Laboratory Safety

Basic Safety Training for Work Access to Chemical Engineering Laboratories

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This training is not a substitute for hazard-specific detailed training that must be provided by PIs

What is Process Safety?
Can Process Safety Principles Prevent Lab Incidents?

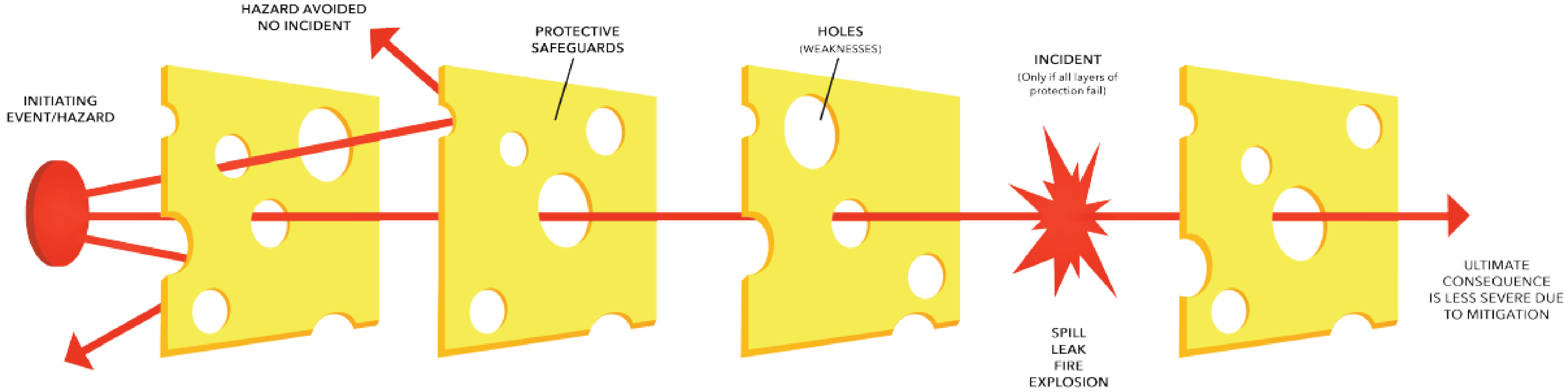
Process safety is the prevention and mitigation of unintentional releases of potentially dangerous materials or energy through the use of robust processes and equipment reliability.

Process Safety is about:

- **Identification and understanding potential hazards**
- **Evaluating consequences, safeguards and risks**
- **Adding layers of protection (safeguards) to prevent and / or mitigate incidents.**
- **Safeguards protect people, the environment, and property**

PROCESS SAFETY

Expect the Unexpected. Assess Your Risks. Prevent Incidents.



Engineering Controls

- Safer Design
- Instrumentation in Protective Systems
- Isolation of Hazardous Energy (Lockout/ Tagout)

Administrative Controls

- Safe Lab Procedures
- Chemical Hygiene Plan
- Job Safety Analysis
- Management of Change
- Safe Work Practices

Behavioral Controls

- Use Personal Protective Equipment (PPE)
- Use the Right Tools
- Use Stop-Work Authority
- Follow Lab Procedures

Post-Incident Mitigation

- Emergency Response Plan
- Fire Suppression
- Safe Work Practices

* Adapted from the Swiss Cheese Model originally developed by James Reason

To learn more about Process Safety visit: mtu.edu/process-safety

What is Process Safety?

Process Safety is about understanding hazards and risk, managing risk by providing the appropriate layers of protection to reduce the frequency and severity of incidents, and learning from incidents when they happen.

How can you help?

Questions to ask yourself

- What can go wrong?
- How bad can it be?
- How often might it happen?
- Are the proper safeguards in place?
- How can I better manage this risk?

Behaviors to practice

- Use PPE
- Use the right tools
- Use stop-work authority
- Follow lab procedures

Avoid the consequences

- Personal injury
- Loss of life
- Contamination of air, water, or soil
- Loss of property

Report concerns

- Contact instructor or lab supervisor
- Contact department chair
- Contact EHS:
  Email ehs@mtu.edu or call 906-487-2118

Process Safety is a team effort!

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What Triggered the Development of Process Safety Management?

Incident at a Union carbide pesticide plant in Central India on 12/3/1984: methyl isocyanate (MIC) released to atmosphere

More than 3,000 people were killed, and more than 100,000 were injured

Clouds of toxic gas surround the Union Carbide pesticide plant in Bhopal, Central India

It happens not only in Industry:
Texas Tech University Chemistry Lab Explosion

From CSB Report

1/7/2010: Grad Student severely injured

Research Hazards:
Other Academic Institution Lab Incidents

- **August 1996: Renowned Professor poisoned in a lab at Dartmouth College (died in June 1997)**
- **July 23, 2001: Grad Student severely injured due to major lab fire at UCI; $3.5 mil. Damage**
- **April 8, 2005: explosion and fire at Ohio State University; lab and research records destroyed**
- **December, 29, 2008: Lab Research Assistant killed by reactive chemical fire at UCLA**
- **April 13, 2011: Student killed at Yale University while operating large machine used in woodworking and metal working in the lab’s machine shop**

A R Da Costa

Why do Process Safety and Lab Incidents Happen?

What Causes Process Safety and Lab Incidents?

- <u>**Lack of understanding**</u>
  - **What can go wrong? (Hazard)**
  - **How bad can it be? (Consequence)**
  - **How often might it happen? (Likelihood)**
  - **Are the proper safeguards in place?**
  - **How can I better manage this risk?(Recommendations)**
- <u>**Poor Safety Culture**</u>

What is Safety Culture?

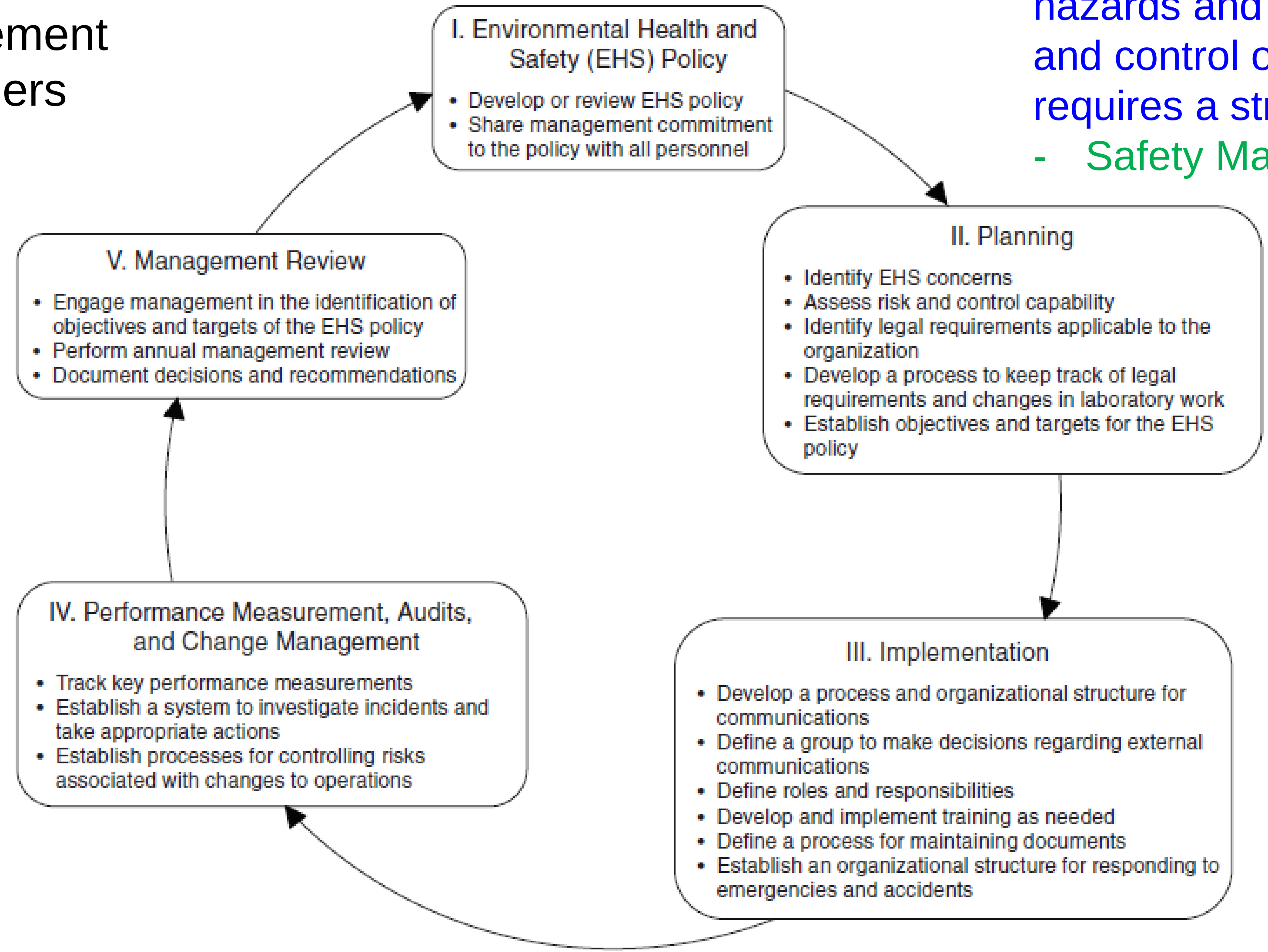
The common set of values, behaviors, and norms at all levels in an organization that determine how safety is managed. The normal way things are done in an organization, reflecting expected organizational values, beliefs, and behaviors, that set the priority, commitment and resource levels for safety programs and performance.

It's how we behave when no one is looking!

Environmental Health and Safety Management System

Lab EHS Management
- Many Stakeholders
- Complex

Excellence in the identification of hazards and the evaluation and control of work-related risks requires a structured approach:
- Safety Management System



MTU Safety Management System

Safety and Training Programs –
Coordinated by the **Office of Environment, Health, and Safety (EHS)**
To: - ensure the safety and well-being of Michigan Tech's campus community and the environment
- provide guidance on handling chemicals from purchase to disposal
- provide guidance on addressing bio and physical hazards

Key Documents

Safety Manual

- Responsibilities
- Emergency Action and Fire Prevention Plan
- Safety, Health and Environmental Policies
- Safety Committees
- General Safety
- Storage and Handling of Hazardous Materials
- Environmental Protection
- Electrical Safety
- Equipment Safety
- Lab Safety

Chemical Hygiene Plan (CHP)

The OSHA Laboratory Standard, 29 CFR § 1910.1450, Occupational Exposure to Hazardous Chemicals in Laboratories defines CHP:

"a written program developed and implemented by the employer which sets forth procedures, equipment, personal protective equipment and work practices that are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace."

CHP

- The foundation of lab safety program
- Reviewed and updated, as needed, or annually to reflect changes in policies and personnel

Chemical Hygiene Plan

- Purpose and Responsibilities
- Hazard Assessment, Determination & Implementation of Control Measures
- Controls for Mitigating Lab Hazards
- Lab Employee Training
- Medical Consultation and Examination
- Lab Work Requiring Prior Approval
- Lab Employee Protection from Lab-specific Hazardous Substances
- Writing Lab-specific Standard Operating Procedures (SOPs)

Responsibilities

Ensuring a safe laboratory environment is the combined responsibility of:

Ultimate Responsibility for Safety Culture

Ultimate Responsibility for Safety Program

Primary Responsibility for working safely

- **Administration** (Chairs, Dean VP Research)
- **Principal Investigator and Lab Supervisor** (Faculty)
- **Lab Employees** (Students, Postdocs, Visiting Scientists, Lab Technicians)
- **Lab Safety Officer** (Senior Grad Student, Postdoc or Lab Manager)
- **Non-Lab Personnel** (Support Staff/Maintenance & Janitorial Services)
- **Department Chemical Hygiene Officer**
- **Department**
- **Office of Environment, Health and Safety (EHS)**

Responsibilities: PI/Lab Supervisor

- Ensures lab employees receive Chemical Hygiene Plan (CHP) training before working with hazardous materials and any other required training – keep written records of the training, including content, trainer and attendees
- Ensures work conducted in the lab complies with occupational and environmental health and safety regulations
- Ensures appropriate PPE (e.g., laboratory coats, gloves, eye protection) and engineering controls (e.g., chemical fume hood, equipment guards, shields, barriers) are made available, in good working order, and being used properly
- Ensures that all lab employees have access to Safety Data Sheets for chemicals used in the lab
- Observes the behavior of employees while working in the lab and enforce all applicable safety procedures and ensure that the CHP is followed; enforce progressive disciplinary action for non-compliance
- Conducts or provides guidance for hazard assessments to identify hazardous conditions or operations in the lab and establishes Standard Operating Procedures (SOPs) to effectively control or reduce hazards
- Promotes periodic lab inspections and immediately takes steps to abate any hazards that may pose a risk to individuals working in the lab
- Investigates all incidents resulting in injury or property damage or near misses with such potential and reports them to department chair/safety committee and to EHS
- Designates a responsible person to oversee safe operations when the PI/lab supervisor is immediately unavailable or traveling

Responsibilities: Lab Employees/Students

Each student and every employee is responsible for the safety of their own actions, both for themselves and for their coworkers

- Review and follow the requirements of the CHP
- Follow all verbal and written lab safety rules, regulations, and Standard Operating Procedures (SOPs) required for the tasks assigned
- Develop and practice good personal chemical hygiene habits such as keeping work areas clean and uncluttered
- Plan, review, evaluate and understand the hazards of materials and processes in the lab prior to conducting work
- Utilize appropriate measures to control hazards, including consistent and proper use of engineering controls, administrative controls, and PPE (Personal Protective Equipment)
- Understand the capabilities and limitations of PPE
- Immediately report all accidents, near misses, and unsafe conditions to the lab supervisor
- Complete all required safety training and provide written documentation to the lab supervisor
- Inform the lab supervisor of any work modifications ordered by a physician as a result of medical conditions, occupational injury, or chemical exposure
- Participate in the development of safe work procedures and methods of protecting the environment

Responsibilities: Lab Safety Officer

A member of the lab designated by the PI/Lab Supervisor to act as a Lab Safety Officer, to assist with managing daily operations of the lab's safety program including compliance and the authority to instruct other lab employees in following all safety procedures

- Provides training to new lab personnel; ensure appropriate training is given and that the training is properly documented
- Enforce lab safety rules
- Work closely with the departmental Chemical Hygiene Officer and Safety Liaison to ensure the laboratory complies with university safety programs/policies
- Report safety issues back to the PI when necessary

Responsibilities: Non-Lab Personnel

Custodians and maintenance staff/support staff need access to labs to perform routine tasks such as cleaning and equipment maintenance

- Follow posted lab safety rules
- Must wear minimum PPE: safety glasses, long pants, and closed-toe shoes
- Must comply with any additional PPE requirements when a cautionary sign is posted at the entrance
- Must accept new training before beginning the task if there is potential for exposure to hazards
- Shall not assist in cleaning up spills of lab chemicals

Responsibilities: Dept. Chemical Hygiene Officer

CHO is responsible for implementation of the CHP within the department, working closely with PI/Lab Supervisors and University's Chemical Safety Officer

- Works with EHS to get the latest information or requirements for the Dept.
- Member of the Dept. Space and Safety Committee
- Coordinates and updates Dept. Safety Manual Annually
- Reviews and evaluates the effectiveness of Dept. CHP and updates at least annually
- Ensures Dept. CHP is followed
- Be familiar with the hazards in each lab in the department and the safety controls used to minimize risk (engineering controls, administrative controls, and PPE)
- Technical resource: helps develop and implement appropriate environmental health and safety policies and procedures
- Conducts regular lab inspections (annual inspections are recommended, but may be more or less frequent depending on hazards present in the lab)
- Ensures hazard assessments and SOPs are being prepared and filed within each lab's CHP
- Reports non-compliance with lab, departmental and university safety procedures and policies to the department chair and EHS

Responsibilities: EHS

EHS ensures the health and safety of the campus community through compliance with all federal and state regulations governing workplace safety and environmental health. Many of these regulations apply directly to laboratory safety, the OSHA/MIOSHA Laboratory Standard in particular.

- Provide and manage services to facilitate compliance with OSHA/MIOSHA Lab regulations:
  - Training
  - Lab Inspections
  - Access to Safety Data Sheets (MSDSonline)
  - Waste disposal: chemical, biological and radioactive.
- Oversight of all lab safety with direct reporting to VP of Research

Introduction To Regulatory Requirements

Michigan Tech is a state institution, Federal regulations do not apply. However, the State of Michigan is an OSHA certified state, which means that the safety regulations in Michigan are consistent with Federal regulations.

- **OSHA 29 CFR 1910.1450 Occupational Exposure to Hazardous Chemicals in Laboratories**
- The primary regulation.
- **The General Duty Clause of the Occupational Safety and Health Act**
- Requires an employer to “furnish to each of his employees . . . a place of employment . . . free from recognized hazards that are likely to cause death or serious physical harm . . .” and requires an employee to “comply with occupational safety and health standards and all rules . . . issued pursuant to this chapter which are applicable to his own actions and conduct”.
- **Other Federal Safety Laws and Regulations That Pertain to Laboratories**

OSHA – US Occupational Safety and Health Administration
An agency of the US Dept of Labor. Established by Congress under the Occupational Safety and Health Act of 1970
OSHA's mission is to "assure safe and healthy working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance“.

CFR – Code of Federal Regulations - codification of the general and permanent rules and regulations published in the Federal Register by the executive departments and agencies of the federal government of the United States.

Lab Work Requiring Prior Approval

- Hazardous Substances per MIOSHA
  - Highly Toxic Chemicals: Oral, Dermal or Inhalation
  - Carcinogenic Substances
- Hazardous Procedures
  - Radioactive/Biohazardous materials
  - Recombinant DNA (Humans/Animals)
- Hazardous Waste
  - > 5 gallons
  - Mixed Hazards (chemical, radioactive, biological)
  - Left over of acutely hazardous waste
- Working Alone
  - Non hazardous tasks: set up check in/check out notification system with external party
  - Hazardous tasks: include in SOP hazard analysis for working alone
  - Define additional check in/check out procedures or implement new emergency signaling requirements
- Unattended Operations
  - Avoid for hazardous substances
  - Plan safe shutdown due to loss of utilities (power, cooling water, flow of inert gas)
  - Post emergency contact of responsible person
  - Post signs identifying the nature of experiments and substances used
  - Make arrangements with others to periodically inspect
  - If necessary, complete the form in the Safety Manual and post on outside of laboratory door

Medical Consultation

Medical exams are required if:

- **Respirators are used (annual physical)**
- **Documented exposures have occurred**
- **Signs or symptoms of exposures have occurred**
- **Exposures due to spills, leaks, or explosions**

See Safety Manual for more details

Lab Clothing

- Long pants required, no shorts
- No neckties, dangling clothes or dangling jewelry
- Long sleeve shirts recommended
- Tie-up long hair to prevent from entanglement
- Non-porous shoes, no sandals
- It is a good practice to wear a lab coat when performing lab experiments

Wear Personal Protective Equipment (PPE) Required for Specific Hazards

Sources of Information

- Chemical Hygiene Plan
- Safety Data Sheets
- Globally Harmonized System for Hazard Communication
- Lab Chemical Safety Summaries
- Labels
- Additional Sources
- Computer Services

Safety Data Sheets

Per OSHA Hazard Communication Standard 29 CFR § 1910.1200, manufacturers and distributors of hazardous chemicals must provide users with SDS

SDS have limitations
Quality varies

- Supplier, address, phone number and date SDS prepared or revised
  - Periodic reviews for up-to-date information
- Chemical
  - Hazardous chemicals identified
- Physical and chemical properties
- Physical hazards
  - Flammability, reactivity, and explosion hazards
- Toxicity data
  - Data from OSHA, NIOSH & ACGIH
- Health hazards
  - Acute and chronic health hazards and carcinogens
- Storage and handling procedures
  - Engineering controls and PPE to prevent harmful exposures
- Emergency and first-aid procedures
  - Includes recommendations for firefighting procedures
- Disposal considerations
- Transportation information
  - Some information is for manufacturing and not relevant to labs

SDS Library

Required by regulation

Must be available to workers at all times

Make Safety Data Sheets available and easily accessible
Latest Versions online: Bottom of page: https://www.mtu.edu/ehs/

GHS – Globally Harmonized System: Introduction

- GHS - Classification and Labeling of Chemicals - is an internationally recognized system for hazard classification and communication
- US organizations responsible for implementing GHS: OSHA, DOT, EPA and the Consumer Product Safety Commission
- Occupational Safety and Health Administration (OSHA), changed their Hazard Communication Standards in 2013 to align wit GHS

GHS: What Changed?

GHS changes to the Hazard Communication Standards are as follows:

- Hazard classification: The standard requires chemical manufacturers and importers to determine the hazards associated with the chemicals they produce or import. The specific health and physical hazards of these chemicals must be provided to the consumer.
- Labels: Chemical labels must include the name of the chemical as well as a signal word, pictograms, hazard statements, and precautionary statements that describe the hazards associated with chemical.
- Material Safety Data Sheets: Now called Safety Data Sheets or SDS's, the new format requires 16 specific sections, ensuring consistency in the presentation of important safety information about a chemical.

NFPA Diamond

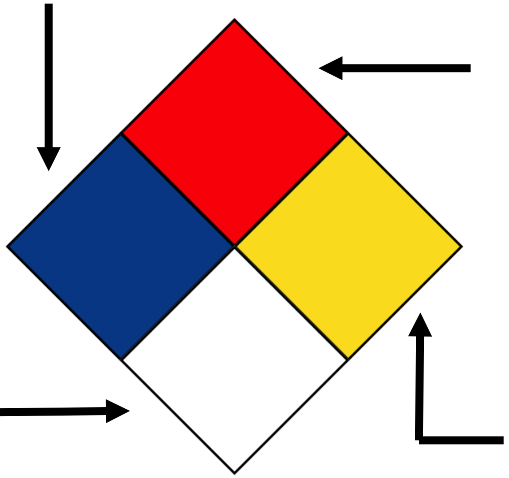
- NFPA Diamond was created in 1960
- Used by firefighters
- Identifies precautions or special measures
- Usually seen on:
  - Trucks transporting chemicals
  - Chemical storage containers
  - Cylinders
  - Drums
  - Outside of labs

Health

4 – Deadly
3 – Extreme Danger
2 – Hazardous
1 – Slightly Hazardous
0 - Normal Material

Fire:

Flash Point
4 – Below 73^{0}F
3 – Below 100^{0}F
2 – Below 200^{0}F
1 – Above 200^{0}F
0 - Will not burn



Specific Hazard:

Oxidizer	**OXY**
Acid	**ACID**
Alkali	**ALK**
Corrosive	**COR**
Use no Water	~~W~~
Radiation Hazard	

Reactivity / Stability:

4 – May Detonate
3 – Shock and Heat May Detonate
2 – Violent Chemical Change
1 – Unstable if Heated
0 - Stable

NFPA Diamond Examples

Sodium

- Spontaneously ignites in the presence of air
- Severe burns from metal or caustic soda formed during reaction
- Violent chemical changes at elevated temp and pressure

Sodium Hydroxide

- Highly corrosive
- Reacts with water producing excessive heat
- Causes severe eye, skin and respiratory tract burns

Oxygen Gas

- Eye and skin contact may cause frostbite
- Inhalation may cause dizziness
- Strong oxidizer
- Capable of igniting combustibles

Acetone

- Highly volatile & flammable liquid
- Causes muscle weakness mental confusion & coma
- Causes kidney and liver damage
- Causes dermatitis (chronic)

GHS Compared with NFPA Ratings

Signal Word	GHS Hazard Statement/Criteria	GHS Hazard Category	NFPA Rating
Danger	Extremely flammable liquid and vapor Flash point < 23^oC, Boiling point < 35^oC	1	4
Danger	Highly flammable liquid and vapor Flash point < 23^oC, Boiling point > 35^oC	2	3
Warning	Flammable liquid and vapor 23^oC <Flash point < 60^oC	3	2
Warning	Extremely flammable liquid and vapor 60^oC <Flash point < 93^oC	4	1

GHS Pictograms

<u>Standardized Three Elements:</u>
Pictograms
- Graphical signs

Signal Words: "Danger", "Warning"
- Reflect hazard severity

Hazard Statements
- Describe nature of hazard

- 16 physical hazards
- 10 health hazards
- 1 environmental hazard

Health Hazard  • Carcinogen • Mutagenicity • Reproductive Toxicity • Respiratory Sensitizer • Target Organ Toxicity • Aspiration Toxicity	**Flame**  • Flammables • Pyrophorics • Self-Heating • Emits Flammable Gas • Self-Reactives • Organic Peroxides	**Exclamation Mark**  • Acute Toxicity • Skin Sensitizer • Irritant (skin and eye) • Narcotic Effects • Respiratory Tract Irritant • Hazardous to Ozone Layer
Gas Cylinder  • Gases Under Pressure	**Corrosion**  • Skin Corrosion/Burns • Eye Damage • Corrosive to Metals	**Exploding Bomb**  • Explosives • Self-Reactives • Organic Peroxides
Flame Over Circle  • Oxidizers	**Environment**  • Aquatic Toxicity	**Skull and Crossbones**  • Acute Toxicity (fatal/toxic)

Additional Sources of Information

Seek additional information if planning to use chemicals with a high degree of acute or chronic toxicity or to use a particular toxic substance frequently or over an extended period of time

- International Chemical Safety Cards: www.cdc.gov/niosh or www.ilo.org
- NIOSH Pocket Guide to Chemical Hazards: http://www.cdc.gov/niosh
- A Comprehensive Guide to the Hazardous Properties of Chemical Substances, 3rd edition (Patnaik, 2007)
- 2009 TLVs and BEIs: Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (ACGIH, 2009s)
- Fire Protection for Laboratories Using Chemicals (NFPA, 2004)
- Fire Protection Guide to Hazardous Materials, 13th edition (NFPA, 2001)
- Bretherick's Handbook of Reactive Chemical Hazards, 7th ed (2007)
- Wiley Guide to Chemical Incompatibilities, 2nd edition (Pohanish and Greene, 2003).
- Occupational Health Guidelines for Chemical Hazards (HHS/CDC/NIOSH, 1981) and supplement (HHS/CDC/NIOSH, 1995)
- Catalog of Teratogenic Agents, 11th edition (Shepard and Lemire, 2004)
    - Reproductive and developmental toxins

Computer Services

In addition to computerized SDSs, a number of computer databases are available that supply data for creating or supplementing SDSs

- NIOSH: www.cdc.gov/niosh
- OSHA: www.osha.gov
- Environmental Protection Agency: www.epa.gov
- The National Library of Medicine Databases
  - TOXNET, TOXLINE, HSDB, CPDB, DART, GENE-TOX, IRIS, CCRIS, PubMed
- Chemical Abstracts Databases (CAS)
  - www.cas.org
- ECOTOX: www.epa.gov/ecotox

Hazard Identification and Risk Assessment

Synonyms:

- Job Safety Analysis (JSA)
- Job Hazard Analysis (JHA)
- Hazard Analysis
- Risk Analysis
- Hazard Assessment, etc.,

Hazard Identification and Risk Assessment

A **Hazard** is anything that has the potential to cause harm, injuries, accidents or other undesirable effects.

A **Risk** is the possibility that a personal injury, property loss or environmental harm will occur when working with or near a hazard. When thinking about the risks associated with a hazard it is important to think about the specific types of injuries, loss or harm that the hazard may cause.

Risk = Severity x Likelihood

https://www.acs.org/content/acs/en/about/governance/committees/chemicalsafety/hazard-assessment/ways-to-conduct-hazard-assessment.html

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Ways to Conduct a Hazard Assessment

HAZARD ASSESSMENT In Research Laboratories

Hazard Assessment | Fundamentals | Ways to Conduct Assessments | Tools

What-if Analysis | Job Hazard Analysis | Checklists | Standard Operating Procedures | Control Banding

There are many ways to identify and evaluate safety hazards in a chemical laboratory. No matter what method or combination of methods you choose, they all help you achieve hazard identification, which will inform your risk assessment and control measures selection.

Hazard Identification and Risk Assessment

Five Steps:

1. Identify the specific task, procedure or experiment that will be performed.
2. Determine if there are hazards associated with performing these tasks.
3. Identify the risks connected with the hazards.
4. Develop a list of controls (things you can do) to eliminate or minimize the risks.
5. Create a standard(safe) operating procedure (SOP) that describes how you will safely complete each task.

Standard Operating Procedure (SOP)

- Start up and shut down procedure
- Material handling
- Chemical composition
- Understand the reactions
- Equipment
- Monitor the process
- Emergency shutdown response

Create a Standard Operating Procedure (SOP)

Development of an effective SOP requires a comprehensive approach to hazard analysis and must address:

- Detailed description of the procedure
- Identification of the hazards and risks associated with the procedure
- Compliance with regulatory concerns
- Human Factors (experience and training)
- Management of hazardous materials (use, storage and disposal)
- Details about the controls you will use to minimize the risks.
  - Engineering (splash guards, fume hoods, explosion proof equipment, etc.,)
  - Administrative (training, controlled access, warning signs, etc.,)
  - Personal protective equipment (safety glasses, lab coat, gloves, etc.)
- Emergency response

Because of its comprehensive nature, development of an SOP requires more time and effort but results in a greater appreciation and understanding of the potential hazards associated risks.

Validate your SOP

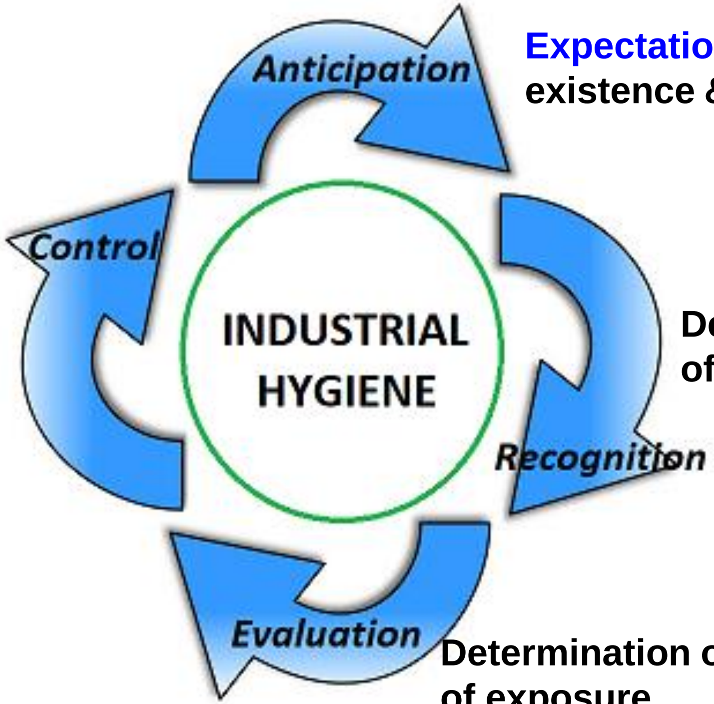
Procedures with a medium or high level risk rating should be validated by performing a trial run. The trial run will help you familiarize yourself with the equipment and the performance of each step of the procedure.

- If possible, substitute hazardous materials for non-hazardous
- Scale down the experiment.
- Evaluate what went well, and what did not go as planned.
- Were there any unanticipated problems? close calls?
- Are refinements needed?
- Modify your procedure accordingly based on the results of the trial run.

Hazard Identification and Risk Assessment: Industrial Hygiene

Industrial Hygiene – the science concerned with occupational conditions that cause sickness and injury, e.g: exposures to toxic vapors, dust, noise, heat, cold, radiation, other physical factors

Expectation of hazard existence & exposure



Reduction to acceptable levels

Determination of presence of workplace exposure

Determination of magnitude of exposure

Chemical Labs: Chemical Hygiene Officers collaborate with lab researchers and EHS personnel to apply & maintain control measures

Hazard Identification and Risk Assessment: Anticipation & Recognition (Identification)

Many chemicals are used in labs – potential chemical and physical hazards

Identification

Resources
- CHO
- Researchers
- Students
- Lab Tech
- PIs

Study:
- Chemistry
- Operating Conditions
- Operating Procedures

Source of Information:
- Op Instructions
- Safety Reviews
- Equipment Description
- Chemicals Description (SDS)

Potential Hazards:
- Liquids
- Vapors
- Dusts
- Noise
- Radiation
- Temperature
- Mechanical

Methods of Contact:
- Inhalation
- Body Absorption
- Ingestion
- Injection

Hazard Data:
- Physical State
- TLV
- Odor Threshold
- Vapor Pressure
- Sensitivity to temp/impact
- Rate & Heat of Reaction
- Reactivity
- Flammability
- Explosion Limits
- By-products
- Noise Levels

Risk Assessment
- Potential for hazards to result in an incident

All potential hazards must be identified!

Exposure Evaluation: Vapors, Dust and Noise

Exposure Type	Exposure Equation	Comments
Volatile: Vapor - Continuous Monitoring	$TWA = \frac{1}{8}\int_0^{t_w} C(t)\,dt$	Exposure always normalized over 8 hours, independent of actual time worked
Volatile: Vapor - Intermittent Monitoring	$TWA = \frac{1}{8}\sum_{i=1}^{n} C_i T_i$	More common. Assumes concentration C_i is fixed (averaged) over time period T_i
Volatile: Multiple Toxicants (Vapors) Additive	$\sum_{i=1}^{n} \frac{C_i}{(TLV - TWA)_i} < 1$ $(TLV - TWA)_{mix} = \frac{\sum_{i-1}^{n} C_i}{\sum_{i=1}^{n} \frac{C_i}{(TLV - TWA)_i}}$	Combined exposures must not exceed 1 Both approaches are equivalent Sum of concentrations of toxicants in the mixture must not exceed this amount
Dust (0.2-5.0 μm)		Similar to volatile vapors. TLV in mg/m^3 or mppcf (millions of particles per cubic foot)
Noise	$Noise\ Intensity\ (dB) = -10\log_{10}\left(\frac{I}{I_o}\right)$	Noise is measured in decibels. dBA instead of ppm and hours instead of concentration for vapors

Chemical Hazards:
Handling Chemicals

"A commitment to purchase a chemical is a commitment to handle and store the chemical safely and to dispose of the chemical in an environmentally acceptable fashion."

The technology and management systems exist to handle all chemicals safely

Chemical Exposure:
Steps in Chemical Handling

1. What are the hazardous properties of the chemical?
2. How much to purchase?
3. How do I keep track of the chemical?
4. How do I store the chemical?
5. How do I handle the chemical?
6. How do I dispose of the chemical?
7. What do I do if a chemical spill occurs?

Chemicals Storage: Chemical Labeling

A chemical label is required for any chemical or sample that will not be in your physical possession at any time

Parts of the label:

- **Identity of contents**
- **Date chemical was acquired**
- **Disposal date (for unstable chemicals)**
- **Responsible person**
- **Hazardous characteristics**
- **Other pertinent safety information**

Chemicals Storage: Chemical Labeling

- Label container prior to use
- Chemical label must be legible, in English
- Must have actual chemical name, not a number
- Must not obscure existing labels or safety information

Chemicals Storage: Chemical Labeling

Hazards Laboratory

Chemical Name:______________________

Date Rec'd:__/__/__ Disposal Date:__/__/__

Dept:__________ Location:__________

Responsible Party:______________________

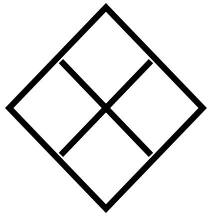
Safety Info:_________ Remarks:_________

___________________ _________________

___________________ _________________

___________________ _________________

Fire

Health  Reactivity

Labeling of All Chemical Storage Cabinets

Update label as needed

Storage of Chemicals: Flammable Storage Cabinets

Offers protection from external fire.

Must be electrically grounded to prevent static accumulation.

Vent hole is left closed, unless stored materials have an odor, in which case the vent is connected to the ventilation system.
Do not store anything on the top. Store only flammables, nothing else.

Storage of Chemicals: Corrosive Storage Cabinets

Used to store acids and other corrosives.

Do not store anything on top of cabinet

Chemicals Disposal

Michigan Tech has a waste disposal program, however, they collect and dispose of chemicals on an infrequent basis, dependent on volume. The user must pay for the service. This service is very costly if the material is unknown (factor of ten).

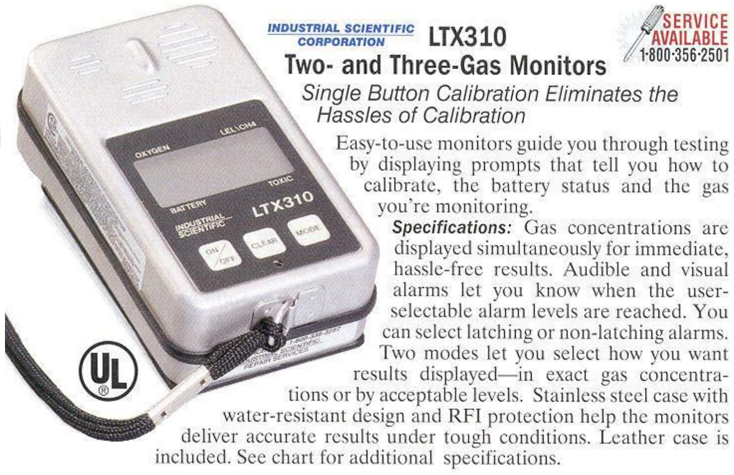
See Chemical Engineering Waste Disposal Manual

Chemical Exposure:
Measurement of Volatile Concentrations

Colorimetric Tubes

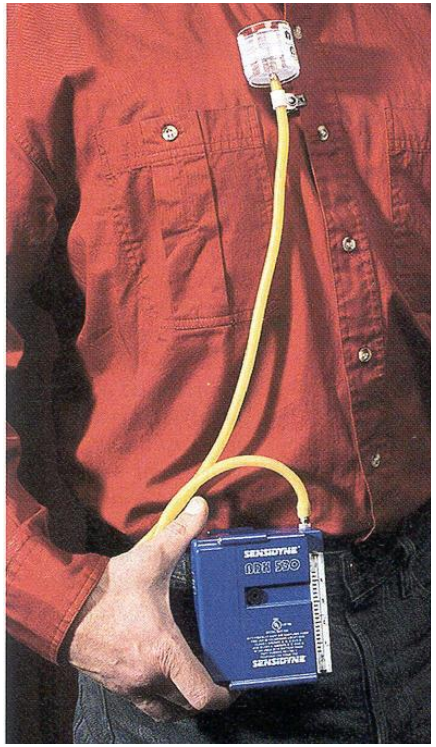
- Powder in glass tubes changes color
- Volatile concentration read on glass tube scale

Electronic Monitor



- Battery powered
- Sensor replacement required

Pump and Filter



← **Filter unit, usually contains activated charcoal.**

← **Battery powered air pump**

- The worker carries unit around
- Good to measure actual individual exposure

Chemical and Dust Exposure: Control

Laboratory Control Techniques

Environmental	
Substitution	- Less toxic solvents, higher flash points
Attenuation	- Boiling point reduction by vacuum
Isolation	- Separate laboratories
Intensification	- Reduce chemicals, small continuous reactors
Enclosures	- Contain experiment in hood
Local ventilation	- Hoods
Dilution ventilation	- Ventilation in general laboratory
Good housekeeping	- Keep toxics contained
Personal protection	Last defense: always compromises workers

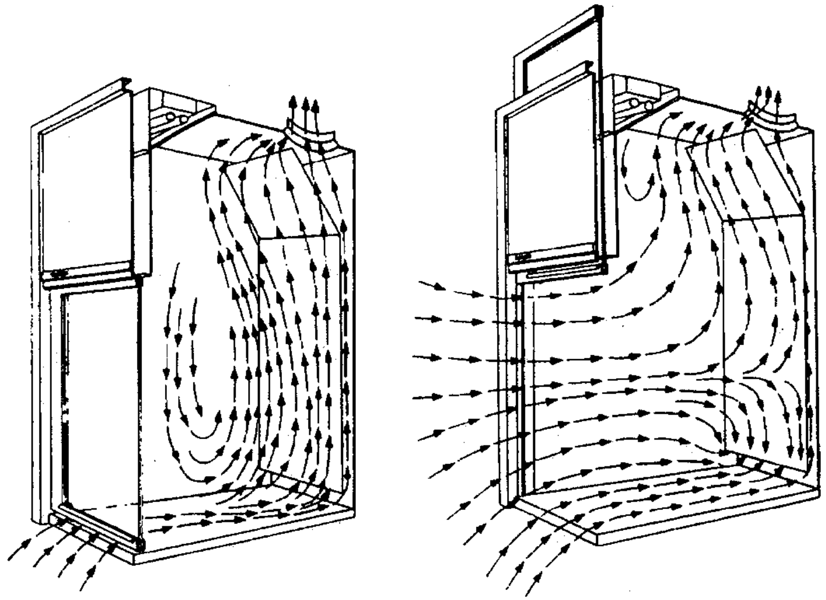
Training is required for using dust masks!

Control of Toxic Exposure:
Ventilation – Standard Hoods

Face Velocity: Air velocity through hood opening.

Use 100 - 124 feet per min (fpm).

Sash controls
airflow patterns
and velocity



Advantages of Hoods:
- **Eliminates exposure**
- **Minimal air flow**
- **Containment if fire or explosion**
- **Sliding door shield**

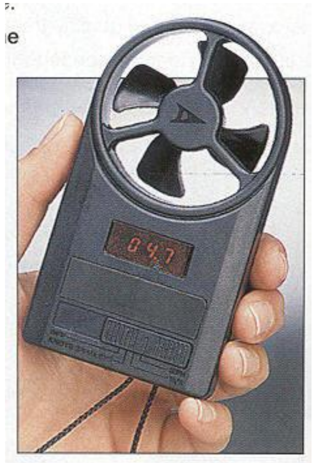
Disadvantages of Hoods:
- **Limited workspace – can only fit small bench-scale equipment**

- **Sash and hood itself can be used to contain process.**
- **Positive indication of hood function required by OSHA.**
- **Hoods should not be used for storage of equipment or chemicals**

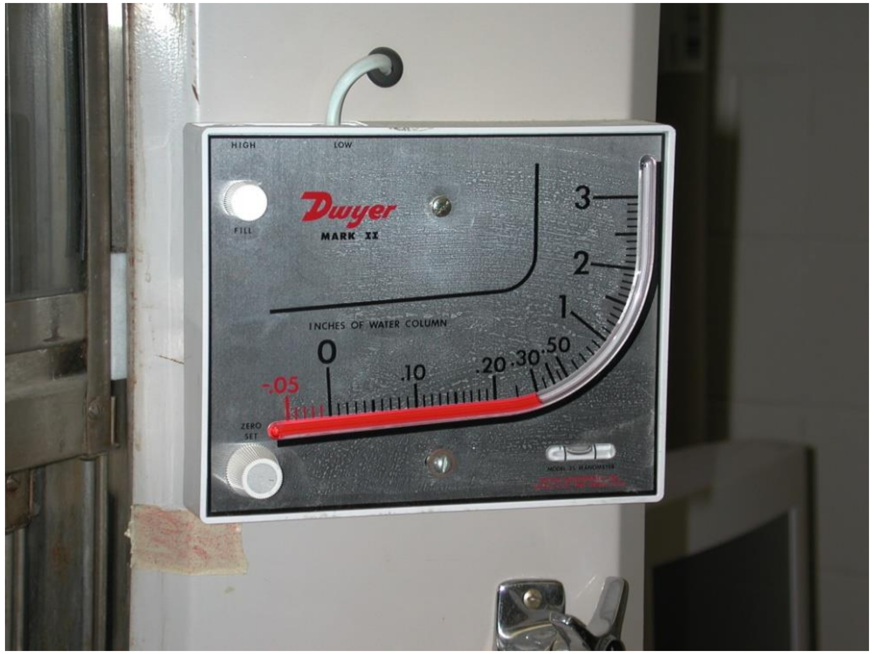
Control of Toxic Exposure

Flow Measurement and Operation of Hoods

Typical Hood



Velometer used to measure hood flow



- Manometer indicates air flow in the hood
- Red liq height increases with air flow
- No electrical power required

- Hood flow indicator
- Electrical power required

Control of Toxic Exposure
Ventilation – Elephant Trunks

Provides a movable ventilation source that can be located very close to emission sources.

Control of Skin Exposure
Safety Showers / Eyewashes

Useful for fires and chemical spills.

For chemical spills, clothing must be removed.

Must be used, with assistance, for 15 min.

Minimum flows:
Eyewash: 4 gpm
Shower: 30 gpm

Water must continue to flow once handle is released.

Current OSHA standard requires water temperature control.

Problems with:

- Dirty water
- Rust from pipes
- Water temperature

Both must be tested regularly.

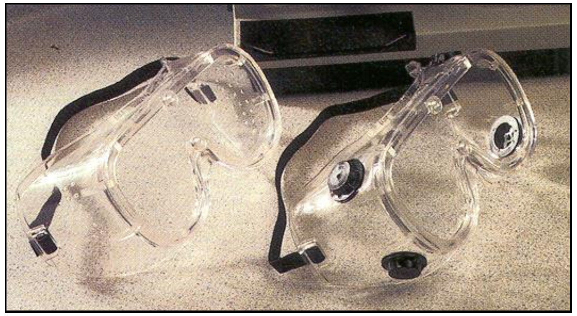
Area around unit must be unobstructed.

Required within the lab if chemicals are used.

PPE for Eye Protection: Safety Glasses & Goggles

Safety Glasses

Face Shield



Safety Goggles

Safety glasses provide eye protection against flying objects, liquid chemicals, light radiation, etc.

Safety glasses must be ANSI rated (ANSI Z87)

Must include permanently affixed side shields

Must be worn at all times in the lab

Face shield provides additional, full face protection

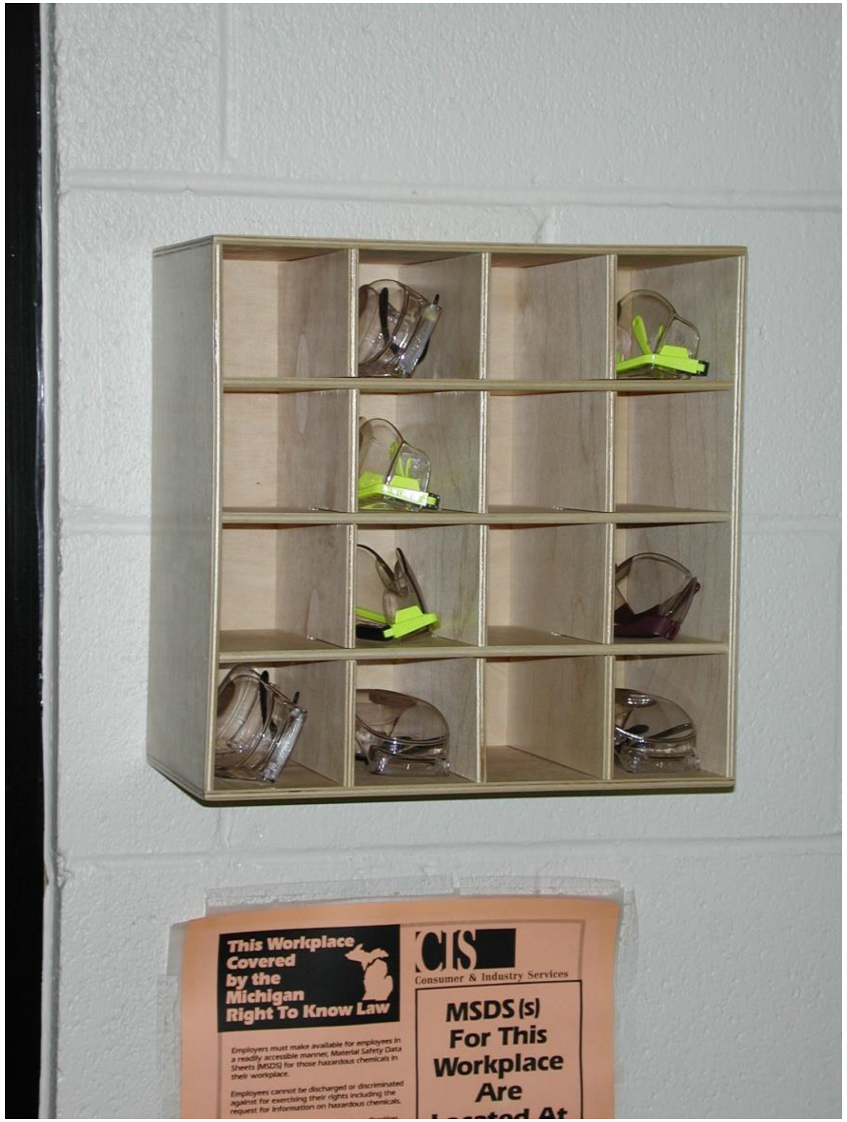
Can wear over safety glasses or goggles for additional protection

Goggles provide additional protection over safety glasses

Can be worn over safety glasses

Come in vented and unvented styles

PPE for Eye Protection - Accessibility



This storage rack is mounted near the door of the laboratory. It provides access to safety glasses for all who enter the lab.

Provide alcohol-based wipes for disinfection!

PPE for Hand Protection - Gloves

Gloves protect the hands against chemical, mechanical, electrical and thermal hazards.

Come in many styles, shapes and materials.

Must be compatible with chemical used. See selection chart in Vendor Catalogue

Hazard Mitigation:
Spill Kits

Provide materials to clean up chemical spills. Required if you use chemicals in the laboratory.

Usually contains:
* Absorbent spill blankets
* Spill dams or pigs.
* PPE for cleanup.
* Disposal materials.

Hazard Mitigation:
Fire Extinguishers

Several Types:

- **A: Wood, cloth, paper.**
- **B: Gas, liquid, grease**
- **C: Electrical fires**
- D: Combustible metals
- K: Cooking oil or fat

Our labs have type ABC.

Must be sized correctly for lab area

Must be inspected monthly.

Must be free of obstructions.

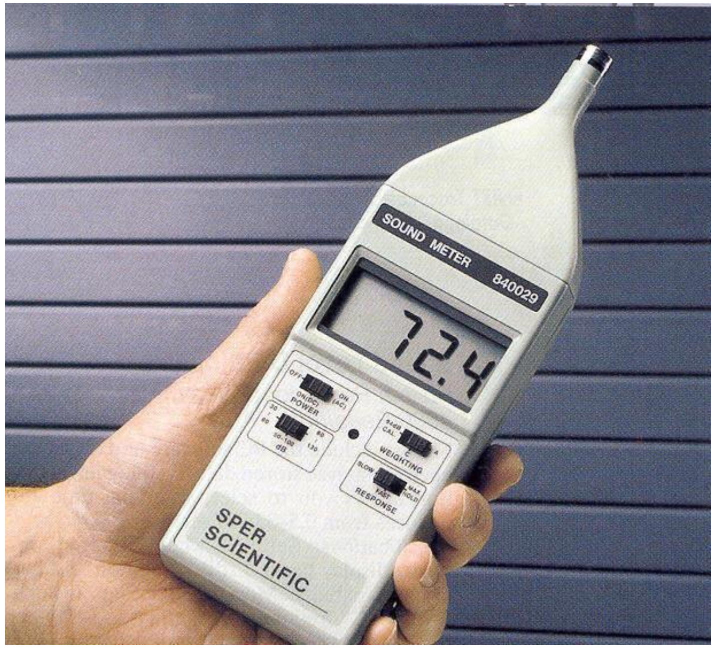
Hazard Mitigation:
Fire Extinguisher Usage

Must direct fire extinguisher discharge at base of flames, not at the flames

PASS: Pull, Aim, Squeeze, Sweep

Control: Noise Measurement and Control

Sound Intensity Measuring Device



Derating: Applying NRR

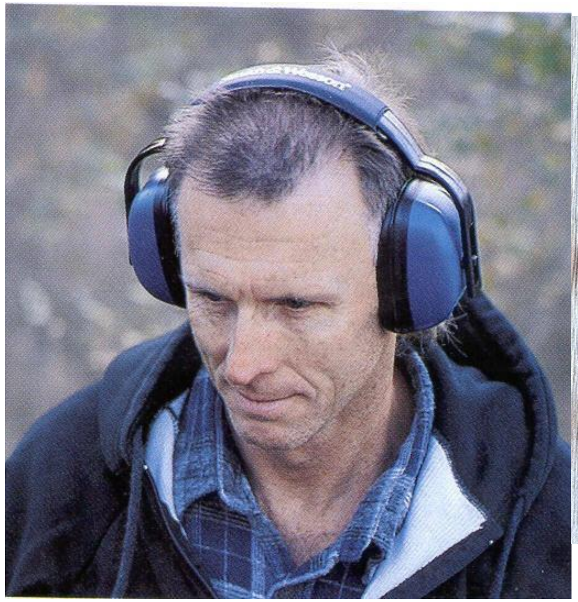
1. Subtract 7 dB from the NRR
2. Divide the result by 2
3. Subtract from dBa exposure

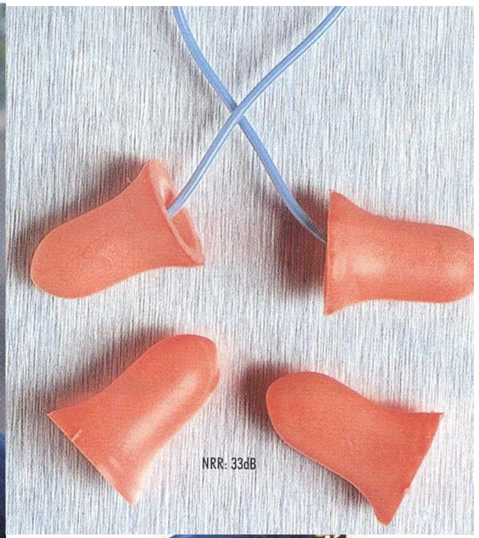
Maximum Allowable Noise Exposure for 8 h: 90 dBA (decibels)

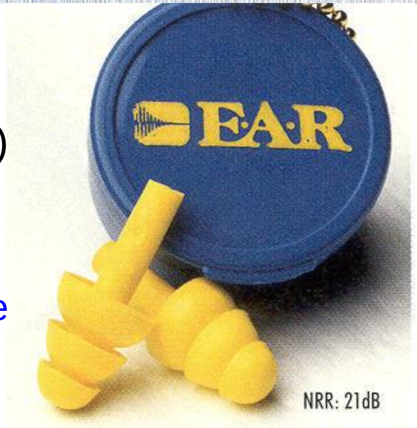
Example:
A particular hearing protector has an NRR of 18.
If the ambient noise level is 95 dba, what is the worker exposure?

$$95 - \frac{18 - 7}{2} = 89.5\ dBa$$

Hearing Protection







Noise Reduction Rating (NRR)

Unit of measurement to determine effectiveness of hearing protection devices to decrease sound exposure within a given working environment.

Hearing protection usually lists the NRR for that PPE

Hazard Identification and Risk Assessment: Physical Hazards

- Compressed Gases
- Nonflammable Cryogens
- High-Pressure Reactions
- Vacuum Work
- Ultraviolet, Visible, and Near-Infrared Radiation
- Radio Frequency and Microwave Hazards
- Electrical Hazards
- Magnetic Fields
- Sharp Edges
- Slips, Trips, and Falls

Compressed Gases and Nonflammable Cryogens

- **Compressed Gases**
  - **Chemical Hazards: flammability, reactivity, toxicity and asphyxiation**
  - **Physical Hazards: Pressure due to tank rupture or valve failure**
- **Nonflammable Cryogens**
  - **Tissue damage due to contact with extreme cold liquid or boil-off gases nitrogen**
  - **Asphyxiation due to inhalation of gas due to boil off or spills**
  - **Storage Dewars rupture due to ice plug or vent valve failure**

1 volume of liquid N_2 at atmospheric pressure vaporizes to 694 volumes of N_2 gas at 20 °C, generating enormous pressure, which can rupture a vessel.

Storing Gas cylinders, Highly Reactive Chemicals and Toxic Substances

- ✓ Ensure cylinders are securely chained to wall
- ✓ Store cylinders with label clearly showing the nature of its content and depicting whether the cylinder is empty, in use or full
- ✓ Store gas cylinders away from where other chemicals are store

- ✓ Learn(from SDS) the storage conditions of highly reactive chemicals before acquiring the chemicals.
- ✓ Store as little quantity as the amount needed for immediate purpose.
- ✓ Prompt and proper labeling of highly reactive materials is nonnegotiable.

- ✓ Label storage areas with appropriate warning signs that display the associated health risk
- ✓ Limit access to storage areas
- ✓ Keep quantities at a minimum working level

Transfer, Transport and Shipment of Chemicals

- Transport of chemicals **within an institution** should be done **using a secondary containment like rubber bucket**
- For transferring **experimental materials** outside the lab, materials must be **completely labeled** detailing key information like originator and receiver's names, potential hazards , date materials were labeled in the container
- On-site and off-site transfer and transport of Nanomaterial should be done in accordance with steps specified in the institution's CHP

Gas Cylinders

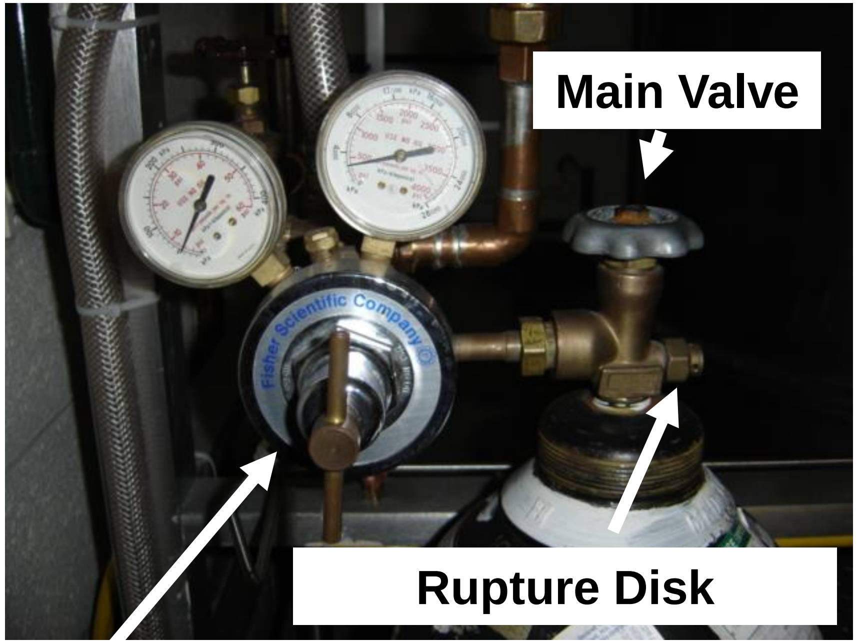
- Transport using a cylinder cart. Cylinder cap must be in place for transport
- All cylinders must be secured prior to use
- All cylinders must have a regulator and a shut-off valve downstream of the regulator
- It is a good practice to have a pressure relief valve on equipment connected to a gas cylinder
- Cylinder fittings depend on material in cylinder – these fittings cannot be mixed!

Gas Cylinders

Cylinders Have A Rupture Disk Near Main Valve

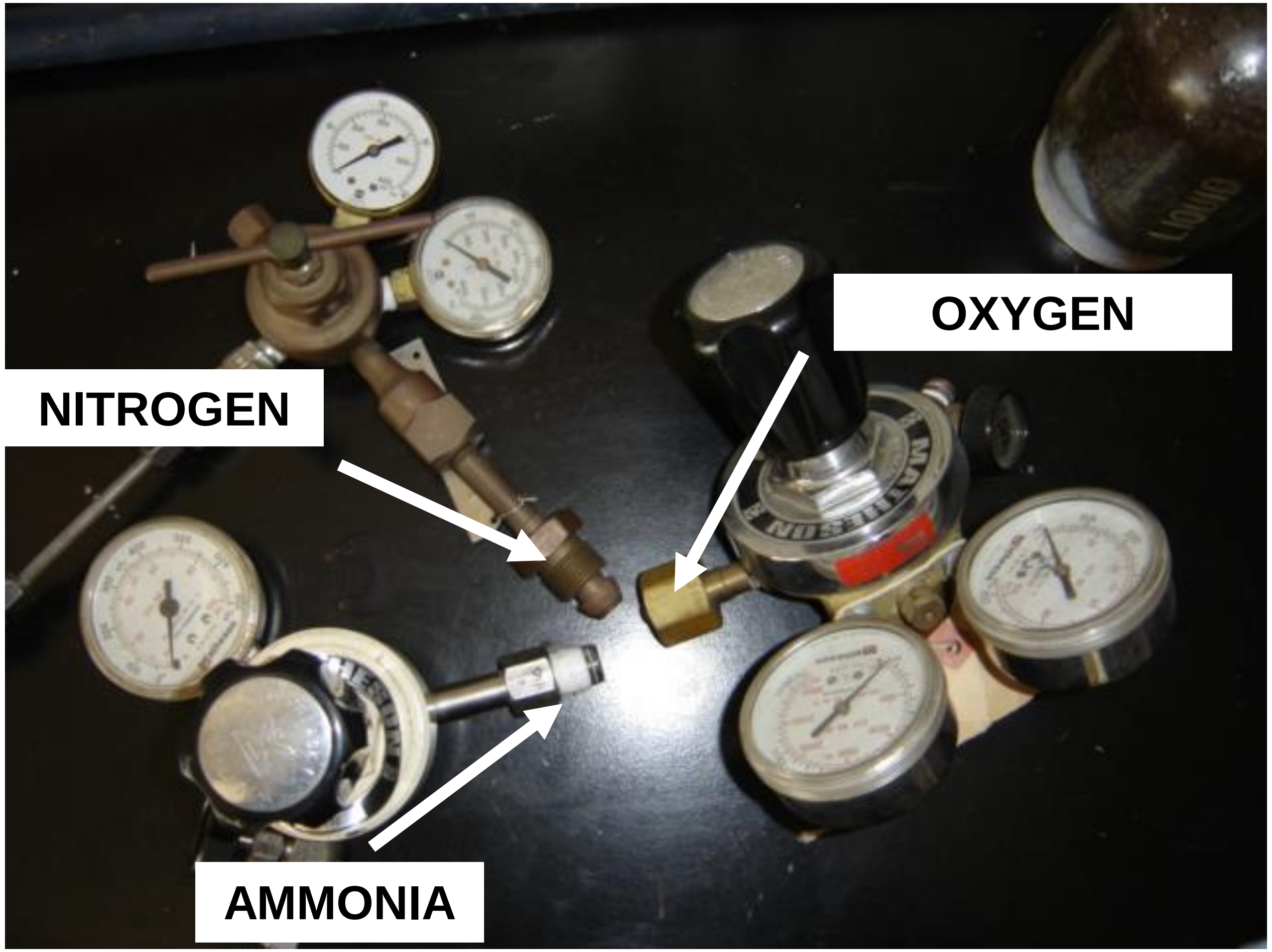
Should pressure exceed a certain limit, rupture disk will pop

This prevents the cylinder from rupturing which can cause great damage



Two Stage Regulator for Nitrogen

Regulators have Special Fittings for the Gas they Service



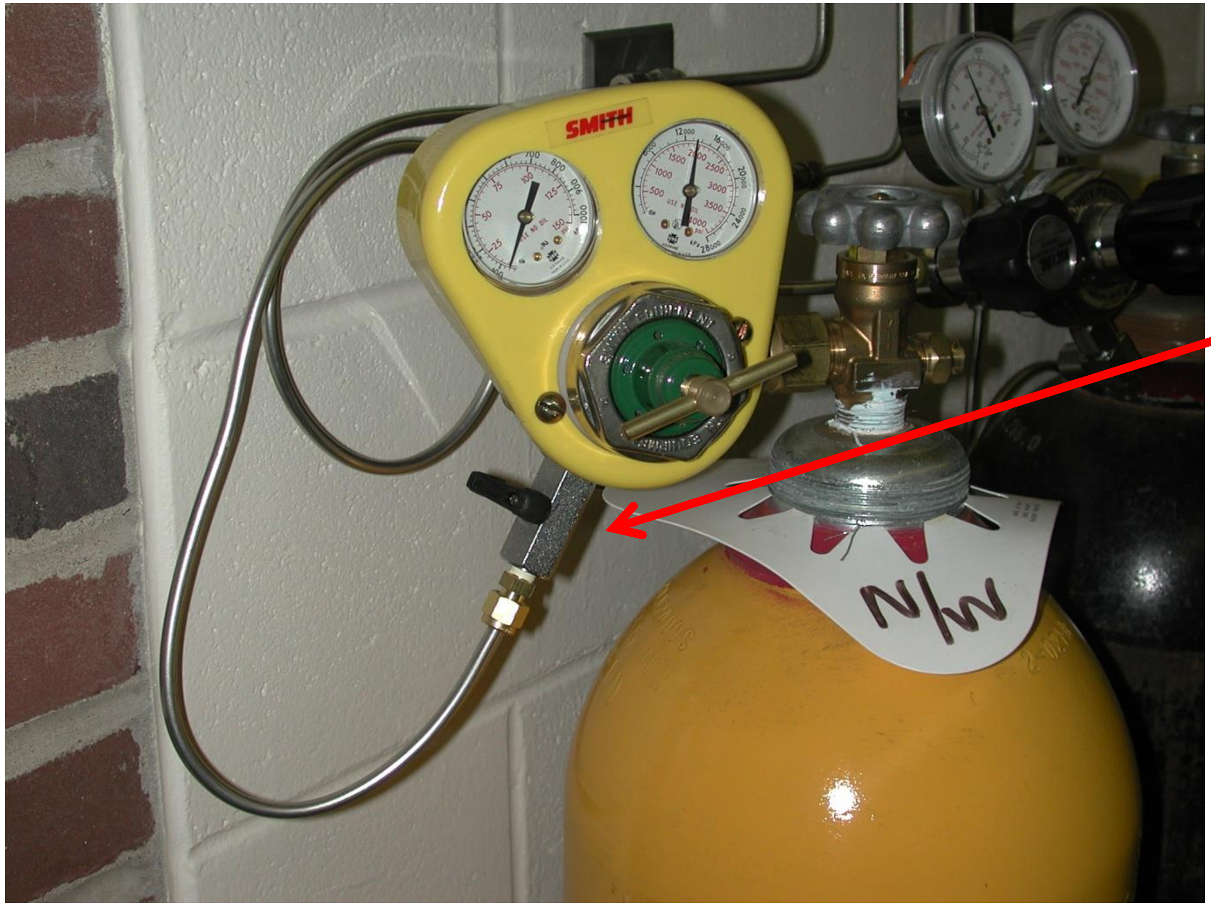
Some fittings are left handed threads and some are right handed!

Cannot mix regulator in oxygen service with regulator in fuel service

Gas Cylinders

Cylinders must be secured during usage.

Gas Cylinders



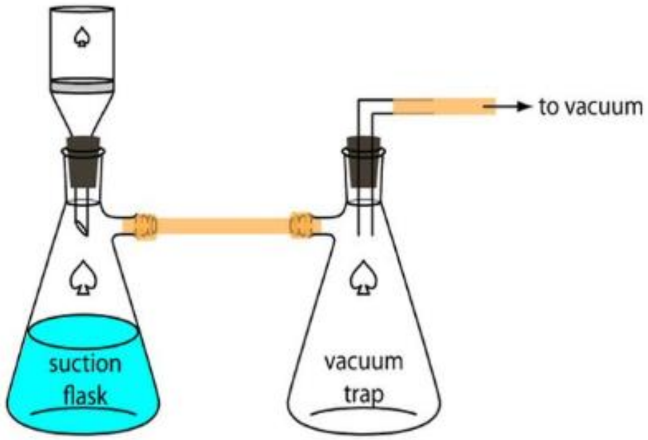
Must have a shut-off valve after regulator.

High-Pressure Reactions

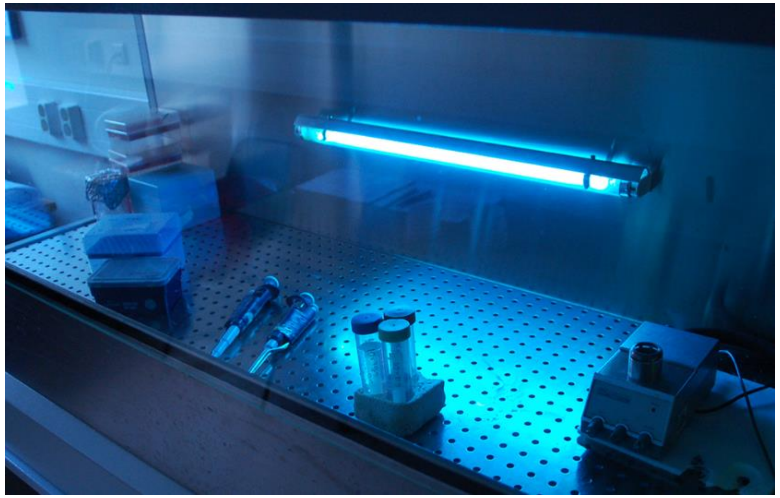
- Hydrogenation at elevated pressures
  - Potential formation of explosive O_2/H_2 mixtures and the reactivity/pyrophoricity of the catalyst
- Supercritical fluids
- Control
  - Consider the kinetics and thermodynamics of the reaction
  - Consider the characteristics of reactants, products and intermediates
  - If scaling up, calculate the expected temperatures and pressures and the rates of pressure generation
  - Select appropriate equipment for all stages of the reaction
  - Ensure ventilation is adequate to handle discharge from a high-pressure reaction to prevent asphyxiation
  - Ensure hearing protection is adequate to guard against the sound of a rupture disc failure
  - Provide adequate barricades if catastrophic failure could
  - result in injury or death of laboratory personnel

Vacuum Work

- **Hazards**
  - **Even low vacuum may cause injuries**
  - **Glass breakage**
  - **Exposure to toxicity, fire, cryogens (cold traps between pumps)**
  - **Health hazards from vacuum gauges: mercury, electric shock with hot cathode ionization systems, radioactivity of the thorium dioxide used in some cathodes**



Hazard Identification and Risk Assessment: Ultraviolet, Visible, and Near-Infrared Radiation



- Ultraviolet irradiation
  - Medium-pressure Hanovia 450 Hg lamps for photochemical experiments
  - UV lights in biosafety cabinets
  - UV lights in light boxes to visualize DNA
  - UV can cause serious skin and corneal burns
- Powerful arc lamps: can cause eye damage and blindness within seconds; chlorine dioxide is explosively photosensitive
- Lasers
  - Eye hazard
  - Fire hazard
  - Lasers classified based on ability to cause damage to individuals
  - Select protective eyewear with the proper optical density for the specific type of laser in use
  - When operating or adjusting lasers, remove or cover any reflective objects on hands and wrists to reduce the chance of reflections

Radio Frequency (rf) and Microwave Hazards

- Frequency: 10 kHz - 300,000 MHz
- Use: rf ovens and furnaces, induction heaters, and microwave ovens
- Health hazard: cataracts and/or sterility
- Other Hazards
  - Use of metal in microwave ovens can result in arcing with potential for fire and explosion
  - Superheating of liquids
  - Capping of vials and other containers can result in explosion from pressure buildup within the vial
  - Inappropriately selected plastic containers may melt
- Only microwave ovens designed for laboratory

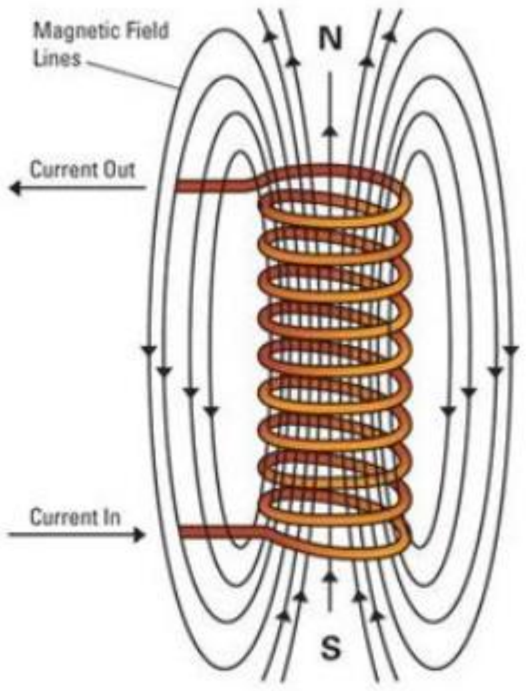
Electrical Hazards

- Electrical equipment: building, repairing or modifying by licensed electricians only
- All lab personnel should know the location of electrical shutoff switches and circuit breaker switches
- All lab personnel should know how to turn off power to burning equipment
- Lab equipment should be correctly bonded and grounded to reduce the chances of electric shock if a fault occurs
- Eroded insulation on electrical equipment in wet locations such as cold rooms or cooling baths must be repaired immediately
- Large capacitors are capable of storing lethal amounts of electrical energy and should be regarded as live even if the power source has been disconnected
- Loss of Power
  - Flammable or toxic vapors from chemicals in freezers and refrigerators
  - Hoods may cease to function
  - Stirring required for safe reagent mixing may cease
  - Power restoration may cause ignition of flammable vapors

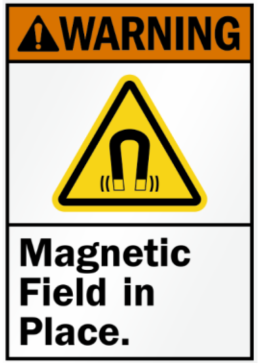
Labeling of All Power Boxes

Do not operate if unlabeled and unsure – contact facilities

Magnetic Fields



- Earth's magnetic field ~ 0.5 G
- NMR spectrometers magnetic fields: 14,000 - 235,000 G (1.4 to 23.5 T)
- Ferromagnetic materials can become a projectile aimed at the magnet
  - Scissors, knives, wrenches, and other tools, keys, steel gas cylinders, buffing machines, and wheelchairs
- Superconducting magnets use liquid nitrogen and liquid helium coolants: potential cryogenic exposure
- Health hazards: unknown



Sharp Edges

- Broken glass cuts: common
- Reduce class cutting risks
  - Correct procedures: e.g., for inserting glass tubing into rubber stoppers and tubing
  - Wear appropriate PPE and careful manipulation
  - Check and discard any glass with chips or cracks
  - Dispose in specific glassware disposal bins
- Other Cut Hazards: razors, box cutters, knives, wire cutters, and any other sharp-edged tools
- Other Risk Reduction
  - PPE: eye protection and cut-resistant gloves
  - Inspect tools prior to use; do not use if damaged
  - Use cutting tools for intended purpose only: e.g., do not use as screwdriver or to open containers
  - Never submerge sharp objects in soapy or dirty water; poses a risk to the dishwasher

Storage of Glass

Use soft lining for the drawer to avoid breakage on opening

Disposal of Broken Glass

The box is disposed of directly so that the janitor is protected from the broken glass contents.

Get box from Chemical Stores.

Slips, Trips, and Falls

- Spills related to handling chemicals
  - Dropping chemicals not stored in protective rubber buckets or lab carts
  - Attempts to retrieve 5-gallon bottles of distilled water, jars of bulk chemicals, and rarely used equipment stored on high shelves
  - Fall injury and exposure to the chemical
  - Back injuries
- Housekeeping
  - Tripping over bottles of chemicals stored on lab floors
  - Wet floors around ice, dry ice, or liquid nitrogen dispensers

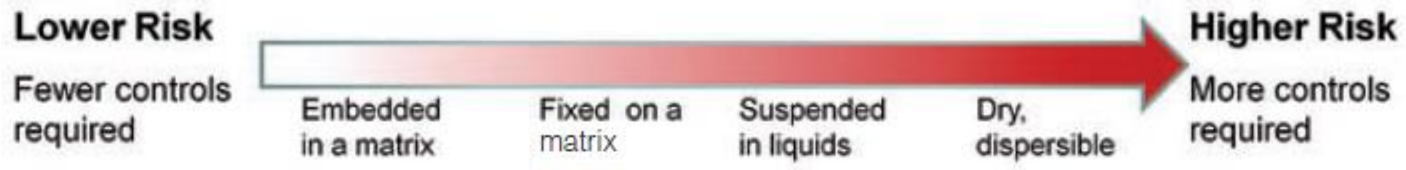
Ergonomic Hazards in the Lab



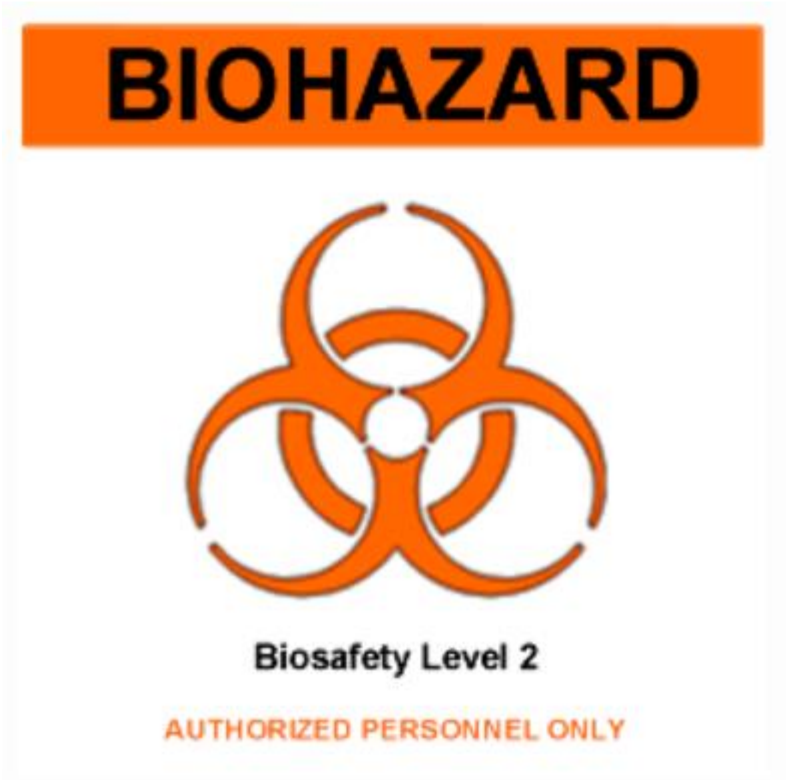
- General workplace hazards
  - Repetitive-motion injuries: e.g., pipetting and computer work
  - Back injuries: e.g., working at a bench or at a microscope without considering posture
  - Noise: e.g., in-room ventilation that may raise the background noise level to uncomfortable or hazardous levels
  - Other: high/low temperature
- Control Measures
  - Reduce risk: e.g., use camera/computer screen to view images, rather than direct viewing through a microscope eyepiece to reduce back and eye strain
  - The Centers for Disease Control and Prevention www.cdc.gov and the National Institute of Health www.nih.gov posted information describing specific ergonomic concerns for labs and proposed solutions, including, self-assessment form to evaluate these hazards

Nanomaterials

- **Nanomaterials (NM)**
  - **Nanometer-scale objects: nanoplates, nanofibers (including nanotubes) and nanoparticles**
  - **Nanoparticles: dispersible particles 1-100 nm**
  - **Chemical and physical properties change at nanoscale**
- **Exposure: inhalation, dermal contact, accidental injection, and ingestion**
- **NM suspended in solution or slurry hazards**
  - **Mechanical energy imparted: sonication, shaking, stirring, pouring or spraying; dermal exposure potential**
- **NM fixed within a matrix hazards**
  - **Mechanical disruption: grinding, cutting or burning**
- **Risk Control**
  - **Well-designed ventilation system with high-efficiency filtration**
  - **Warning: conventional hoods may create turbulence that can push the materials back into the lab space**



Biohazards



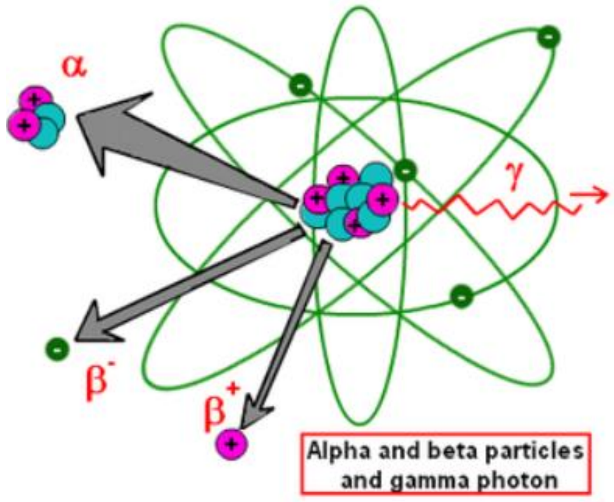
- Involve microorganisms
- OSHA's Bloodborne Pathogen Standard, 29 CFR § 1910.1030 covers those likely to come in contact with blood or potentially infectious materials in the lab
- Hazards present in:
  - Clinical and infectious disease research labs
  - Labs handling bodily fluids, tissues, or primary or immortalized cell lines of human or animal origin
  - Labs handling microorganisms, including replication-deficient viral vectors, for protein expression or other in vitro applications
  - Water and sewage test labs
  - Labs in the production of biological products
- Assume synthesized microorganisms identical to those found in nature have similar risks
- If synthesizing novel microorganisms, take extra caution until the characteristics of the agent are well understood
- Risk assessment for biohazards complicated due to the number of factors that must be considered

Guide to Risk Assessment for Biological Hazards in the Lab

Consider these questions for a risk assessment of activities involving biohazardous materials.

1. Identify the risk group of the parent organism
2. This Risk Group assignment is only a starting point
3. Refer to the Agent Summary Statement in Biosafety in Microbiological and Biomedical Laboratories
4. Identify the natural route of transmission for the parent organism
5. Consider any modifications made to the organism
6. Consider the transgenes expressed by the organism
7. What volume and concentration of agent are handled at any one time?
8. Will research animals be used in any procedures?
9. Are sharps utilized in any procedures?
10. Will any manipulations generate aerosols (e.g., vortexing, centrifuging)?
11. Are vaccinations or treatments available for the agents in question?
12. Are the organisms used particularly hazardous for certain groups of people (e.g., pregnant women, immunocompromised individuals)?

Hazards from Radioactivity



- Radioactive material - unstable atomic nuclei or isotopes - achieve stability by emitting radiation
  - Particulate: α, β, proton, or neutron
  - Electromagnetic (γ rays or X rays)
- Receipt, possession, use, transfer and disposal of radioactive materials is strictly regulated by the U.S. Nuclear Regulatory Commission (USNRC):
  - 10 CFR Part 20, Standards for Protection Against Radiation and/or by state agencies
  - USNRC set occupational exposure limit at 5,000 mrem/year
- Protection: good facility design, operation, monitoring, and good work practices
- Minimize amount of radioactive material used
- Minimize exposure by shielding radiation sources, lab personnel and visitors
- Use robotic / remote operations to reduce exposure of personnel

Emergency Management

- Minimize the likelihood of incidents
- Limit/Mitigate the effects of incidents
    - Procedural: e.g., safe storage of materials
    - Physical: e.g., sprinkler system

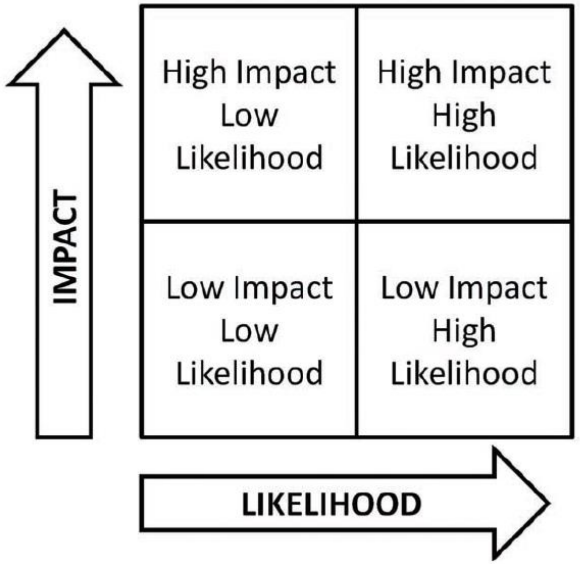
- Develop plans for managing and ensuring readiness for emergency
- Ensuring supplies are available
- Train personnel
- Preparing communication plan

- Manage emergency as it occurs
- Outside responders & lab staff

- Restore the lab
- Resume lab functions safely

Emergency Planning

Preplanning



Vulnerability Assessment

What kinds of emergencies are most likely?
What is the possible effect on laboratory operations?

- Fire
- Natural Disasters
- Loss of Access to Lab
- Loss of Equipment
- Loss of e-Data
- Loss of Power

Lab Survival Kit

- Emergency contact information
- Flashlight
- Radio and batteries
- First-aid kit
- Safety glasses and gloves
- Change of clothing and shoes
- Medications
- Contact lens solution
- Nonperishable snacks
- Water
- Blanket, jacket, or fleece

Lab Priorities

- 1: Protect human life.
- 2: Protect research animals:
  - Grant-funded research animals,
  - Thesis-related research animals,
  - Other research animals.
- 3: Protect property & environment:
  - Mission-critical property,
  - High-value equipment,
  - Difficult to replace materials.
- 4: Maintain integrity of research:
  - Grant-funded research,
  - Thesis-related research,
  - Other research.

Communication

- Key Contacts
- Phone/Cell
- Email/alternative email

Evacuations

- Shutdown Procedures
- Special Procedures
- Unattended Experiments

Lab Security

- Physical or architectural security: doors, walls, fences, locks, barriers, controlled roof access, cables and locks on equipment
- Electronic security: access control systems, alarm
- Systems, password protection procedures, and video surveillance systems
- Operational security: sign-in sheets or logs, control of keys and access cards, authorization procedures, background checks, and security guards
- Information security: passwords, backup systems, shredding of sensitive information