using two different materials, or purchase a multilayered laminated glove such as a Silvershield or a 4H.

b) Eye ProtectionEye protection is required for all personnel and any visitors whose eyes may be exposed to chemical or physical hazards. Side shields on safety spectacles provide some protection against flying particles, but goggles or face shields are necessary when there is a greater than average

danger of eye contact with liquids. A higher than average risk exists when working with highly reactive chemicals, concentrated corrosives, or with vacuum or pressurized glassware systems. Contact lenses may be worn under safety glasses, goggles or other eye and face protection. Experts currently believe the benefits of consistent use of eye protection outweigh potential risks of contact lenses interfering with eye flushing in case of emergency.

c) Respiratory Protection

Respiratory protection is generally not necessary in the laboratory setting and must not be used as a substitute for adequate engineering controls. Availability of respiratory protection for emergency situations may be required when working with chemicals that are highly toxic and highly volatile or gaseous. If an experimental protocol requires exposure above the action level (or PEL) that cannot be reduced, respiratory protection will be required. Rarely, an experimental situation may potentially involve IDLH (immediately dangerous to life or health) concentrations of chemicals, which will require use of respiratory protection. All use of respiratory protective equipment is covered under the University of Minnesota Respiratory Protection Program. For departmental policies, see the NFC Respiratory Protection Plan (appendix T).

3. Hygiene Practices

Eating, drinking and chewing gum are all strictly prohibited in any laboratory with chemical, biological or radioactive materials. Researchers must also be careful to restrict other actions (such as applying lip balm or rubbing eyes) which could inadvertently cause exposure to research materials. Consuming alcohol or taking illegal drugs in a research laboratory are strictly prohibited, as such actions potentially endanger the health and safety of not only the user, but everyone in the building. Infractions will be met with serious disciplinary action.
Before leaving the laboratory, remove personal protective equipment/clothing (lab coat and gloves) and wash hands thoroughly. Do NOT wear laboratory gloves, lab coats or scrubs in public spaces such as hallways, elevators or cafeterias.

4. Administrative Controls

Supervisors shall consider the hazards involved in their research, and in written research protocols, detail areas, activities, and tasks that require specific types of personal protective equipment as described above. Researchers are strongly encouraged to prioritize research so that work with hazardous chemical, biological or physical agents occurs only during working hours (8 am – 5 pm, Monday through Friday). After-hours work (on nights and weekends) should be restricted to nonhazardous activities such as data analysis and report writing. If hazardous materials must be used at nights or on weekends, ensure that at least one other person is within sight and ear-shot to provide help in an emergency. Undergraduate workers are prohibited from working alone in the laboratory unless there is a review and formal approval by the department's RSO and/or safety committee.

Research Safety Officers must coordinate and/or conduct inspections of laboratories in their area of responsibility and ensure laboratory supervisors address any noted deficiencies. An audit checklist is available in Appendix G. RSOs can report cases of continued non-compliance to the unit head and to the Department of Environmental Health and Safety (DEHS). The RSO, in conjunction with DEHS and the unit head, has the authority to halt research activities that present an imminent hazard.

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Chapter 4 - Management of Chemical Fume Hoods and Other Protective Equipment

1. Monitoring Safety Equipment

Fume hoods must be monitored daily by the user to ensure that air is moving into the hood. Any malfunctions must be reported immediately to Facilities Management (612-624-2900). The hood should have a continuous reading device, such as a pressure gauge, to indicate that air is moving correctly. Users of older hoods without continuous reading devices should attach a strip of tissue or yarn to the bottom of the vertical sliding sash. The user must ensure the hood and baffles are not blocked by equipment and bottles, as air velocity through the face may be decreased. DEHS staff will measure the average face velocity of each fume hood annually with a velometer or a thermoanemometer. A record of monitoring results will be made.

If biological safety cabinets are used for Biosafety Level 2 work, including handling human cells, they must be certified annually by an outside contractor. A list of contractors is available on the Biosafety section of the DEHS web site. It is the responsibility of the department to schedule and pay for the contractor to perform annual certification.

Eye washes must be flushed weekly by the user. This will ensure that the eye wash is working, and that the water is clean, should emergency use become necessary. The user should coordinate with Facilities Management to ensure that emergency showers and eye washes are checked annually. Fire extinguishers will be checked annually by a University contractor. The user is responsible for checking regularly to ensure that other protective equipment is functioning properly. Environmental Health and Safety staff can assist with these evaluations, should assistance be necessary.

General laboratory conditions must be monitored periodically by the users. A generic laboratory audit form is included in Appendix G, and may be tailored for use by individual laboratories. The departmental Research Safety Officer or the University's Chemical Hygiene Officer may also use this form for spot-checks of the laboratories.

2. Acceptable Operating Range

The acceptable operating range for fume hoods is 80 to 150 linear feet per minute, at the designated sash opening (usually 18 inches). If, during the annual check, a hood is operating outside of this range, DEHS staff may request that you check to ensure the baffles are adjusted properly, and that the exhaust slots are not blocked by bottles and equipment. If these adjustments do not help, DEHS staff will report the deficiency to the appropriate Facilities Management zone office for servicing.

3. Maintenance

During maintenance of fume hoods, laboratories must clean out and if necessary, decontaminate the fume hood and restrict use of chemicals to ensure the safety of maintenance personnel. See "Safe Practices During Servicing of Exhaust Systems in Research Facilities" in Appendix E.

4. Training

Training in the appropriate use and care of fume hood systems, showers, eyewashes and other safety equipment must be included in the initial and update training described in Section 5.

5. New Systems

When new ventilation systems, such as variable air volume exhaust, are installed in University facilities, specific policies for their use will be developed by the Department of Environmental Health and Safety and employees will be promptly trained on use of the new equipment.

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Chapter 5 - Employee Information and Training

All laboratory researchers and their supervisors (Principal Investigators included) must be trained according to the requirements of the Laboratory Safety Standard. Colleges and non-academic departments that engage in the laboratory use of hazardous chemical, physical or biological agents are responsible for identifying such employees. The employees must be informed about their roles and responsibilities as outlined in this standard, as well as hazards associated with their work and how to work safely and mitigate those hazards.

DEHS provides web-based training modules on the basic information and training topics described below on the 'Training' page of the DEHS website. At a minimum, new laboratory employees should complete the modules "Introduction to Research Safety", "Chemical Safety", and "Chemical Waste Management".

In addition, each laboratory supervisor is responsible for ensuring that laboratory employees are provided with training about the specific hazards present in their laboratory work area, and methods to control such hazards. Such training must be provided at the time of an employee's initial assignment to a work area and prior to assignments involving new potential exposures, and must be documented. Refresher training must be provided at least annually.

Volunteers conducting research in University laboratories, in addition to completing the training described below, must complete the Volunteers and Visitor's Laboratory Use Agreement. If the volunteer is a minor, a parent or guardian must also sign the agreement. A minor who is paid to work in a research laboratory must file an Application for Child Labor Exemption with the Minnesota Department of Labor and Industry.

1. Information

It is essential that laboratory employees have access to information on the hazards of chemicals and procedures for working safely. Supervisors must ensure that laboratory employees are informed about and have access to the following information sources:

The contents of the OSHA Laboratory Safety Standard

> "Occupational Exposure to Hazardous Chemicals in Laboratories" and its appendices (29 CFR 1910.1450). A copy of this federal standard can be found in Appendix A of this Laboratory Safety Plan.

The University of Minnesota's Laboratory Safety Plan

> This generic LSP is available to all employees on the Department of Environmental Health and Safety's web site (http://www.dehs.umn.edu/ressafety_rsp.htm. Individual department Laboratory Safety Plans are available within those departments.

The Permissible Exposure Limits (PELs)

> PELs for OSHA regulated substances can be found in Appendix B. Also included in Appendix B are the ACGIH Threshold Limit Value (TLV) list, a list of OSHA health hazard definitions, lists of "select carcinogens" and reproductive toxins, and chemicals having a high degree of acute toxicity.

Signs and symptoms associated with exposures to hazardous chemicals.

> Laboratory Chemical Safety Summaries (LCSSs) are included on pages 235-413 of the 1995 edition of Prudent Practices (http://fermat.nap.edu/books/0309052297/html/235.html). LCSSs are similar to Material Safety Data Sheets (MSDS), but are tailored to the hazards of laboratory use of those

chemicals. The LCSSs include toxicity information, and signs and symptoms of exposure to the chemicals.

Material Safety Data Sheets (MSDSs)

MSDSs are available online through links from the Department of Environmental Health and Safety's web site. Hard copies of MSDS for many laboratory chemicals are also available from DEHS or departmental safety offices. Individual researchers are encouraged to keep hard copies in an easily accessible location for materials that are used in large quantities, which are used frequently, or which are particularly toxic.

Information on chemical waste disposal and spill response

The University of Minnesota guidebook, Hazardous Chemical Waste Management 5th edition provides detailed information on proper waste handling procedures.

2. Training

Employee training programs will include, at a minimum, the following subjects:

Methods of detecting the presence of hazardous chemicals;

Methods include visual observation, odor, real-time air monitoring, time-weighted air sampling, etc.).

Basic toxicological principles;

Principles include toxicity, hazard, exposure, routes of entry, acute and chronic effects, dose-response relationship, LD50, threshold limit values and permissible exposure limits, exposure time, and health hazards related to classes of chemicals.

Prudent laboratory practices;

Prudent laboratory practices include general techniques designed to reduce personal exposure and to control physical hazards, as well as specific protective mechanisms and warning systems used in individual laboratories. Appropriate use of fume hoods is to be specifically addressed. As noted in Chapter 2, the text Prudent Practices in the Laboratory: Handling and Disposal of Chemicals (National Research Council, 1995) details general procedures to be followed in U of MN laboratories.

Description of available chemical information;

Container labels, Material Safety Data Sheets, etc.

Emergency response actions appropriate to individual laboratories;

Lists of emergency phone numbers, location of fire extinguishers, deluge showers, eyewashes, etc.

Applicable details of the departmental Laboratory Safety Plan;

Details should include general and laboratory-specific Standard Operating Procedures.

An introduction to the Hazardous Chemical Waste Management guidebook.

No NFC user is permitted to handle chemicals at wet benches in the Nanofabrication Center without first obtaining safety training on chemical handling and disposal by taking the short course entitled "Wet Benches", which is offered periodically by NFC staff. Within NFC facilities, no one is allowed to use potentially hazardous equipment without first receiving adequate training on safe use and operation. This training will be done by NFC staff members through the short

courses which are offered periodically. A written record of completed training is maintained in the NFC office (1-165 EECS).

3. Updates

Update training is required for all laboratory researchers and supervisors / principal investigators (PI's) at least annually. Departmental Research Safety Officers (RSOs) are responsible for coordinating and tracking update training. Often, RSOs may arrange for departmental-wide update-training sessions, focusing on results of laboratory audits, and highlighting issues that may need improvement. Videos from DEHS's library may be borrowed to supplement these training sessions. Individual PI's may conduct research-group-specific safety reviews to supplement or even stand in place of departmental update sessions. However, documentation (paper or electronic) of safety training must be maintained according to the requirements outlined in Chapter 10 of this Lab Safety Plan.

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Chapter 6 - Required Approvals

'High hazard' research is that which due to the nature of the hazard, or the quantity of the material, or the potential for exposure poses higher than usual risk to the worker. Such research may require formal review and approval by a researcher's departmental safety committee, perhaps with involvement of DEHS personnel. High hazard research could include gases or chemicals listed in Tables 1-5 of this Laboratory Safety Plan, or certain biological or physical agents. RSOs should conduct laboratory audits and consult with Principal Investigators to identify research programs which may fall into this 'high hazard' category.

PI's whose research is identified as 'high hazard' should provide copies of their SOPs to the RSO and their department's safety committee for review and approval. The committee should respond with any comments or requests for changes in a timely manner, and keep a written record of approvals within the department.

NFC Required Approvals

1. The Nanofabrication Center requires pre-approval for the use of chemicals not already in current use within NFC facilities. All such chemicals must be pre-approved by the NFC Safety Officer and NFC Laboratory Manager. Any non-NFC owned equipment must be approved by the NFC safety officer and the NFC director prior to installation in NFC space.

2. The Nanofabrication Center requires researchers to adhere to the following procedure for obtaining approval for the operations/chemicals listed above.
    a. Discuss the situation with the laboratory manager and laboratory safety officer, and provide appropriate material safety data sheets, equipment schematics and drawings (showing safety interlocks), and standard operating procedures for equipment..
    b. Proceed with proposed chemical usage after receiving permission from the laboratory manager and laboratory safety officer. Proceed with equipment installation after receiving permission from the laboratory safety officer, the laboratory manager, and the director.

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Chapter 7 - Medical Consultation and Examination

1. Employees Who Work With Hazardous Substances

All employees who work with hazardous substances will have an opportunity to receive medical attention, including any follow-up visits that the examining physician determines to be necessary, under the following circumstances:

Signs or symptoms of exposure

> Whenever an employee develops signs or symptoms associated with a hazardous substance or organism to which the employee may have been exposed in the laboratory, the employee will be provided an opportunity to receive an appropriate medical examination.

Exposure monitoring

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

Exposure incident

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

Physical Injury

> Whenever an employee is physically hurt or injured on the job, the affected employee will be provided an opportunity for a medical consultation and/or examination. Physical injuries include but are not limited to cuts, burns, punctures and sprains.

Contact the Chemical Hygiene Officer whenever the need for medical consultation or examination occurs, or when there is uncertainty as to whether any of the above criteria have been met.

2. Medical Examinations and Consultations

In the event of a life-threatening illness or injury, dial 911 and request an ambulance. Employees with urgent, but non-life-threatening, illnesses or injuries should go to the nearest medical clinic. The University of Minnesota's Occupational Medicine Program is located in Boynton Health Service. If off-hours medical attention is required, the employee should be taken to the emergency room at Fairview University Medical Center's University campus. All medical examinations and consultations will be performed by or under the direct supervision of a licensed physician and will be provided without cost to the employee, without loss of pay and at a reasonable time and place.

3. Workers' Compensation Procedures and Forms

It is very important that even minor job-related injuries or illness are reported. These statistics help the Department of Environmental Health and Safety track trends that may indicate occupational hazards that need evaluation. To report an illness or injury, go to the Workers' Compensation website. University of Minnesota's Policy for Reporting Workers' Compensation Related Injuries is also available on the web. Both sites provide links to the forms listed below.

This policy explains the procedures and provides the necessary reporting forms. As long as the illness or injury is not life threatening, the supervisor should provide the employee with:

- ✓ a brochure describing Workers' Compensation Information for the University of Minnesota;
- ✓ a completed Employers' Authorization for Care form; and
- ✓ a Work Status Report for the physician to complete and return to the supervisor.

Within 24 hours, the supervisor should complete:

- ✓ a State of Minnesota First Report of Injury form;
- ✓ a U of MN Employee Incident Report form; and
- ✓ a U of MN Supervisor Incident Investigation Report.

Within 24 hours, supervisors must fax the State form to Sedgwick Claims Management Services at (612) 826-3785, and the U of MN forms to the University of Minnesota's Workers' Compensation Department (612)-627-1855.

4. Information Provided to Physician

The employee's supervisor or department will collect and transmit the following information to the examining physician:

- ✓ The identity of the hazardous substance(s) to which the employee may have been exposed;
- ✓ A description of the conditions under which the exposure occurred including quantitative exposure data, if available; and
- ✓ A description of the signs and symptoms of exposure that the employee is experiencing, if any.

5. Information Provided to the University of Minnesota

Supervisors should request that the examining physician provide them with a written report including the following:

- ✓ Any recommendation for further medical follow-up;
- ✓ The results of the medical examination and any associated tests;
- ✓ Any medical condition which may be revealed in the course of the examination which may place the employee at increased risk as a result of exposure to a hazardous chemical found in the workplace; and
- ✓ A statement that the employee has been informed by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment.

The written opinion will not reveal specific findings of diagnoses unrelated to occupational exposure.

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Chapter 8 - Personnel

The following individuals and groups have responsibilities for implementation of various aspects of the University of Minnesota's Laboratory Safety Plan.

Chemical Hygiene Officer

> The University of Minnesota's Chemical Hygiene Officer is Dawn C. Errede, Department of Environmental Health and Safety. Ms. Errede is a Certified Industrial Hygienist (CIH) and chemical hygiene specialist with an M.S. in Environmental Health. Address: W-140 Boynton Health Service. Phone: 612-626-2330.

College or Departmental Research Safety Officer

> The research safety officer for the Nanofabrication Center is Greg Cibuzar (cibuzar@umn.edu 612-625-8079). The specific duties of each safety officer will be determined at the college or departmental level. The duties of this RSO are included in Appendix K.

College or Departmental Safety Committee

> The designation of a safety committee to assist the safety officer in his/her required duties is strongly encouraged. Names of the safety committee members should be listed in this paragraph.

Department of Environmental Health and Safety

> The Department of Environmental Health and Safety offers assistance in a wide range of health and safety issues. Staff phone numbers are included in Appendix L. Address: W-140 Boynton. Phone: 612-626-6002.

Occupational Physician

> The University of Minnesota's Boynton Health Service provides limited occupational medicine services. The phone number for the Occupational Medicine program, which covers Research Animal Resources, respiratory protection, and pesticide exposures only, is 612-625-4906. Non hospital employee chemical exposures should go through Boynton's urgent care.

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Chapter 9 - Additional Employee Protection for Work with Particularly Hazardous Substances

Additional employee protection will be considered for work with particularly hazardous substances. These include select carcinogens, reproductive toxins and substances that have a high degree of acute toxicity (see Appendix B). Pp. 90-93 of the 1995 edition of Prudent Practices provides detailed recommendations for work with particularly hazardous substances. These pages may be accessed from DEHS's web site at www.dehs.umn.edu. Laboratory supervisors and principal investigators are responsible for assuring that laboratory procedures involving particularly hazardous chemicals have been evaluated for the level of employee protection required. Specific consideration will be given to the need for inclusion of the following provisions:

1. Planning;
2. Establishment of a designated area;
3. Access control
4. Special precautions such as:
    - use of containment devices such as fume hoods or glove boxes;
    - use of personal protective equipment;
    - isolation of contaminated equipment;
    - practicing good laboratory hygiene; and
    - prudent transportation of very toxic chemicals.
5. Planning for accidents and spills; and
6. Special storage and waste disposal practices.

Note: Only NFC fulltime employees are allowed to handle toxic gas cylinders, and then only in compliance with the procedures in the NFC Respiratory Protection Plan (appendix T).

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Laboratory Safety Plan

Chapter 10 - Record Keeping, Review and Update of Laboratory Safety Plan

1. Record Keeping

Exposure evaluation

Any records of exposure evaluation carried out by individual departments (including continuous monitoring systems) will be kept within the department and also sent to the Department of Environmental Health and Safety. Results of exposure evaluations carried out by DEHS will be kept by DEHS and sent to the affected department. Raw data will be kept for one year and summary data for the term of employment plus 30 years.

Medical consultation and examination

Results of medical consultations and examinations will be kept by the Boynton Health Service for a length of time specified by the appropriate medical records standard. This time will be at least the term of employment plus 30 years as required by OSHA.

Training

Historically, individual employee training has been recorded on form BA 725A (see Appendix M) and kept in the individual's department or college for five years. More recently, web-based training and many in-person training sessions for employees are tracked electronically in the university's PeopleSoft system. The records must include the name and title of the trainer, the trainee, the date and the content of training. Training records for laboratory volunteers must also be maintained for at least five years. Hard copy and/or electronic forms must be available in the event of an audit by the University Audit Department or state or county regulators.

Fume hood monitoring

Data on annual fume hood monitoring will be kept in the Department of Environmental Health and Safety. Fume hood monitoring data are considered maintenance records and as such the raw data will be kept for one year and summary data for 5 years.

Laboratory audits and reports

Research Safety Officers must coordinate and/or conduct formal audits of laboratories in their sphere of responsibility at least annually. A checklist is available in Appendix G, and a template report form is available in Appendix P. Checklists and reports should be kept for at least 5 years.

Accident investigation reports

Research Safety Officers work with PIs and researchers to complete the Accident Investigation Form in Appendix N. Reports should be kept for at least 5 years.

2. Review and Update of Laboratory Safety Plan

On an annual basis, this Laboratory Safety Plan will be reviewed and evaluated for effectiveness by the Department of Environmental Health and Safety and updated as necessary. Any changes in the

Laboratory Safety Plan will be transmitted to college and departmental research safety officers, who are responsible for carrying out a similar review and modification of their plans, and submitting a revised copy to the Chemical Hygiene Officer.

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Table 1 - Poisonous Gases

The gases on this list are either on the Department of Transportation's Category 1 list, or the Linde Specialty Gases company's Group 6 – Very Poisonous list. These chemicals are highly toxic gases at ambient temperature and pressure. They have an extremely high potential for causing significant harm if not adequately controlled.

Arsine	Boron trichloride	Chlorine pentafluoride
Chlorine trifluoride	Cyanogen	Cyanogen chloride
Diborane	Dinitrogen tetroxide	Fluorine
Germane	Hydrogen selenide	Nitric oxide
Nitrogen dioxide	Nitrogen trioxide	Nitrosyl chloride
Oxygen difluoride	Phosgene	Phosphine
Phosphorus pentafluoride	Selenium hexafluoride	Stibine
Sulfur tetrafluoride	Tellurium Hexafluoride	Tetraethyldithiopyrophosphate
Tetraethylpyrophosphate		

Guidance: Departments may choose to add other chemicals to the above list. For example, sulfur-containing compounds such as mercaptans can cause significant odor problems when used in the laboratory. Pre-approval of the conditions under which they can be used may prevent odor complaints.

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Table 2 - Shock Sensitive Chemicals

The classes of chemicals listed below may explode when subjected to shock or friction. Therefore users must have appropriate laboratory equipment, information, knowledge and training to use these compounds safely.

- Acetylenic compounds, especially polyacetylenes, haloacetylenes, and heavy metal salts of acetylenes (copper, silver, and mercury salts are particularly sensitive)
- Acyl nitrates
- Alkyl nitrates, particularly polyol nitrates such as nitrocellulose and nitroglycerine
- Alkyl and acyl nitrites
- Amminemetal oxosalts: metal compounds with coordinated and hydrazine, or similar nitrogenous donors and ionic perchlorate, nitrate, permanganate, or other oxidizing group
- Azides, including metal, nonmetal, and organic azides
- Chlorite salts of metals, such as AgClO2 and Hg(ClO2)2
- Diazo compounds such as CH2N2
- Diazonium salts, when dry
- Fulminates such as mercury fulminate (Hg(CNO)2)
- Hydrogen peroxide (which becomes increasingly treacherous as the concentration rises above 30%, forming explosive mixtures with organic materials and decomposing violently in the presence of traces of transition metals
- N-Halogen compounds such as difluoroamino compounds and halogen azides
- N-Nitro compounds such as N-nitromethylamine, nitrourea, nitroguanidine, and nitric amide
- Oxo salts of nitrogenous bases: perchlorates, dichromates, nitrates, iodates, chlorites, chlorates, and permanganates of ammonia, amines, hydroxylamine, guanidine, etc.
- Perchlorate salts (which can form when perchloric acid mists dry in fume hoods or associated duct work. Most metal, nonmetal, and amine perchlorates can be detonated and may undergo violent reaction in contact with combustible materials)
- Peroxides and hydroperoxides, organic
- Peroxides (solid) that crystallize from or are left from evaporation of peroxidizable solvents (see the following Section 3)
- Peroxides, transition-metal salts
- Picrates, especially salts of transition and heavy metals, such as Ni, Pb, Hg, Cu, and Zn
- Polynitroalkyl compounds such as tetranitromethane and dinitroacetonitrile
- Polynitroaromatic compounds especially polynitrohydrocarbons, phenols, and amines (e.g., dinitrotoluene, trinitrotoluene, and picric acid)

Note: Perchloric acid must be used only in specially-designed perchloric acid fume hoods that have built-in wash down systems to remove shock-sensitive deposits. Before purchasing this acid, laboratory supervisors must arrange for use of an approved perchloric acid hood.

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Table 3 - Pyrophoric Chemicals

The classes of chemicals listed below will readily oxidize and ignite spontaneously in air. Therefore, users must demonstrate to the department that they have the appropriate laboratory equipment, information, knowledge and training to use these compounds safely.

- Grignard reagents, RMgX
- Metal alkyls and aryls, such as RLi, RNa, R3Al, R2Zn
- Metal carbonyls such as Ni(CO)4, Fe(CO)5, Co2(CO)8
- Alkali metals such as Na, K
- Metal powders, such as Al, Co, Fe, Mg, Mn, Pd, Pt, Ti, Sn, Zn, Zr
- Metal hydrides such as NaH, LiAlH4
- Nonmetal hydrides, such as B2H6 and other boranes, PH3, AsH3
- Nonmetal alkyls, such as R3B, R3P, R3As
- Phosphorus (white)

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Table 4 - Peroxide-Forming Chemicals

The chemicals listed below can form explosive peroxide crystals on exposure to air, and therefore require special handling procedures after the container is opened. Some of the chemicals form peroxides that are violently explosive in concentrated solution or as solids, and therefore should never be evaporated to dryness. Others are polymerizable unsaturated compounds and can initiate a runaway, explosive polymerization reaction. All peroxidizable compounds should be stored away from heat and light. They should be protected from physical damage and ignition sources. A warning label should be affixed to all peroxidizable materials to indicate the date of receipt and the date the container was first opened. Due to these special handling requirements, users must have the appropriate laboratory equipment, information, knowledge and training to use these compounds safely.

A. Severe Peroxide Hazard with Exposure to Air (discard within 3 months from opening)

- diisopropyl ether (isopropyl ether)
- divinylacetylene (DVA)
- vinylidene chloride (1,1-dichloroethylene)
- potassium metal
- sodium amide (sodamide)
- potassium amide

B. Peroxide Hazard on Concentration

Do not distill or evaporate without first testing for the presence of peroxides (discard or test for peroxides after 6 months)

- acetaldehyde diethyl acetal (acetal)
- cumene (isopropylbenzene)
- cyclohexene
- cyclopentene
- decalin (decahydronaphthalene)
- diacetylene (butadiene)
- dicyclopentadiene
- diethyl ether (ether)
- diethylene glycol dimethyl ether (diglyme)
- dioxane
- ethylene glycol dimethyl ether (glyme)
- ethylene glycol ether acetates
- ethylene glycol monoethers (cellosolves)
- furan
- methylacetylene
- methylcyclopentane
- methyl isobutyl ketone
- tetrahydrofuran (THF)
- tetralin (tetrahydronaphthalene)
- vinyl ethers

C. Hazard of Rapid Polymerization Initiated by Internally-Formed Peroxides

Liquids (discard or test for peroxides after 6 months)

Chloroprene (2-chloro-1, 3-butadiene)

- vinyl acetate
- styrene

- vinylpyridine

Gases (discard after 12 months)

- butadiene
- vinylacetylene (MVA)
- tetrafluoroethylene (TFE)
- vinyl chloride

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Table 5 - Carcinogens, Reproductive Toxins or Highly Toxic Chemicals

The chemicals listed below are extremely hazardous. Workers must have knowledge of the dangers of these chemicals prior to use, and documentation of training in safe working procedures.

Biologically active compounds

- protease inhibitors (e.g. PMSF, Aprotin, Pepstatin A, Leopeptin);
- protein synthesis inhibitors (e.g. cycloheximide, Puromycin);
- transcriptional inhibitors (e.g. a-amanitin and actinomycin D);
- DNA synthesis inhibitors (e.g. hydroxyurea, nucleotide analogs (i.e.
- dideoxy nucleotides), actinomycin D, acidicolin);
- phosphatase inhibitors (e.g. okadaic acid);
- respiratory chain inhibitors (e.g. sodium azide);
- kinase inhibitors (e.g. NaF);
- mitogenic inhibitors (e.g. colcemid); and
- mitogenic compounds (e.g. concanavalin A).

Castor bean (Ricinus communis) lectin: Ricin A, Ricin B, RCA toxins

Diisopropyl fluorophosphate: highly toxic cholinesterase inhibitor; the antidote, atropine sulfate and 2-PAM (2-pyridinealdoxime methiodide) must be readily available

Jaquirity bean lectin (Abrus precatorius)

N-methyl-N'-nitro-N-nitrosoguanidine: carcinogen (this chemical forms explosive compounds upon degradation)

Phalloidin from Amanita Phalloides: used for staining actin filaments

Retinoids: potential human teratogens

Streptozotocin: potential human carcinogen

Urethane (ethyl carbamate): an anesthetic agent, potent carcinogen and strong teratogen, volatile at room temperature

Appendices

***See the DEHS Web site at http://www.dehs.umn.edu/ressafety_rsp.htm for appendices A to Q.**

Appendix R

Nanofabrication Center NFC

SAFETY MANUAL AND EMERGENCY RESPONSE PROCEDURES

UNIVERSITY OF MINNESOTA

1-165 ELECTRICAL ENGINEERING/COMPUTER SCIENCE BLDG.
(612) 624-8005
March 2004

The safety rules and emergency response procedures for use of NFC facilities must be read, understood, and practiced at all times. Use common sense when thinking of safety. Think of how your actions will affect other lab users as well as yourself.

The rules outlined in this course have evolved from experience and exist to protect you and your fellow researchers. Failure to follow them will result in expulsion from the lab. If you have any questions, feel free to ask a staff member. Remember, there is no excuse for not following these safety procedures.

In addition to this safety manual, users should also be familiar with the Laboratory Safety Plan for the Nanofabrication Center. The LSP contains more complete information regarding University of Minnesota safety requirements. This safety manual, which forms an appendix in the LSP, contains information and procedures specific to the Nanofabrication Center.

TABLE OF CONTENTS

1. GENERAL

1.1 Buddy System

NEVER WORK ALONE. This rule is absolute. Find out if others are working in the lab. Locate one of them and tell him/her where you will be working. You should check up on each other frequently, at least every 30 minutes. If no one else is present you may not work until you can find another lab user. It is a good idea to plan ahead if you want to work in the evening or on a weekend. No one is ***EVER*** permitted to work alone.

1.2 Handling Emergencies After Hours

If an emergency arises on weekends or after hours when staff are not immediately available, call 911 in the event of a serious emergency (for example a fire or an accident requiring first aid), and the University Building System Automation Center (BSAC):

BSAC: 625-0011

Environmental Health and Safety: 626-6002

Medical Emergency:
U Hospital: 626-2700
Police: 624-3550

The nature of the emergency will determine whether you will call police, staff, or both. If there is no response and matters are serious, dial 911. If someone is injured, the police and an ambulance should be called before calling staff. If there is a facilities problem that does not represent danger to others, but may result in damage to equipment, i.e., a flood, only staff and BSAC need be called. University Police should always be called when a potentially life threatening situation exists (gas leak, suspected bomb, etc.).

1.3 Safety Awareness

Please report any safety problems you encounter to a staff member. Your input and observations will be appreciated.

1.4 Restrictions

No open shoes, sandals, or shorts are permitted. We discourage the use of contact lenses in the laboratory due to the hazard of trapping dissolved chemicals in or under your lenses. If you still choose to wear contact lenses, we strongly suggest you to wear "chemical splash goggles" at all times when in the laboratory. All laboratory users must wear protective eye wear at all times when in the cleanroom.

2. ALARMS AND EVACUATION

As part of the laboratory safety systems, a toxic gas monitoring system constantly checks the air in various parts of the lab. If this system determines that a leak into an occupiable area has occurred, and the resulting concentration of toxic gas is above the OSHA defined safety levels, the fire alarm will sound inside the lab. In addition, if the combustible gas monitoring system determines that a certain amount of oxygen or hydrogen has been released from the house distribution system, the fire alarm will also sound. The fire alarm could also sound due to a fire in the lab or in another part of the building. Regardless of the cause of the alarm, a lab occupant should be concerned with only one thing-exiting the facility calmly in the most direct way. Know the evacuation routes from all parts of the laboratory. Exit immediately upon hearing the alarm, don't wait to make that last notebook entry. If you are in the process of a procedure (such as pouring a chemical), finish the task as quickly as possible (cap the bottle) and exit. ***DO NOT RUN.***

3. CHEMICALS

3.1 Chemical Information and Reference Materials

A large variety of chemical information exists in the staff office (including the following two books) and users should familiarize themselves with them.

"The Merck Index"
"Toxic Gases - First Aid Medical Treatment"

Materials Safety Data Sheets (MSDS) are available in the staff office and at the entrance to bay 2 in the cleanroom. These supply all chemical specifications and some safety information. If you need additional information, call the NFC office at 624-8005.

If you have any questions regarding a given chemical, consult these sources BEFORE using it. Handling chemicals requires common sense.

3.2 Protecting Yourself

Before you start working with chemicals, make sure you are properly protected. Working with acids and other corrosive chemicals means you must wear rubber gloves ***AND*** safety goggles. If you will be working with large volumes of corrosive or caustic, wear a blue chemical splash apron as well. Always work with chemicals in exhausted wet benches in the laboratory, and if possible keep the chemicals in containers which fit down into the wet bench openings (this maximizes the exhaust capabilities).

Remember that the cleanroom gloves you put on when you enter the lab are to prevent particulate contamination, and are ***NOT*** sufficient to protect against chemical burns. They are also soluble in some solvents. Use the chemical gloves provided at the wet bench for handling chemicals (put these chemical gloves on over your cleanroom gloves). If gloves, aprons, or face shields aren't readily available near the wet bench, contact the office and the necessary items will be provided to you.

Two types of gloves are commonly used in the lab:

a) Latex gloves (yellow)

These prevent you from contaminating your wafers, or anything that comes in contact with wafers, such as teflon cassettes.

b) Rubber Gloves (orange)

If there are none, you can obtain them from the the process staff. These must be worn whenever you work with caustics or corrosives.

If immersion or exposure of your gloved hands in caustic or corrosive material is anticipated, it is a good idea to leak-check your rubber gloves. This is accomplished by pressurizing them with a nitrogen gun, then immersing them in water. Check for bubbles, a sure sign of a leak. After using the gloves thoroughly rinse the outside surfaces and discard them if they appear damaged or leak. Otherwise, dry them and store them near the wet bench.

3.3 Transporting Chemicals Through the Lab

No glass chemical bottles are to be transported through the lab by hand. All chemicals are to be moved using either a cart or individual polypropylene bottle carriers. The acid cart with plastic bins, located in cleanroom hallway, is available if you need to move more than 2 bottles through the lab at any given time. Individual bottle carriers are available near the chemical storage cabinets. Please return these carriers and the cart when you have finished with them.

Please be sure to check that there are no bottles of the chemical you need in your area before bringing in and opening new ones.

3.4 Handling Chemicals

When measuring out chemicals, ***NEVER POUR A CHEMICAL BACK INTO ITS REAGENT BOTTLE***. This can contaminate the chemical and damage the next user's devices. When removing dry chemicals, pour them out if possible. Scoop only when necessary and use freshly cleaned spatulas.

If you pour out way too much, instead of throwing it away, you might want to store it in a clean, labeled container for your later use.

3.5 Chemical Burns

If you are exposed to chemicals, immediately remove affected clothing and flush the area with large volumes of water for 15 minutes; ***NOT LESS.*** Use the emergency shower and/or eye washes if necessary. Hands can be rinsed in a wet bench using either the faucet or the DI water spray gun. Know where they are located. Contact a staff member as soon as possible. After flushing, seek medical attention, as damage may not occur for several hours, and it is a good precaution.

HF burns are particularly hazardous. An insidious aspect of HF burns is that there may not be any discomfort until long after exposure. These burns are extremely serious and result in massive tissue damage. If you contact HF, flush the area well and be sure to scrub under and around your finger nails. This is the classic area where people receive burns, having washed off the HF and not realizing it went under their nails. If washed off within a few minutes of exposure, HF will do no harm. Remember, it doesn't produce any burning sensation until after it has already done damage. Any HF burns or other serious acid burns should be looked at by a physician. "Acid Aid" for HF burns can be found on the chemical spill cart in Chase 1, as well as near the chemical storage cabinets containing HF.

3.6 First Aid

Injuries such as minor burns and cuts can be treated with first aid supplies located in the metal cabinet in the gowning room.

3.7 Chemical Spills

In the event of chemical spills you should be aware of the Chemical Spill Cart located in Chase 1, between Bay 1 and Bay 2. This cart contains several chemical absorbing materials. The Spill Pillows are used to absorb and neutralize chemicals. They are contained in absorbent bags and designed so as to minimize interference with our clean rooms. The vermiculite is very absorbent and used on solvent spills to prevent fires. The Spill Pillows should be disposed of by placing in plastic bags (also available in the front of the lab) and contacting a staff member. Personal protective equipment is also stored on the cart for your convenience.

3.8 Mixing Chemicals

When mixing acids with water, remember to ***ADD ACID TO WATER*** and ***NEVER WATER TO ACID!*** Use appropriate containers. Never put HF in a glass container. Always place fuming containers down inside the wet benches. If you must leave an area where you have a process in progress, make sure you leave your process clearly labeled with your name, date, time, your expected time of return, and chemicals involved. Please do not leave chemical processes unattended unless absolutely necessary.

3.9 Chemical Disposal

When you are through with a process, clean up completely. Dispose of your solutions properly as follows:

NO CHEMICALS ARE TO BE DISPOSED OF BY WASHING DOWN THE DRAIN WITHOUT APPROVAL OF NFC STAFF. Waste disposal containers exist for all the chemicals which we stock in the lab. After finishing with your process, dispose of the waste in the appropriately marked container. If this container is not available or is full, obtain an empty container and affix a properly filled out hazardous waste label before storing the container in the appropriate chemical storage cabinet. If the container is full, place it in the chemical cart in the main hallway.

4. COMPRESSED GASES

4.1 Handling Gas Cylinders

Cylinders of both toxic and non-toxic compressed gases are used throughout the lab. No one is allowed to install or disconnect these bottles except a staff member. There are several reasons. The gases in these can be at pressures as high as 3000 psi. That makes a cylinder as powerful as a rocket. Regulators are designed to handle specific gases and can explode if not chosen properly. Some gases, such as phosphine and arsine, are extremely toxic. Improper installation and purging will contaminate a full bottle of gas. Some of our etching gases cost thousands of dollars and their loss or contamination is very costly.

All gas cylinders must be chained or strapped down.

4.2 Toxic Gases

Many toxic gases such as arsine, silane, ammonia, and phosphine are used in the laboratory. These are extremely toxic gases with characteristic odors. Phosphine smells like decaying fish, while ammonia has a pungent, acrid odor. Arsine is also very toxic (the toxic threshold level is 50 parts per billion). Silane, a pyrophoric gas (i.e., it explodes upon contact with air) is found throughout the lab. Hydrogen is used in the lab by the Tylan furnaces. Its explosive quality is well known. The lab must be evacuated should a leak even be suspected. If you notice any unusual odors, leave the lab and report it to the staff immediately. The toxic and combustible gas monitoring systems are designed to detect leaks and initiate appropriate evacuation procedures.

If you notice an unusual odor and suspect a gas leak when staff are not immediately available, such as on a weekend or after hours, leave the lab immediately and take everyone else with you. Call a staff member at home and ask for instructions.

4.3 Nitrogen Guns

Nitrogen guns and compressed air, if not used properly, can inflate the skin like a balloon, tearing it away from the tissue underneath. Be cautious to avoid cuts when spraying nitrogen or working around air streams.

5. CYROGENIC HAZARDS

Liquid nitrogen or "LN2" is used commonly in the lab. Its major hazards are burns from freezing and damage to the lab floor from cracking. Never put LN2 in a closed (unvented) container. Containers not specifically designed for transportation of LN2 are prohibited.

6. FIRE HAZARDS

6.1 Fire Prevention

Fires in the lab can result from the ignition of flammable gases, or solvents, and combustion of materials. A major cause of lab fires is ignition of chemical solutions on hot plates. Always use a water bath to heat flammable organics. Avoid water around electrical appliances.

6.2 In Case of Fire

In the event of a fire, pull the nearest fire alarm. Evacuate the laboratory and the building immediately. Occupants of the laboratory are not obliged to fight fires.

If you ignite your clothes, use the showers immediately and don't panic. There are also fire suppression blankets in each of the bays near the entrance. ***MAKE SURE YOU ARE AWARE OF THE LOCATION OF THE SHOWERS AND EYE WASH STATIONS.***

6.3 Sprinkler System

The lab is covered by a water type sprinkler system. Although this type of system is highly reliable, it is possible a sprinkler head could be broken. This system is designed to deliver 15 gallons/minute. When water flows, an alarm is automatically sent to the fire station and firemen will respond.

7. ELECTRICAL SAFETY

All electrical wiring is to be done by staff/physical plant personnel only. Know the locations of the circuit breakers and electrical disconnects required by the equipment you will use. In case of electrocution of someone in the lab, ***DO NOT GRAB THEM.*** Disable the power immediately by closing the appropriate circuit breaker or disconnect. Do not overload circuits. Report all problems to the staff.

8. SUMMARY OF LABORATORY PROCEDURES

To protect the interest of all users and the laboratory, a summary of the many do's and don'ts is listed here.

DO:

- Sign into the lab by using your access card.
- Work only when others are in the lab and check up on each other often.
- Follow proper gowning procedures.
- Know the location of the phones.
- Know the location of the eye washes and showers..
- Minimize entry into areas you don't require, such as the chases.
- Training is required on any equipment used. Become a qualified user by taking a shortcourse!
- Report all equipment problems to staff.
- Wear appropriate safety items when handling chemicals.
- Put on rubber gloves and safety goggles when handling chemicals. Rinse gloves when through.
- Use the chemical cart or bottle carriers to move chemicals through the lab.
- Place fuming chemicals inside the wet bench openings.
- Label any ongoing chemical process.
- Let staff know of safety problems.
- Always return tools and lab accessories to their proper locations.
- Wear your ID badge at all times in the lab.
- Wear vinyl gloves at all times in the lab.
- Sign in to all required log books and billing books.

DON'T:

- Eat or drink in the lab.
- Wear sandals, open shoes or shorts.
- Bring visitors into the lab for tours without permission.

- Enter the lab unless you belong there.
- Bring ordinary paper or cardboard into the lab.
- Handle things ungloved.
- Play with equipment or knobs.
- Use equipment for which you are not properly trained.
- Work on equipment or modify it without talking first to the Lab Manager or a staff member.
- Use other people's supplies.
- Mix solvents and acids at any time.
- Move a chemical bottle without a cart or carrier.
- Hook up or change gas cylinders.
- Spill liquid nitrogen on the floor.

These do's and don'ts are a reminder for you. The bottom line here is to provide the best research environment possible for you and other users of the lab. Please respect it and each other.

9. LAB ETIQUETTE

Mutual consideration of your fellow researchers is essential to the efficient operation of the lab. It will also make life a lot more pleasant for all involved. Please think about how you would like others to deal with you when you are working in a space that is shared by so many.

1. Leave your work area the way you would like to see it when you come in:
   a. No unlabeled containers with chemicals on work areas.
   b. No unlabeled beakers cluttering up the drying area.
   c. No unreported equipment problems.
   d. No used gloves lying around.
   e. A clean photoresist spinner.
   f. No empty bottles lying around.

2. Be considerate of your fellow lab users:
   a. Share sink space cleanly and safely.
   b. If you reserve equipment, show up. If you cannot show up, cancel your reservation.

3. Consider the general welfare of the lab:
   a. Remember, you have a stake in its operating smoothly. The lab staff is here to ***HELP***, not to serve you. Students should clean, etc., when they know how to do so. When you do need staff help, assist them, and learn from them.
   b. If an equipment alarm goes off, try and find out why. Know what the alarms mean in your work area. See if there is anything you can do. Notify someone. Don't just turn it off!
   c. When you have the slightest doubt about anything, ***ASK!!*** Staff would rather answer questions than fix broken equipment. Use other students as a resource!
   d. Pay particular attention to sources of particulate and chemical contamination.

10. DISCIPLINE

The above write-up is intended to provide information and guidelines necessary to keep the lab running smoothly. Many of these guidelines are simply common sense and require consideration of the other laboratory users. Others require specific knowledge of either proper equipment use or of chemical handling and safety. It is ***YOUR*** responsibility and obligation to be trained in on a particular piece of equipment or to be aware of correct chemical handling procedures. If you do not have these skills, learn them from lab staff before performing the task.

The guidelines are subject to revision dependent upon laboratory procedural changes. Be aware of new or changing lab guidelines.

Please encourage proper lab usage among the other lab users and report any serious violations of the guidelines to lab staff.

The following procedure will be used to discipline offenders in the laboratory. For each offense by a particular individual which is deemed unique by the safety officer, the following three step system will be used:

First Offense: The individual would meet with the safety officer. If the offense was a rule the individual was unaware of, a warning would be given. If the offense was more severe, a memo would be sent to the advisor. This determination would be made by the safety officer and the offender.

Second Offense: The individual would meet with safety officer, lab manager, and advisor. The corrective action would then be decided by this group. This action may include suspension of lab use.

Third Offense: Expulsion from the laboratory.

II. NFC CHEMICAL SPILL EMERGENCY RESPONSE PLAN

I. Policy Statement

All NFC employees and laboratory users are responsible for cleaning up their own spills. You may be given directions on how to do this on your own or, if the situation warrants, directly assist in cleaning up the spill.

II. Purpose

The purpose is to outline spill response procedures that minimize the risk of injury to occupants of NFC.

III. Procedures

A. Evacuate personnel from spill area.
   1. Alert neighbors.
   2. Close doors

3. Isolate area.

B. Attend to victims.

1. Remove person from spill area to fresh air.
2. Immediately remove contaminated clothing.
3. Wash skin with soap and water.
4. Flush skin with water for at least fifteen minutes. (You may not feel any effect from base spills, but it is still important to wash immediately and thoroughly.)
5. If chemicals spilled on body over a large area:

- Remove contaminated clothing while under shower.
- Flood affected body area in cold water for at least fifteen minutes.
- Resume water wash if pain returns.
- Wash off chemicals with mild detergent and water; do not use neutralizing chemicals, unguents, creams, lotions, or salves. (Special precautions for HF).

6. Be sure medical personnel understand exactly what chemicals are involved.

C. Remove ignition sources.

1. Turn off hot plates, stirring motors, flame sources.
2. Shut down all equipment.

D. Evaluate whether help is needed.

1. Notify the NFC Laboratory Staff, Manager, and/or Director. (Phone numbers are listed in the Laboratory Rules for after hours emergencies.)

2. General guidelines to follow:

A) less than one gallon.....handle it yourself, with the assistance of NFC Staff.
B) more than one gallon.....call Environmental Health and Safety (626-6002).
C) very toxic or poses a fire hazard.....call Environmental Health and Safety (626-6002).

E. Locate the spill kit in the NFC clean room in chase 1.

F. Choose appropriate personal protection.

1. Always wear protective gloves and goggles or face shield.
2. If there is a chance of body contact, wear apron and coveralls.
3. If spill is on floor, wear boots.
4. If there are inhalation hazards, wear a respirator.

G. Confine or contain spill.

1. Small amounts of inorganic acids/bases:
   - Use neutralizing agent and absorbent material.
2. Small amounts of other materials:

- Absorb with non-reactive material (e.g. vermiculite, sand, towels, Floor-Dri)

3. Large amounts of inorganic acids/bases:

- Neutralize and call for help.

4. Large amounts of other materials:

- Make a judgment call: depending on the amount, toxicity, or what the substance can run into or react with, you may handle it yourself or call for help.

H. Spills that require special handling:

1. Acid chlorides:
    - Use Oil-Dri, Zorb-All, or dry sand.
    - Avoid water, avoid sodium bicarbonate.
2. Mercury:
    - Use aspirator bulb or suction device (available from Edmond Scientific and Markson Scientific).
    - Mop with mercury decontaminating powder.
    - Don't use vacuum cleaners.
    - Call Department of Environmental Health and Safety and ask for mercury-vapor monitoring instrument.
3. Alkali metal:
    - Smother with dry sand.
    - Put in hood.
    - If possible, dispose of by reaction with isopropyl alcohol.
4. White (yellow) phosphorus:
    - Blanket with wet sand or wet absorbent.

I. Remove absorbent material with a broom and dust pan.

1. Place in plastic bag or other appropriate container.
2. If spilled chemical is a volatile solvent, transfer plastic bag to a fume hood for evaporation of solvent.
3. After evaporation, discard with other non-hazardous solid waste.
4. If spilled substance is non-volatile, hazardous chemical, dispose as a hazardous chemical waste.
5. If spilled substance is non-volatile, non-hazardous chemical, dispose as normal trash.

J. Wet mop spill area.

K. SPECIAL TREATMENT

Treat victims of HF spills:

- Flush with cool water until any whitening of tissue disappears.
- Treat affected area with Acid Aid HF neutralizing cream available near HF storage cabinets.
- Swath injured area with soaking wet, iced cloths.
- Get immediate medical help.

III. EMERGENCY RESPONSE FOR THE NFC LABORATORY

This document determines the Emergency Response to be initiated in the event of the

four alarm conditions of the Laboratory. These alarm conditions are:

1. Smoke Detector Alarm

2. Combustible Gas Sensor Alarm

3. Toxic Gas Monitor Alarm

4. Ventilation Failure Alarm

The items 2-4 above are "Warning" conditions with a Laboratory wide alarm consisting of sounding of the fire alarm. The Minneapolis Fire Department will respond to

- smoke detector alarms (item 1)
- Combustible gas alarms item (2)
- Toxic gas alarms in occupied spaces item(3).

A combination of (2) and (4) or (3) and (4) will cause the building fire alarm to be activated, resulting in building evacuation and response from the Fire Department.

A local NFC Laboratory alarm, identified by the sounding of the fire alarm within the Laboratory, means the Laboratory should be evacuated immediately. If the building fire alarm is also sounding (meaning the fire alarm horns outside the laboratory), then the building should also be evacuated. Go to the nearest stairwell and proceed up to the third floor emergency exit.

If an occupant, who is incapacitated, can be helped to evacuate the area, help should be given and this person should also evacuate the area and/or the building as required. The incapacitated should obtain immediate medical emergency help through the 911 response.

It is not the responsibility of the NFC Laboratory occupants or the NFC staff to fight fires.

Appendix S

Standard Operating Procedures (SOPs) exist for the following NFC process equipment, and are available from the NFC www site at www.nfc.umn.edu:

Equipment Name	Location	Vendor
AJA Sputterer	Bay 3	AJA Intl
CEE Photoresist Spinner	Bay 2	Brewer Science
CHA Electron Beam Evaporator	Bay 3	CHA
Dielectric Film Thickness Monitor	Bay 1	Nanometrics
Electron Beam lithography System	Bay 4	Raith
Iced CAD Layout	Area 3	ICED
MABA6 Aligner	Bay 2	Karl Suss
Optical Pattern Generator	Bay 4	Interserv
Oxygen Asher	Bay 2	Technics

STS Etcher	Bay 3	ST Systems
P16 Surface profiler	Bay 3	KLA-Tencor
Temescal Electron Beam Evaporator	Bay 3	Temescal
Thermco LPCVD	Bay 1	Thermco
Tylan Furnace	Bay1/Area 1	Tylan
Wet Benches	All Bays	Various
Critical Point Dryer System	Bay 4	Tousimis
DC Sputterer	Bay 3	Perkin Elmer
Deep Trench Etcher	Bay 3	Plasmatherm
Ellipsometer	Bay 1	Gaertner
Headway Photoresist Spinner	Bay 2	Headway
Ion Mill	Bay 3	Technics
MA6 Contact Aligner	Bay 2	Karl Suss
MJB3 Contact Aligner	Bay 2	Karl Suss
Nano215 nanospec	Bay 1	Nanometrics
Optical Microscopes	Bays 2-4	Various
Atomic layer deposition	Bay 1	Cambridge Nano
PECVD	Bay 3	Plasmatherm
Rapid Thermal Annealer #1	Bay 1	Modular Process
Surface Profiler 3030	Bay 3	Dektak
Trion RIE #2	Bay 3	Trion Technology
Wafer Bonder	Bay 2	Karl Suss
Wafer Saw	Chase 4	Disco
Hs-scope confocal microscope	Bay 3	HS systems
CMP	Area 2	Strasbaugh
CV-IV Measurement System	Area 2	HP
Ellipsometer	Bay 1	Rudolph
Flood Exposure System	Bay 2	Oriel
Four Point Probe System	Bay 1	Varian
Linewidth Measurement System	Bay 2	Nanometrics
M-gage Resistivity Meas System	Bay 4	Tencor
Photoresist Bake Ovens	Bay 2	
Photoresist Track System	Bay 2	SVG
Probe Station/Curve Tracer	Bay 3	Tektronix
Thermal Evaporator #1	Area 2	Various
Trion RIE #1	Bay 3	Trion Technology
Varian Electron Beam Evaporator	Area 1	Varian
Wire Bonder #1	Area 2	K&S

Appendix T

NFC STANDARD OPERATING PROCEDURES FOR TRANSPORT, CHANGEOUT, AND USE OF HAZARDOUS GASES

SOP FOR TRANSPORT OF HAZARDOUS GASES

1 GENERAL

1.1 All gases are ordered from either UM Stores, a gas supplier or manufacturer. Gases should be delivered to the EECS loading dock with delivery coordinated with NFC staff for immediate pickup. At no time are toxic gas cylinders to be left unattended anywhere in this building except in an appropriate gas cabinet in the NFC laboratory.

2 PURPOSE

2.1 The purpose of this procedure is to outline the requirements for transporting hazardous gases in the Nanofabrication Center.

3 PROCEDURES FOR MOVING HAZARDOUS GASES

3.1 Only NFC staff will be allowed to transport hazardous gases in the Nanofabrication Center. Exceptions to this rule must be approved in advance by the Director of NFC.

3.2 The cylinder cap must be secured in place during transport.

3.3 Cylinders must never be rolled as a means of transportation to a using department.

3.4 Cylinders must be placed on cylinder carts and secured for transport through hallways. Lecture bottles are to be transported in the lecture bottle original packaging.

3.5 A properly vented gas cabinet must be prepared and available prior to actually bringing a toxic gas cylinder into the laboratory. Check to be sure that the gas cabinet exhaust is working properly.

SOP FOR CHANGE-OUT OF HAZARDOUS GASES

GENERAL

For the safe change-out of hazardous gas cylinders, the wearing of personal protective equipment by the involved parties is necessary. Additionally for certain gases, two person change-outs and isolation of the change-out area are necessary. In all cases, at least one person performing these procedures must be a member of the NFC staff or approved in advanced by the Safety Officer. This person must have a thorough understanding of the practices and procedures outlined in this document.

PURPOSE

The purpose of this specification is to provide safety protective equipment requirements and safety procedures for all hazardous gas cylinder change-outs.

SCOPE

This specification shall apply to all individuals who must change-out hazardous compressed gas cylinders in the Nanofabrication Center. Final determinations as to the correct interpretation of this specification's requirements shall be made by the Director of NFC.

DEFINITIONS

Compressed Gas - Any material or mixture contained in the metal gas cylinder with an absolute pressure exceeding 40 pounds per square inch at 70°F, or regardless of the pressure at 70°F, with an absolute pressure exceeding 104 pounds per square inch at 130°F, or any liquid flammable material with a vapor used as a gas source.

Corrosive Gas - A gas which burns, irritates or destructively attacks organic tissue. Corrosive gases can be either acidic or basic.

Oxidizing Gas - A gas that provides oxygen for reacting with another chemical substance. Oxidizing gases react vigorously with hydrocarbon-based greases and vigorously increase the combustion rate of a burning substance.

Inert Gas - A gas that is non-corrosive, non-flammable, non-oxidizing, non-pyrophoric and causes human distress primarily by displacing available oxygen in confined areas.

Flammable Gas - A gas which is flammable in a mixture of 13 percent or less (by volume) with air or the flammable range is wider than 12 percent regardless of the lower limits.

Pyrophoric Gas - A gas which can ignite spontaneously on contact with air.

Toxic Gas - A gas which is extremely detrimental to human health upon inhalation, ingestion or skin contact, or which by generally accepted criteria is designated as such by Occupation Health and Safety.

Compressed Gas Cylinder Change-Out - A procedure whereby a compressed gas cylinder whose contents are piped to a process is turned off and removed from the piping connection and replaced with another cylinder.

Face Shield - A device worn in front of the eyes and a portion of, or all of, the face to supplement protection afforded by a primary protective device.

Spectacle, Safety (Safety Glasses) - A device patterned after conventional type spectacle eyewear but of more substantial construction, either with or without side shields, and with plain or corrective (Rx) lenses of clear or shatter resistant, absorptive filter glass or plastic.

Chemical smock - A smock constructed of a chemically impervious material which affords chemical protection to the wearer's trunk and arms.

Chemical glove - A substantially constructed glove, that is chemically resistant, and affords chemical protection to the wearer.

CGA Cap - A metal cap provided by the vendor to prevent contamination or damage to the inside of the CGA fitting, and which must be removed for connection of a gas cylinder.

Chemical coveralls - Impermeable coveralls which are chemically resistant, and afford protection to the wearer's trunk, arms and legs.

Fire-resistant suit - A suit made of material which is fire resistant (asbestos cloth, aluminized coated rayon, leather, cloth with powdered aluminum).

Respirator, airline - A full face-piece respirator which utilizes an external air source such as a tank to provide breathing air to the wearer, and has a five minute supplementary, self contained emergency supply of air.

HAZARDOUS GASES USED IN NFC FACILITIES 6-07

Gas and Formula	Conc (%)	Qty (lbs)	To Com-ponent wt (lbs)	DOT Class	NFC Hazard Class	IDLH (ppm)	TLV-TWA (ppm)	Loca-tion	Flamma-bility Limits (%)	Process Equip	Manifold type
Silane SiH_4	100	15	15	2.1 Flammable gas	Pyrophoric	NA	5	Area 1 1-146	1.4-96 2-96 pyrophoric	LPCVD	5 valve automatic
Dichloro-silane $SiCl_2H_2$	100	53	53	2.3 Poison Gas	Pyrophoric Corrosive	100	NA	Area 1 1-146	4.6-98	LPCVD	5 valve manual
Phosphine in hydrogen PH_4	15	4	Less than 1	2.3 Poison Gas	Flammable	200	0.3	Area 1 1-146	1.0-2.0	LPCVD	5 valve automatic
Diborane in hydrogen B_2H_6	15	4	Less than 1	2.3 Poison Gas	Flammable	40	0.1	Area 1 1-146	0.8-98	LPCVD	5 valve automatic
Ammonia NH_3	100	7	7	2.2 Non-flammable gas	Corrosive	500	25	Area 1 1-146	15-28	LPCVD	5 valve automatic
Oxygen O_2	100	100	100	2.2 Non-flammable gas	Oxidizer	None	None	O2 bunker 1-147B	NA	Oxidation Furnace tube21-tube24 5 valve auto	5 valve automatic

Hydrogen H_2	100	4	4	2.2 Non-flammable gas	Flammable	Asphyxiant	Asphyxiant	H2 bunker 1-147A	4.0-75	Oxidation Furnace tube 24	5 valve automatic
Silane in Nitrogen SiH_4	2	5	0.1	2.1 Flammable gas	Flammable	NA	5	Chase 2 1-158	1.4-96 2-96 pyrophoric	PECVD	5 valve automatic
Ammonia NH_3	100	146	146	2.2 Non-flammable gas	Corrosive	500	25	Chase 2 1-158	15-28	PECVD	5 valve automatic
Nitrous Oxide N_2O	100	60	60	2.2 Non-flammable gas	Oxidizer		50	Chase 2 1-158	NA	PECVD	5 valve automatic
Ammonia NH_3	100	5	5	2.2 Non-flammable gas	Corrosive	500	25	Chase 3 1-164	15-28	MOCVD	5 valve automatic
ChlorineCl_2	100	12	12	2.3Poison Gas	Corrosive	30	1	Chase 31-164	NA	Trion 2	
Boron Trichloride BCl_3	100	10	10	2.3 Poison Gas	Corrosive	100	NA	Chase 3 1-164	NA	Trion 2	
Silicon Tetra-chloride $SiCl_4$	100	12	12	2.3 Poison Gas	Corrosive	100	NA	Chase 3 1-164	NA	Trion 2	
Methane CH_4	100	10	10	2.1 Flammable gas	Flammable	Asphyxiant	Asphyxiant	Chase 3 1-164	5.0-15	Trion 1	

Hydrogen H_2	100	4	4	2.2 Non-flammable gas	Flammable	Asphyxiant	Asphyxiant	Chase 3 1-164	4.0-75	Trion 1	
Trimethyl Aluminum	100	0.06	0.06	4.2 Flammable Liquid	Pyrophoric	NA	2mg/M3	Bay 1 1-156	Pyrophoric / Water Contact	ALD	Single Valve /Internal to tool
Tetraxis Hafnium	100	0.06	0.06	4.3 Flammable Liquid	Flammable /Water Reactive	NA	0.5 mg/M3	Bay 1 1-156	Water Contact	ALD	Single Valve /Internal to tool
Diethyl Zinc	100	0.06	0.06	4.2 Flammable Liquid	Pyrophoric	NA	5mg/M3	Bay 1 1-156	Pyphoric Water Contact	ALD	Single Valve /Internal to tool
Ammonia NH_3	100	5	5	2.2 Non-flammable gas	Corrosive	500	25	Area 1 1-146	15-28	RTVPE	5 valve automatic

Table 1: Hazardous Gases used in NFC facilities (Aug 2007)

6 SAFETY REQUIREMENTS FOR THE CHANGE OUT OF COMPRESSED GASES

6.1. Inert and Oxidizing Compressed Gases

6.1.1. Person performing change-out shall wear safety spectacles (Face shield over spectacle is recommended).

6.1.2. No person shall attempt to change-out a compressed gas cylinder unless thoroughly trained in the change out procedure.

6.1.3. Person changing out cylinder shall wear shoes of a closed toe/closed heel design, heel not greater than 2-1/2" and material of shoe construction - leather or leather like.

6.1.4. Long trousers are required for person changing out cylinder.

6.2. Flammable Compressed Gases

6.2.1. Person performing the change-out shall wear safety spectacles (Face shield over spectacles is recommended).

6.2.2. No person shall attempt to change out a compressed gas cylinder unless thoroughly trained in the change out procedure.

6.2.3. Person changing out cylinder shall wear shoes of a closed toe/closed heel design, heel not greater than 2-1/2" and material of shoe construction - leather or leather like.

6.2.4. Long trousers are required for person changing out cylinder.

6.2.5. No non-involved personnel in the same room or area shall be allowed within 10 feet of the change-out procedure. Barring of the means of access shall involve signs or barricades but no egress doors shall be locked.

6.3. Corrosive Compressed Gases

6.3.1. Person performing change-out shall wear an airline respirator during the removal of the CGA fitting, installation and removal of CGA cap, reconnection of CGA fitting, and re-pressurization of system.

6.3.2. While wearing a full face-piece airline respirator during the procedure, the use of contact lenses shall be prohibited.

6.3.3. Person performing change-out shall wear chemical gloves and chemical smock or coverall during procedure.

6.3.4. No person shall attempt to change out a compressed gas cylinder unless thoroughly trained in the change-out procedure.

6.3.5. Person changing out cylinder shall wear shoes of a closed toe/closed heel design, heel not greater than 2-1/2" and material of shoe construction - leather or leather like.

6.3.6. Long trousers are required for person changing out cylinder.

6.3.7. A second person protective equipment as specified in 6.4.1, 6.4.3, 6.4.5, and 6.5.6 shall be on hand to offer assistance during the change-out procedure.

6.3.8. No non-involved personnel in the same room or area shall be allowed within 20 feet of the change-out procedure. Barring of the means of access shall involve signs or barricades but no egress doors may be locked.

6.4. Pyrophoric Compressed Gases

6.4.1. Person performing change-out shall wear safety spectacles and a flame-retardant hood and suit, which affords protection of the upper body to the knees at a minimum. This equipment shall be worn during the removal of the CGA fitting installation and removal of the CGA cap, reconnection of the CGA fitting, and re-pressurization of the system.

6.4.2. Person performing change-out shall wear gloves of a flame-resistant nature.

6.4.3. No person shall attempt to change out a compressed gas cylinder unless thoroughly trained in the change-out procedure.

6.4.4. Person changing out cylinder shall wear shoes of a closed toe/closed heel design, heel not greater than 2-1/2" and material of shoe construction - leather or leather like.

6.4.5. Long trousers are required for person changing out cylinder.

6.4.6. A second person wearing protective equipment as specified in 6.5.1, 6.5.2, 6.5.4, and 6.5.5 shall be on hand to offer assistance during the change-out procedure.

6.4.7. No non-involved personnel in the same room or area shall be allowed within 20 feet of the change-out procedure. Barring of the means of access shall involve signs and barricades but no egress door may be locked.

6.4.8. Dichlorosilane change-outs shall require in addition to the above personal protective equipment requirements; the use of an airline respirator by both the person performing the change-out, and the person providing assistance for the change-out.

6.4.9. Pyrophoric/toxic mixtures shall require the use of flame retardant gear as in 6.5.1, 6.5.4, and 6.5.5 as well as an airline respirator.

6.5. Toxic Compressed Gases

6.5.1. Person performing change-out shall wear an airline respirator during the removal of the CGA fitting, installation and removal of CGA cap, reconnection of CGA fitting, re-pressurization of system.

6.5.2. While wearing an airline respirator during the procedure the use of contact lenses shall be prohibited.

6.5.3. No person shall attempt to change-out a compressed gas cylinder unless thoroughly trained in the change-out procedure.

6.5.4. Person changing out cylinder shall wear shoes of a closed toe/closed heel design, heel not greater than 2-1/2" and material of shoe construction - leather or leather-like.

6.5.5. Long trousers are required for person changing out cylinder.

6.5.6. A second person wearing protective equipment as specified in 6.6.1, 6.6.4, and 6.6.5 shall be on hand to offer assistance during the change-out procedure.

6.5.7. No non-involved personnel in the same room or area shall be allowed within 20 feet of the change-out procedure. Barring of the means of access shall involve signs and barricades but no egress door may be locked.

7. GAS CYLINDER CHANGE-OUT PROCEDURES

7.1. For the gas involved, use the table in section 5 to determine the NFC Hazard classification. Based upon this classification, follow the safety requirements as specified in the appropriate part of section 6.

7.2. Determine the type (manual or automatic) of 5 valve manifold/purge assembly involved from the "Manifold type" column of table 1.

7.2.1. Manual 5 Valve Purge Assemblies

7.2.1.1. Refer to Appendix A, "Series AT 5-Valve Manual Manifold with Vacuum Generator Cylinder Change Manual", Semi-Gas Systems, Inc. March, 1991 for complete details.

7.2.1.2. Procedure

7.2.1.2.1. Isolate the manifold and shutoff the cylinder
7.2.1.2.2. Test the cylinder shutoff valve
7.2.1.2.3. Purge cylinder connection (pre-purge)
7.2.1.2.4. Disconnect and remove cylinder
7.2.1.2.5. Install full cylinder and connect
7.2.1.2.6. Leak test CGA connection
7.2.1.2.7. Purge cylinder connection (post-purge)
7.2.1.2.8. Test the purge gas inlet (PGI) valve shutoff
7.2.1.2.9. Turn on cylinder and adjust regulator

7.2.2. Automatic 5 Valve Purge Assemblies

7.2.2.1. For information on the Autopurge GSM Gas Safety Monitor (which sits atop the gas cabinet), the Auto-Purge M Multi Purge Controller (MPC), the remote module that connects to the GSM and enables automatic purging of the manifold, see Appendix B.

7.2.2.2. Procedure

7.2.2.2.1. Connect MPC to GSM, mounting the MPC on the gas cabinet door.
7.2.2.2.2. Press the Service/Purge switch on the GSM, next follow the instructions as displayed on the MPC.
7.2.2.2.3. Shut off the cylinder valve, and then press the yellow ACK acknowledge switch on the MPC. The MPC now will control the procedure (with appropriate acknowledgment from the operator).
7.2.2.2.4. Process gas is removed from the pigtail and manifold and leak tests are performed. Pre-purge of the manifold is performed.
7.2.2.2.5. Remove cylinder, install new cylinder.
7.2.2.2.6. MPC tests cylinder connection for leaks.
7.2.2.2.7. Post-purge is performed, consisting of cyclical purges and backfills of the pigtail and high pressure side of manifold.
7.2.2.2.8. Purge gas is removed from the manifold.
7.2.2.2.9. Open cylinder valve and adjust regulator.

7.2.3. Custom Gas Manifolds/purge assemblies

7.2.3.1. For information on the custom manifolds associated with the Trion etchers, see appendix C.

7.2.3.2. Procedure

7.2.3.2.1.

SOP FOR THE USE OF HAZARDOUS GASES

1. GENERAL

The utilization of toxic, pyrophoric, flammable, oxidizing and corrosive compressed gases in the microelectronics research laboratory is necessary. In order to protect personnel and property from the deleterious effects of these compressed gases, as well as meet federal, state and local regulations, certain design criteria must be specified for the piping of systems utilizing these gases.

2. PURPOSE

The purpose of this specification is to provide the compressed gas system designer with basic design requirements necessary to protect personnel and property.

3. SCOPE

This specification applies to all hazardous compressed gas processes installed the the Nanofabrication Center. The final determination of whether or not a specific compressed gas system meets this specification's requirements will be made by the Director of NFC.

4. DEFINITIONS

Piping system - The pipe, tubing, flanges, bolting, gaskets, valves, fittings, the pressure containing parts of other components such as expansion joints and strainers and devices which serve such purposes as mixing, separating, stubbing, distributing, metering, filtering or controlling compressed gas flow.

Hazardous gas - A gas exhibiting toxic, oxidizing, flammable, pyrophoric or corrosive properties.

Toxic Gas - A gas which is extremely detrimental to human health upon inhalation, ingestion or skin contact, or which by generally accepted criteria is designated as such by the Department of Environmental Health and Safety.

Oxidizing Gas - A gas which provides oxygen for the reaction with another chemical substance. Oxidizing gases react vigorously with hydrocarbon-based greases and vigorously increase the combustion rate of a burning substance.

Flammable Gas - A gas which is flammable in a mixture of 13 percent or less (by volume) with air or the flammable range is wider than 12 percent regardless of the lower limits.

Pyrophoric Gas - A gas which ignites spontaneously on contact with air.

Corrosive Gas - A gas which burns, irritates or destructively attacks organic tissue. Corrosive gases can be either acidic or basic and some corrosive gases have oxidizing properties.

Zone of Local Exhaust - An atmospheric region formed by means of a pressure differential whereby contaminants are captured near the location where they originate or are dispersed.

5.0 REQUIREMENTS

5.1 Pressure Regulators

5.1.1 Any regulator utilized in a compressed gas system must be constructed of material which is compatible with the specific compressed gas controlled by that regulator. Under no conditions should an adapter be utilized for the fitting of a regulator to a compressed gas cylinder which does not have a compatible CGA.

5.1.2 All regulators containing toxics, flammables, corrosives or pyrophorics are to be equipped with a bonnet vent port that is capable of withstanding a diaphragm rupture and or carrying the escaping gases through a piping system to a suitably equipped scrubbing or exhaust system. As an alternative, a tied diaphragm regulator design with intrinsic overpressure safety mechanism may be substituted.

5.1.3 All two stage regulators shall be equipped with a regulator relief device. This device shall be plumbed to a suitably equipped scrubbing/neutralization system. As an alternative, a tied diaphragm regulator design with intrinsic overpressure safety mechanism may be substituted.

5.1.4 All regulators shall be specified by the manufacturer as being "Cleaned for Oxygen Service".

5.2 Piping and Tubing Requirements

5.2.1 All hazardous gas piping must be of the double containment design with the volume between the inner pipe containing the hazardous gas, and the outer, containment pipe, connected to a cabinet vented to the lab exhaust system.

5.2.2 Where hazardous gas piping passes through walls or floors, it should be protected against chafing or movement by appropriately sized sleeves and clamps. Pipe openings in fire walls must be resealed without compromising the rating of the fire wall. No fitting connections shall be made inside a wall, floor or ceiling penetration.

5.2.3 All piping must be placed in locations which can be readily inspected. Hidden chaseways or plenums must be avoided.

5.2.4 The gas content of the pipelines shall be readily identifiable by appropriate labeling with the name of the gas contained. Such labeling shall be by means of metal tags, stenciling, stamping or adhesive labels in a manner that is legible and permanently affixed. These labels shall be placed every 10 feet along the pipeline and at all locations where the pipeline enters and exits a partition, floor, or ceiling.

5.2.5 All components of the piping system are to be so mounted so as to provide easy access and removal for repair without the movement of any gas cabinet or back panel.

5.2.6 Piping and fittings shall comply with service piping as incorporated into the American National Standard Code for Pressure Piping, Chemical Plant and Petroleum Refinery Piping, ANSI B 31.3. A copy of this standard shall be kept on file by the Department of Environmental Health and Safety.

5.2.7 Piping components such as regulators, filters, valves, packing and seating materials that are not compatible with the gases employed shall not be utilized in such a manner that they will be in contact with the gas stream. For example, brass, monel or viton would not be used with ammonia, nor would aluminum be used with hydrogen chloride, etc.. Care must be taken to consider all components including synthetic materials as well as the metals used. Consult component vendor for compatibility information.

5.2.8 The minimum acceptable standard for tubing is to be Fully Annealed Type 316L seamless stainless steel hydraulic tubing ASTM A-269 or equivalent, hardness Rb 80 or less. Tubing is to be free of scratches. Suitable for bending and flaring, 0.035" wall thickness, 1/4" O.D. with a minimum working pressure of 5906 PSIG. Allowable working pressure loads calculated from S values as specified in ANSI B 31.3. Tubing of larger O.D. is acceptable in select cases for multiple vent lines and headers, however, 1/4" O.D. is the preferred maximum diameter. Where the use rate is low and 1/8 inch stainless steel tubing is feasible, this is preferable to 1/4 inch. For specialized situations, tubing not meeting the above criteria may be substituted provided approval for the tubing is obtained from the Director of NFC.

5.2.9 Pigtails and tubing used for the connection of source cylinders shall contain a coil of tubing (with a 4" diameter minimum) or approved equivalent suitable to act as a means of vibration isolation and to provide for adaptation or accommodation to a variation in cylinder height of three inches. CGA or cylinder inlet connections so affixed shall be welded to the pigtail. This requirement applies to rigid tubing only.

5.2.10 Piping and equipment will be installed so as to accommodate, in an unimpeded manner, the installation of either 52 inch or 55 inch tall cylinders as a standard. Connecting pigtails must be provided to accommodate height variations in cylinders of three inches in all cases and a variation in diameter of one inch.

5.2.11 Teflon tape is to be used at all pipe thread joints with particular care being paid not to overlap tape at the fitting ends so as to expose tape to the gas stream. The use of pastes and greases (even of "inert" composition) is not permitted.

5.3 Purging and Venting

5.3.1 Systems containing process gases shall be capable of being purged at the cylinder CGA connection interface so as to provide:

- personnel protection from exposure during cylinder changes.
- process protection through minimization of contamination by ambient air impurities.

- the capability for "cycle" or dilution purging by repeated pressurization and relief is required. Delivery of or introduction of the purge gases as close to the cylinder valve and CGA fitting as is practical is required.

5.3.2 Inert gas purge cylinders are required for use for all purge gas sources. House purge gas (nitrogen or other) is not permitted. Purge gas systems may feed compatible systems only. That is, classic separating of groups will be observed which requires the separation of flammables, oxidizers, toxics, corrosives, and pyrophoric systems. As an example, one purge cylinder shall not be used to purge, in common, phosphine and silane, or more obviously ammonia and hydrogen chloride, etc. House purge gas is permitted for vacuum generators on purge assemblies.

5.3.3 Purge line effluents from toxics, pyrophorics, flammables and corrosives are to be exhausted through the appropriate laboratory vent system.

5.4 Excess Flow Control

5.4.1 Excess flow control in the form of a fail safe, positive flow shut off mechanism shall be provided as close to the source of high pressure (or cylinder control valve) as is practicable; to shut off flow due to a rupture in piping. This requirement is mandatory on all toxic, pyrophoric, flammable and corrosive gases. It is recommended for oxidizing gases, but not required.

5.5 Valving and Shut Offs

5.5.1 A means of positive shut off is to be provided in the gas cabinet downstream of the control regulator that will facilitate maintenance of the system without contamination of process lines due to component removal for maintenance or replacement.

5.5.2 Only valves constructed with a metal to metal seal such as packless diaphragm or bellows type are acceptable. The use of packed valves on systems containing toxic, pyrophoric, flammable or corrosive gases is not permitted.

5.6 Pressure Relief

5.6.1 Pressure relief is required on all process gas systems down stream of the regulator to be installed between the regulator low pressure chamber and any manual or automatic shut off so as to relieve any over pressure attained as a result of regulator failure. As an alternative, a tied diaphragm regulator design with intrinsic overpressure safety mechanism may be substituted.

5.7 Fittings

5.7.1 All non-welded fittings on all hazardous gas lines are to be contained within the zone of local exhaust. There are to be no fittings utilized on any part of the hazardous gas distribution system that are outside of a zone of local exhaust

control. The only exception to this rule is the house distribution systems for hydrogen and oxygen.

5.7.2 Components utilized for hazardous gas systems shall maximize the use of welds in their fabrication. They shall be so fabricated that removal for repair and/or replacement of major components may be facilitated. The use of Ultraseal (Parker) or VCO, VCR (Crawford) or comparable type fittings for this purpose is required. The use of conventional compression type ferrule fittings is to be discouraged, and only permitted where the preferred fitting is not manufactured. Welds used in systems containing corrosive gases are to be kept to an absolute minimum, especially where crevice corrosion is viewed to be problematical.

5.8 Emergency Shut Down

5.8.1 All systems containing toxic, flammable, corrosive, or pyrophoric gases will be equipped with pneumatically controlled, intrinsically safe or explosion proof means of emergency shut down as close to the cylinder source as is practicable. Control is to be external to the cabinet and should be situated at the exit(s) as well as directly on the system.

5.9 Leak Testing of System

5.9.1 The equipment will be so designed as to stand a static check under high purity nitrogen or helium pressure by blanking off the "process leads" and pressurizing with nitrogen or helium up to 1.5 times the designed working pressure of the delivery side of the systems. The integrity of the vent lines is to be tested separately by using a bubble leak check on all fittings and welded connections. A record of the tests will be provided in written form to the Director of NFC. The method of leak check shall be by use of a reliable method so as to preclude the possibility of inboard or outboard leakage greater than on the order of 10-7 cubic centimeters per second.

5.10 Special Pyrophoric/Flammable Gas Requirements

5.10.1 Operating pressure within any pyrophoric gas line shall not exceed 15 psig without prior approval from the Director of NFC.

5.10.2 A limiting orifice, if available from gas supplier will be installed in all pyrophoric gas cylinders. This orifice will restrict flow given a major failure.

5.10.3 All potentially pyrophoric process effluent shall be combusted in a combustion-oxidation system and transported in metal pipe to the scrubber or other suitable building system. Alternative systems may be incorporated where nonfeasibility of combustion-oxidation systems is demonstrated to the Director of NFC.

5.10.4 Gas cabinets containing pyrophorics or flammables shall be vented in metal pipe to the facility roof or scrubber.

5.11 Scrubber Maintenance

5.11.1 A schematic diagram of each scrubber currently in use of the Nanofabrication Center is attached at the end of this section.

5.11.2 A maintenance schedule, including names of persons responsible, shall be developed for each scrubber and approved by the Director of NFC.

LPCVD Scrubber (room 1-146 Area 1)
Delatech model 857 CDO

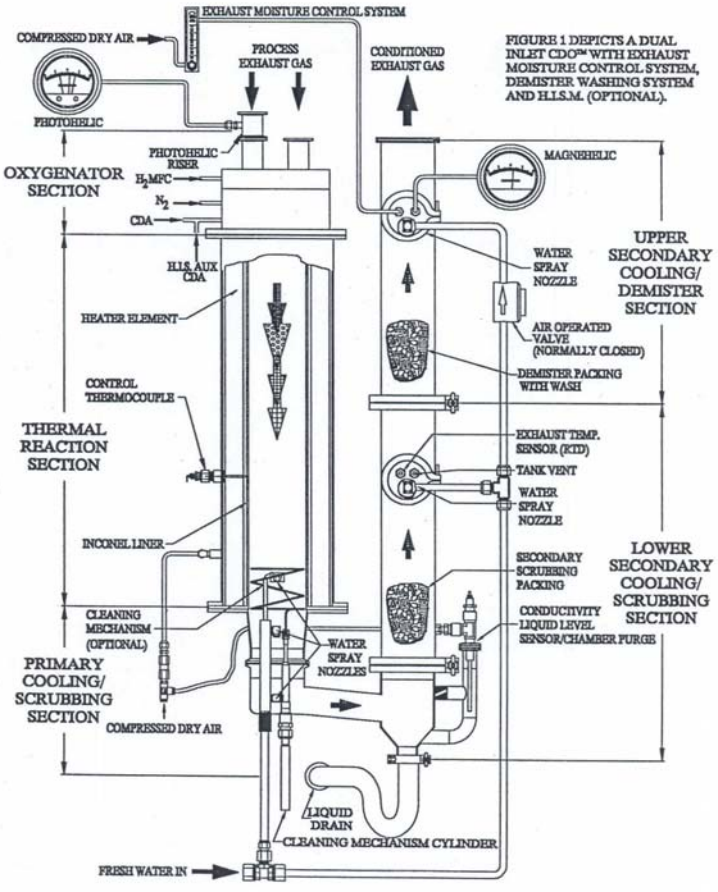

FIGURE 1
CDO™ CUT-AWAY